Telektronikk
4.2001

Mobile Virtual Network Operators

Contents

Telektronikk

Volume 97 No. 4 – 2001
ISSN 0085-7130

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Prepress and printing:
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Circulation:
3,750

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Mobile Virtual Network Operators

Guest Editorial

Do Van Thanh

Front cover: New actors emerge and vanish, compete and co-operate according to market demands.

Traditionally a network operator possessed his own physical network. The operator also provided the services offered in that network. However, the physical networks basically constitute a "road" system enabling an ever-increasing variety of service solutions. Therefore, "virtual" providers/operators need no physical facilities. Instead they rent facilities from others. To make things work properly the virtual operator must extend its service provision management into and through the domains of others. The artist Odd Andersen indicates this situation by showing mobile providers – here abstracted to waves extending outwards – expanding their influence over available network resources – here abstracted to "the band" – be it narrow, medium or broad in nature. The managerial and control mechanisms are indicated by downward beams of hierarchical and collateral influence centred at the core of the virtual operators.

The artist's generic message: Matching each operator's influence to the proper range and hierarchical level.

Ola Espvik, Editor in Chief

There is no business like ... Mobile business. Although being involved with the mobile business for a while now I never stop being amazed and fascinated by the way things happen. One may, of course, imagine an unorganized development since wireless communication is indeed "untethered" and "unguided" by nature, but nobody can ever dream that so many unpredictable things can happen and so many predictable ones never do. Although difficult, one could foresee the success of GSM since it brings a real value to the users, namely freedom in communications. However, few or perhaps no one could have anticipated that SMS actually became the killer application. In fact, how can anybody imagine that typing messages on tiny telephone keypads could gain such popularity among youngsters? Looking into the future – who can say what will be the killer application?

An interesting and strange phenomenon occurred in 1998. As if it is not enough with the disappearance of the wires, the Mobile Network Operator in his turn tends to vanish as well by becoming *virtual*. By launching the concept of the Mobile Virtual Network Operator (MVNO), Sense Communications ("Sense") in Norway created such turmoil in the mobile business. It wanted to get interconnection to operator's mobile networks in Scandinavia. Although obtaining a lot of press coverage and supports from the regulators Sense succumbed due to the lack of commercial agreements with operators who considered MVNO as a threat.

However, the MVNO concept did not die. In fact, Sense came back from bankruptcy in late 1999 as a "thinner" MVNO or Service Provider as many may say, and did not fight against but rather allied themselves with mobile network operators. The MVNO concept may rise stronger with 3G. On one side, mobile network operators having paid high prices for 3G licenses, at least, may need MVNOs who buy available network capacity and help financing their debt. Many operators also realise that they cannot address every sector in the market and need the expertise from MVNOs. On the other hand, companies wishing to offer mobile services may consider MVNO as a good entrance way to the mobile business. The MVNO concept provides also the possibilities for operators to extend their coverage. 2G operators may extend their coverage by having MVNO agreement with 3G license holder and vice versa. Operators may also provide 3G coverage in countries where they do not hold licenses.

Briefly, many things, known and unknown, predictable and unpredictable, will continue to happen in a rather confusing way for the MVNO concept. Therefore, this Telektronikk issue is aiming at shedding light on the Mobile Virtual Network Operator concept by considering the technological, financial, economic aspects.

Within Telenor there have been several activities related to MVNO. Telenor Corporate University has launched the Master of Telecommunication Strategy Program in cooperation with Norwegian University of Science and Technology in 2000. This program has at is core a common project where the students are developing a business plan. The first time this program was run, MVNO was chosen as core project.

Through a workshop on "MVNO, access to mobile networks and the juridical and economic aspects regarding regulation and competition" organised by Telenor Brussels on the 19 March 2001 in Brussels, experts and regulators had the opportunity to meet and extend their view on MVNO. Many authors in this issue have also participated in the session on Mobile Virtual Network Operators: Technologies, Services, Markets and regulations organised by Professor Jan A. Audestad and myself at the World Multiconference on Systemics, Cybernetics and Informatics (SCI 2001), July 22–25, 2001 in Orlando, Florida.

As mentioned, this issue covers different aspects of MVNO from technologies, business, regulation and opportunities. It starts with an elucidation of the MVNO concept. Since MVNO is a business concept several articles in this issues focuses on the business aspects covering everything from the financing, market, pricing business models and service opportunities. The regulatory aspects are also covered. The issue concludes with a look on the future with an article on future network architecture and one on pricing.

I hope that after reading this issue the readers will either have a good understanding about the MVNO concept or get confused and provoked enough to start doing research on MVNO ...

Enjoy your reading.

Thanh

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The Mobile Virtual Network Operator Concept: Truth and Myths

DO VAN THANH

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Introduction

The first idea concerning Virtual Network Operator (VNO), that is, operators not owning their own communication infrastructure, goes back to early nineties. The early VNOs were concerned with resale of traffic and marginal enhancement of services because value-added services required Intelligent Network functionality. The Internet combined with third generation mobile services are likely changing this picture, giving rise to new ways of implementing services.

The concept of Mobile Virtual Network Operator (MVNO) arose three years ago with Sense Communication, called Netsystem International. The company fought for interconnection to mobile operators' networks in Scandinavia. Although having the support of regulators it did not succeed in reaching commercial agreements with mobile operators that consider MVNO as a threat. Sense went bankruptcy but came back again more as a service provider than an MVNO and did not attempt to extend regulatory frontiers.

An MVNO is an operator not owning radio infrastructure. The MVNO carries out its business by roaming, where the customers roam between the radio infrastructures of ordinary mobile operators. The MVNO must, as a minimum, own a subscription database. It may also own additional platforms for executing services (for example Internet services). The MVNO at the same time competes and cooperates with ordinary mobile operators. It competes for the same customers as the ordinary operator and it cooperates by buying infrastructure services (airtime) from that operator, and sometimes, by creating teletraffic that otherwise would not exist. Examples of the latter are offering connection to public information services and supporting fleet management. The role of the MVNO is therefore complex. It is likely that regulators of the telecom market will require that ordinary mobile operators must cooperate with MVNOs in order to enhance competition in the marketplace and stimulate evolution of mobile services.

The definition of the MVNO is vague. The reason is that there will be many ways in which such operator are formed, and that several types of MVNO may compete in the same market. Note also that the concept of MVNO also may

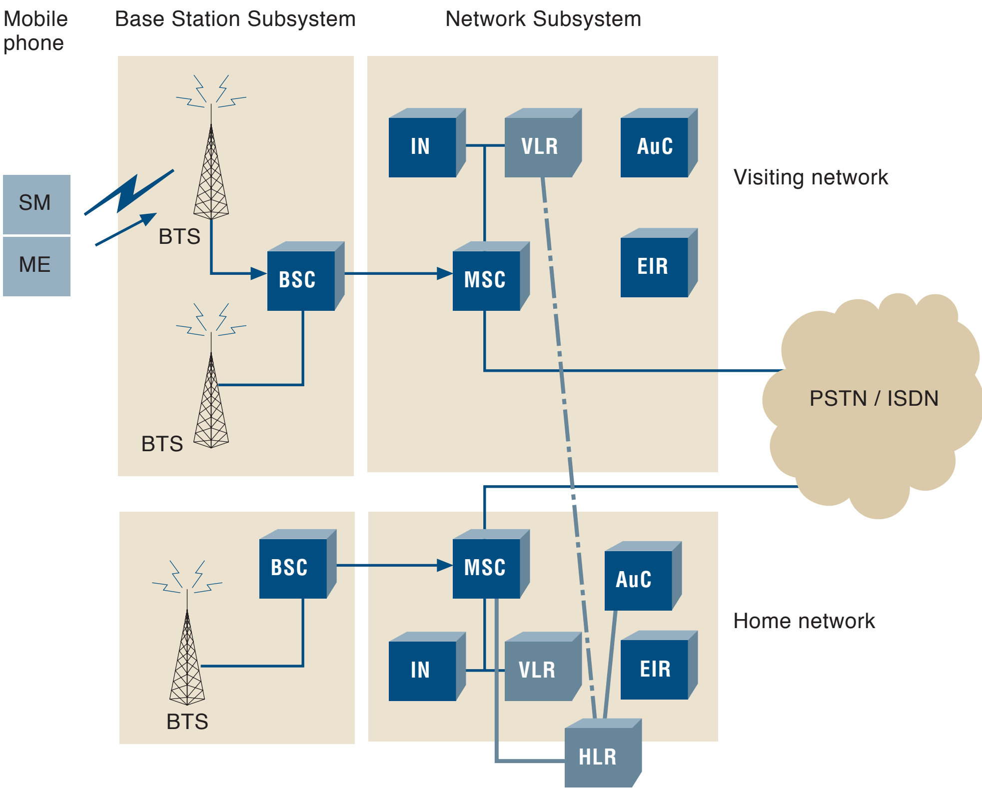

Figure 1 Roaming registration of mobile phone

comprise mobility between fixed network terminations, mobility of sessions and mobility of applications. We are not only referring to traditional services in traditional networks. In this article, we will try to elucidate the MVNO concept and to make difference between truth and myths.

MVNO versus MNO

In order to understand how a mobile network operator (MNO) can be "virtual" let us start recalling what a mobile network operator is and what infrastructure and equipment it must have.

When subscribing to an MNO the subscriber receives a SIM (Subscriber Identity Module), which is a smart card containing the *International Mobile Subscriber Identity* (IMSI), which allows the Mobile Network Operator to uniquely identify the subscriber. Indeed, The IMSI consists of three fields: the *Mobile Country Code*, The *Mobile Network Code* and the *Customer ID*. In addition, each base station broadcasts a location code consisting of information that makes it possible for the mobile terminal to determine the area in which it is operating: cell, VLR, network, country. The mobile phone, also called Mobile Equipment (ME) in GSM terminology cannot operate normally without a SIM and only emergency calls are allowed in this case. The mobile phone has its own identity called *International Mobile Equipment Identity* (IMEI).

The *Mobile Switching Center* (MSC) is organised under the *Network Subsystem*. Other elements in the subsystem are the *Home Location Register* (HLR), the *Visitor Location Register* (VLR), the *Authentication Center* (AuC) and the *Equipment Identity Register* (EIR). The Subsystem may be strengthened with an *Intelligent network Node* (IN) that enables enhanced services such as Call forwarding, Voice mail, etc. The MSC is a switching node providing connection to PSTN/ISDN or other network subsystems belonged to other MNOs.

In order to understand how the MVNO may operate the following describes how the GSM network manages location registration, calls to the mobile terminal (in-calls), and call initiated by the mobile terminal (out-calls). Note that the identity and number referred to below are related to the mobile subscriber and not the physical terminal. The physical terminal is identified with an international equipment identity not used for ordinary communications.

Location Updating

When the mobile terminal accesses an area with a new VLR code, it initiates a location updating toward the new VLR. The procedure is the same whether the VLR is in the home network or in a foreign network (visited network). The VLR updates the HLR of the MS so that the HLR knows in which VLR the MS (mobile subscriber) is currently registered. The updating procedure consists of several operations not important for the context of this paper (authentication, allocation of temporary identity).

In-call

Since the ISDN number (or IP number) of the mobile user is non-geographic, the only information an exchange in the ISDN/PSTN (or router in Internet) can derive from the called number is the identity of the HLR of the MS. In order to route the call to the current location of the MS the network (PSTN/ISDN or Internet) requires a network address identifying this access point where the MS is found. The HLR then, by initiating a complex procedure toward the VLR, derives the addressing information the network requires for routing the call.

However, the capability of accessing the HLR is not generally implemented in the network. Therefore, the network routes the call to an MSC (or router) of the home network of the MS. This MSC then obtains the routing information and forwards the call to the MS. Sometimes this requires unnecessarily long connections. Hence, a network needs an MSC (or router) in order to serve in-calls.

Out-call

This case is simple. The MS just places the call via the serving MSC (or router) that forwards the call to the called user in the normal way.

The infrastructure that an MNO must have consists of both the Base Station Subsystem and the Network Subsystem. It has an own Mobile Network Code (MNC). In addition, it must have the necessary equipment to issue and personalize SIM cards.

An MVNO as its name tells, should not have the complete infrastructure since it is supposed to be "virtual". Indeed, an MVNO does not have the Base Station Subsystem. It does not have a license to use radio spectrum but has access to one or more. There is unanimous agreement about what an MVNO does not have but there is no consensus about what an MVNO must have. There are different views, which go from "plump" MVNO to "skinny" MVNO [1].

Ovum [2] and ODTR, the Irish regulator [3] define an MVNO as an organisation that:

- offers mobile services to customers;
- has it own mobile network code;

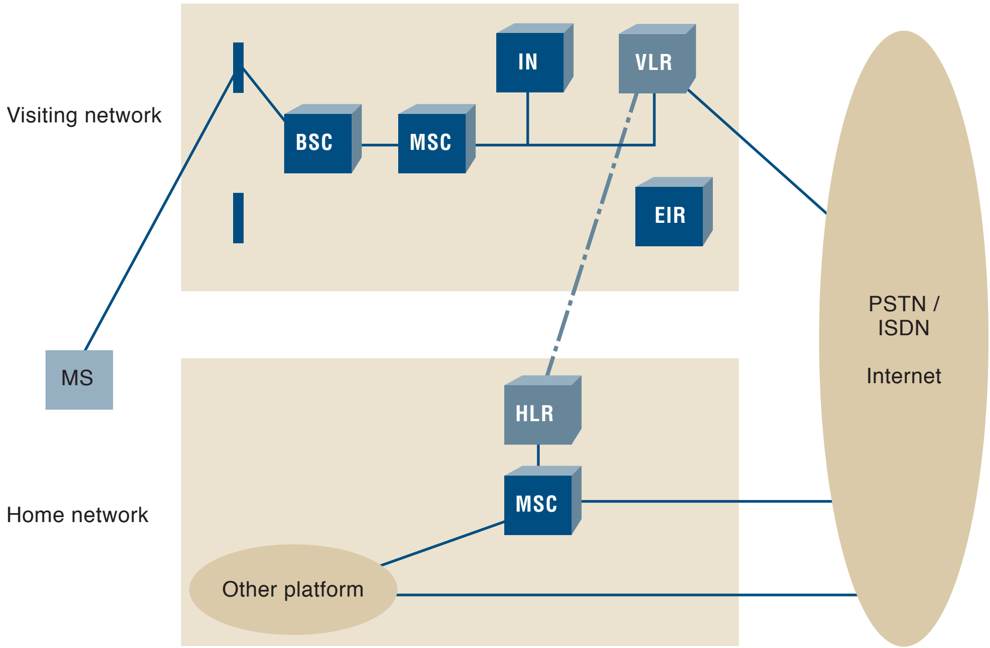

Figure 2 MVNO with MSC

- issues its own SIM card;
- operates its own MSC and HLR;
- does not have its own radio frequency spectrum.

The reason why this configuration is proposed is to provide an access for incoming calls as described above. The MSC then acts as the access point to the MVNO defined by the international ISDN/PSTN (or IP) number of the MSs of subscribing to the services of the MVNO. The configuration of an MVNO operating together with an MNO is shown in Figure 2.

The purpose of the "other platform" is to offer services. This may be a LAN, an Internet, an intranet or any other platform. The platform may, for instance, offer seamless international mobile extension to business LANs.

Note that the MSs of the MVNO is always roaming in the network of other operators. This may lead to difficulties concerning the business agreement between MVNOs and MNOs as described in [5].

However, companies known as MVNOs such as Virgin Mobile in UK, Australia and Singapore do have neither their own MSC nor their own Mobile Network Code but relies heavily on the MNO's facilities. As stated in [1], a skinny MVNO may rely almost totally on the MNO's facilities, and calls to and from its subscribers would be treated as if there were calls to the MNO's own customers.

We believe that the key issue lies on the perception of the customers. An MVNO should be perceived by end users as a real MNO. OFTEL, the British regulator [4], states that subscribers' contract with the MVNOs would cover all services; there would be no contract with the mobile operator (hence the term "virtual" mobile network operator).

Revenues

To survive an MVNO needs to be profitable. The main source of income derives naturally from the customers. The customers pay for call connection and services. The second source of income is the interconnect payment from other operators. In order to succeed an MVNO must be able to provide innovative services since this is unique source of income that it controls totally. Such services may be international extensions of LANs. Other services may be associated with software in the SIM offering capabilities beyond mobility.

On the cost side, the MVNO has to pay to the MNO for both outgoing and incoming calls. In addition, it has to pay interconnect payments to other operators for completing outgoing calls. Last but not least, it has also investment, marketing and operational costs. An MVNO needs to reach commercial agreements with an MNO concerning the charging for using the radio spectrum. There are currently two possible schemes. In the cost plus charging, the payment is derived from the MNO's actual costs. In the retail minus charging, the payment is the MNO's retail price minus some discount. Usually, the retail minus charging is higher and less advantageous for the MVNO than cost plus charging.

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An Analysis of the MVNO Business Model*

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1 Introduction

The purpose of this paper is to analyse different Mobile Virtual Network Operator (MVNO) business models in order to validate their sustainability.

The mobile telecommunication industry is for the time being characterised by a lack of licences, high investments in network building, and deregulation of old monopolies. There is an increased complexity both in the market and in the industry, and there is a search for new business models for expansion.

The mobile market is a market still in strong growth with many players that want to get a slice of the pie. Each country has a limited numbers of available frequencies, and, therefore, can only award a limited number of licenses. As there are a lot of players that want to be mobile operators and only a few of them are able to get a license, both because of the limited number of licenses and the huge cost of building a mobile network, new types of players, MVNOs, have emerged. The regulators have welcomed the new players because they want to enhance competition for the benefit of the users.

An MVNO is a new business model, and faces several challenges, such as the obviously asymmetric agreement with an MNO. The strategic position for an MVNO will depend on the origin of the company. Possible origins are divided into three groups: retailers, expanders and integrators. Each position has different strategic options and possible strategic advantages, which are discussed in this paper.

2 Definition

In a high level description, a service provided by a telecommunication network is the result of an execution of a *function*. Some functions go hand in hand and cannot be separated either from a business or technology perspective. The smallest set of functions that cannot be further divided constitutes a *role*.

The "eco-system" of the telecommunications industry consists of several roles and interfaces between them. The providers of access, switching, transport, service platform, billing, customer handling, etc. each constitute a specific role. A *player* – or a *firm* – on the other hand is a collection of several roles.

It is important to make the distinction between players and roles. The traditional telecommunication operators will often cover many or all roles, mostly due to their history with monopolies and vertically integrated value systems. Breaking up these systems has given rise to new business players like resellers and service providers.

Rather than defining the MVNO as one new role, it makes sense to view an MVNO as a collection of roles. An MVNO could in principle undertake any role, but by definition it must, from a customer perspective, appear to be an MNO, having the same interfaces towards the customer as an MNO. In addition, the MVNO cannot hold its own licensed radio spectrum.

The question for an MVNO is how "deep" (with customer facing being the highest level, and radio access provisioning being the lowest) into the value system it should go. The MVNO has to consider which facilities to own and run, which to outsource and which to lease from the MNO and what type of agreements it should seek with partners in order to appear as an attractive choice to the customers.

3 The Mobile Business Landscape – an Analytical Approach

A business model may be defined as an individual company's set of choices about what to do and how to do it. In this section, some frameworks used to evaluate sustainability of MVNO business models are described. Keywords are network externalities, complementary services / products and value configuration.

Many various environmental aspects may be of great importance. Focus of approach is business strategy, industrial organization and competitive power, but other aspects such as underlying needs of the customer and government policy (regulation) may be crucial.

* *The article is based on a paper by Lars Armyr, Terje Hauger, Anders Lillehagen, Vegard Masdal and Kari-Ann Skow.*

The Value Chain, Value Net and Value Networks frameworks are discussed. In addition, the difference between effectiveness and strategy and increasing return are discussed as well.

Value Chain

The standard approach to the analysis of industry attractiveness is Michael Porter's Five Forces framework [1]. The attractiveness of an industry, such as the telecommunication industry, depends on the state of competition. Competition in an industry is rooted in the underlying economic structure of the industry. The state of competition in an industry depends on five basic competitive forces. The figure below gives a picture of the Porter's "Five Forces" framework: The power of the five forces – Suppliers, Buyers, Potential Entrants, Substitutes and Rivalry among existing firms – depends on some major factors and characteristics listed in the work of Porter.

In his book "Competitive Advantage" [4] Michael Porter suggested analyzing the "cost leadership" and "differentiation" strategies by means of the value chain model, which has become the standard approach to these analyses. An effective competitive strategy according to this approach takes offensive or defensive action in order to create a defendable position against the five competitive forces.

Value Net

The Value Net can be seen as a generalization of the Five Forces framework. Complementors are added as a new dimension. The Value Net emphasizes that the value to the customers can depend on a package of complementary services and/or products. Logically, complementors will influence the attractiveness of an industry. Figure 2 gives a picture of the Value Net of a company.

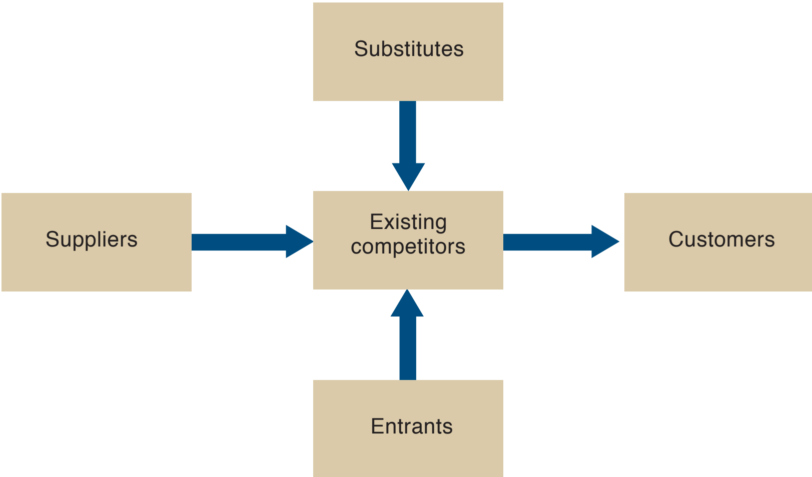


Figure 1 Porter's Five Forces

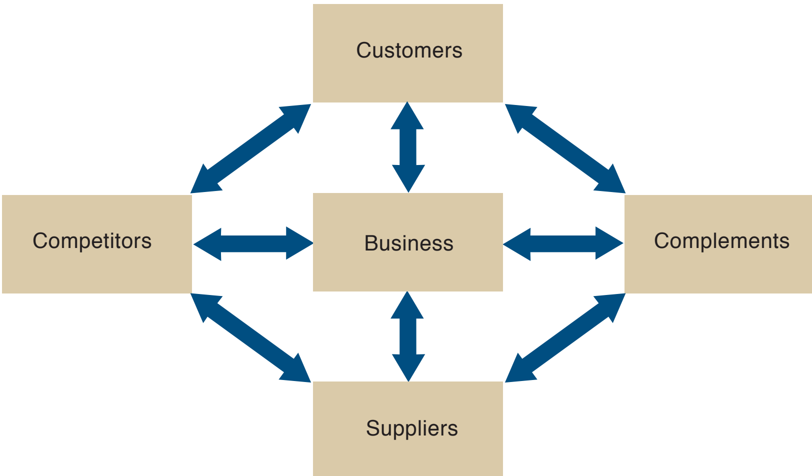
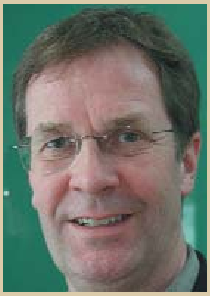


Figure 2 The Value Net



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A player is a complementor if customers value your product more when they have that player's product than when they have your product alone. A player is a competitor if customers value your product less when they have that player's product than when they have your product alone.

To draw the map of the whole Value Net of a company (function) of the telecommunication industry is more and more challenging due to increasing complexity of relations between companies (functions) within the ICT business landscape. The number of companies and types of unbundled functions are increasing. Companies can to various degrees be both horizontally and vertically integrated. In addition, companies can be present in several countries (local markets). Further, the number of different technologies (e.g. access technologies), the number of products and applications etc. is increasing. Various sources of payment, e.g. from subscription, advertising, and transaction, can also increase the level of complexity and the relations between roles and companies.

Nalebuff and Brandenburger [2] apply the Value Net model to illuminate competitive and cooperative business strategies for the digital economy and see the relations between the companies as a game. A game has players and the added value that each player brings. A game has rules that structure the interaction between players. The game is also affected by perceptions, what the players believe. A game can only be changed by changing one of the components. The term coopetition, coined by Noorda, is introduced to describe strategy in a business landscape of both competitors and complementors. A company's strategy towards different types of players has to be different. An example based on pricing and value to customers describe the importance of different strategies. If companies price their competing products independently, price will come down as companies try to compensate for lower margin by gaining profit from increased market share. The reverse situation is true for complements. The natural incentive is to set price too high, which makes the total package too expensive. Complementors should agree to lower prices. This is why we see so much bundling. It's a way of bringing the price of a complementary package down. According to Nalebuff and Brandenburger, there are three approaches to the problem; Do it yourself, Form an alliance or Set up a proprietary business.

Value Networks

Stabell and Fjeldstad [6] suggest that Porter's Value Chain framework is only one of three generic value configurations – the other two being "value shop" – which describes a firm where value is created by mobilising resources and activities to resolve a particular customer problem (e.g. hospitals, professional services and educational institutions) – and "value network" – which may be used to model firms that create value by facilitating a network relationship between their customers using a mediating technology (e.g. telephone companies, transportation companies, insurance companies and banks).

Fjeldstad [7] claims that the Value Chain model (and the related Five Forces model) do not reflect the strategic logic of mediators, and in particular fail to incorporate positive network externalities both as a source of competitive advantage and as a barrier to entry and innovation.

Positive network externalities introduce unique strategic challenges. A new service has relative low value to its first customers; whereas cost is typically highest in the introductory phase. However, because the value of the service is dependent on who else adopts it, it may be difficult to target customers on an individual basis. Consequently, in many cases it is impossible to levy a realistic charge for the service or equipment in this initial phase, leading to "give away strategies" seen in areas such as mobile telephony or Internet browsers.

Like the value chain, the value configuration model distinguishes between primary and support activities: Primary activities are those that create value for the customers, which in the case of telecommunications are those involved in selling and providing a service. Support activities are engaged to perform effectively the primary activities of the firm.

According to Fjeldstad [7] the primary activities of a telecom operator's value network are:

- *Marketing and contract management*, which consists of activities associated with inviting potential customers to join the network, the selection of customers allowed to join, end the initialisation, management and termination of contracts governing provisioning and charging.

- *Service provisioning*, which consists of activities associated with establishing, maintaining and terminating links between customers, and billing for value received. Billing requires measuring customers' use of the network capacity both in volume and time.

- *Network infrastructure operation*, which consists of activities associated with maintaining and running a physical and information infrastructure. These activities keep the network in an alert state, ready to service customer requests.

Support activities include product and process development (development and implementation of new services, reconfiguration of network infrastructure, development of new technology and implementation of standards), human resource management and procurement

Fjeldstad [7] denotes multiple firms contributing to the creation of a service as a co-productive value system. In such industries co-production takes place both between horizontally interconnected firms and between vertically layered firms. Unique structural properties of the telecommunication industry following the patterns of horizontal and vertical co-production are critical to understanding the nature of competition.

Mediators co-produce value in a layered structure in which the network service of one mediator serves as a platform for a higher-level service. Several companies may serve the same customer, but at different levels. Fjeldstad [7] uses electronic payments over the Internet as an example: Currently, the telecommunications network serves as the platform for the Internet service, which in turn serves as a platform for the electronic payment service. The customer typically subscribes to all three and they are used concurrently to produce the desired service, i.e. electronic payment. The banks mediate payments by credibly exchanging transactions between accounts, the Internet service providers mediate standardised packets between IP-addresses, and the telecommunication operators mediate bit streams between phone numbers, so that, together the firms co-produce the payment transfer service in a layered business system.
In the simplest case, with only one firm at each level, the firms supply the same customer with different components of the service. The firms have a strong impact on the value of each other's respective services, but they are not, in the conventional sense, suppliers or customers of each other. It is the common customer of all three networks that typically pays each contributor separately.

The layered structure of co-production in mediation renders the traditional concepts of supplier and customer relationships insufficient for describing and analysing relationships between mediators.

Value configuration analysis is based on the assumption that competitive advantage is found in the activities that a firm performs. Such firms offer value to their customers both through the access option and the actual use of services. Hence, cost and value must be associated with both.

Fjeldstad [7] argues that mediation services offered by value networks represent an extreme case of network externalities because the dependency among customers is the main product delivered. The service of a value network mainly delivers the customers' opportunities to exercise those dependencies. Size and composition of the customer base is therefore the critical driver of value in the value network, and the value of the service offered is affected by the characteristics of the customers that join the network. Capacity utilization is closely related to scale and is both a cost and a value driver, for while it may reduce unit cost, high capacity utilisation also may reduce service levels.

Increasing Return

The term "increasing return" denotes a situation where mechanisms of positive feedback make the leading player maintain his competitive advantage over the trailing player. Main characteristics of a situation of increasing returns are high upfront cost, network externalities and high switching costs for customers. Decreasing return denotes the assumption that products or companies that get ahead in a market eventually run into limitations.

The cost-structure of telecommunication networks is normally characterized by high upfront cost due to license fees and cost of equipment such as switches, antennas, etc. However, when the network is built, the cost of producing one additional call is very low. Telecommunications networks have this cost structure of high fixed cost and low variable cost in common with other products and services of the so-called "new economy" [3].

"Network externalities" denotes the fact that the main asset of a product lies not in the product itself, but in external factors such as how many other people are using it, i.e. demand-side economies of scale. One more customer to the network not only benefits that customer, but also customers already connected since this implies another person to call to.

Positive feedback is a more potent force in the network economy than ever before [3]. Positive feedback is not only related to the demand side, but also to the supply side. The source of positive feedback from the supply side is known as economies of scale in production: large firms tend to have lower unit cost. Both demand-side economies of scale and supply-side economies of scale have been around for a long time, but the combination of the two that has arisen in many information technology industries is new. The two sides feed back to each other making a multiplication effect. The result is especially strong positive feedback and a popular paraphrasing is "the winner takes it all".

Switching costs encompass all the costs incurred by a customer in changing to a new supplier. One example of switching cost is cost related to changing telephone number. Switching cost contributes to lock-in situations.

Effectiveness and Strategy

Strategy should not be confused with operational effectiveness. Strategic positioning means performing different activities from those of rivals or performing similar activities in different ways. Porter [5] argues that robust strategies involve trade-offs. A company must abandon or forgo some product features, services, or activities in order to be unique at others. Further, strategy defines how all the elements of what a company does, fit together. The large numbers of MVNOs, which appear to be similar, most likely lack a distinct strategy.

4 A Generic Business Model

Figure 3 illustrates all roles necessary to provide mobile communication services and the relationships between them. The model reflects the vertical layering in Fjeldstad's [7] model described in the preceding section.

The figure shows four different interfaces between the customer and supplier roles: The sales role takes care of subscriptions and service initiation (corresponding to Fjeldstad's "marketing and contract management"), Service provisioning comprises the continuous activities necessary to establish connectivity between customers, and corresponds to Fjeldstad's category – apart from the fact that our model treats occasional interaction with the customer like invoicing etc. as a separate role (subscription management).

The roles in the lower half of the model correspond to Fjeldstad's "network infrastructure operation". In order to describe a business model for an MVNO it is necessary to separate access network operation from the operation of the transport network. To give room for different technical configurations that an MVNO may choose, we have also separated the switching/routing role. The service platform operator provides functionality that is common for many applications (authentication, accounting, authorization, catalogue services, presence management). Service provisioning may include telephony services, messaging services, Internet services etc. Each service represents a distinct role, and different players may supply each of the services. The sales and subscription roles in our model comprise administrative activities.

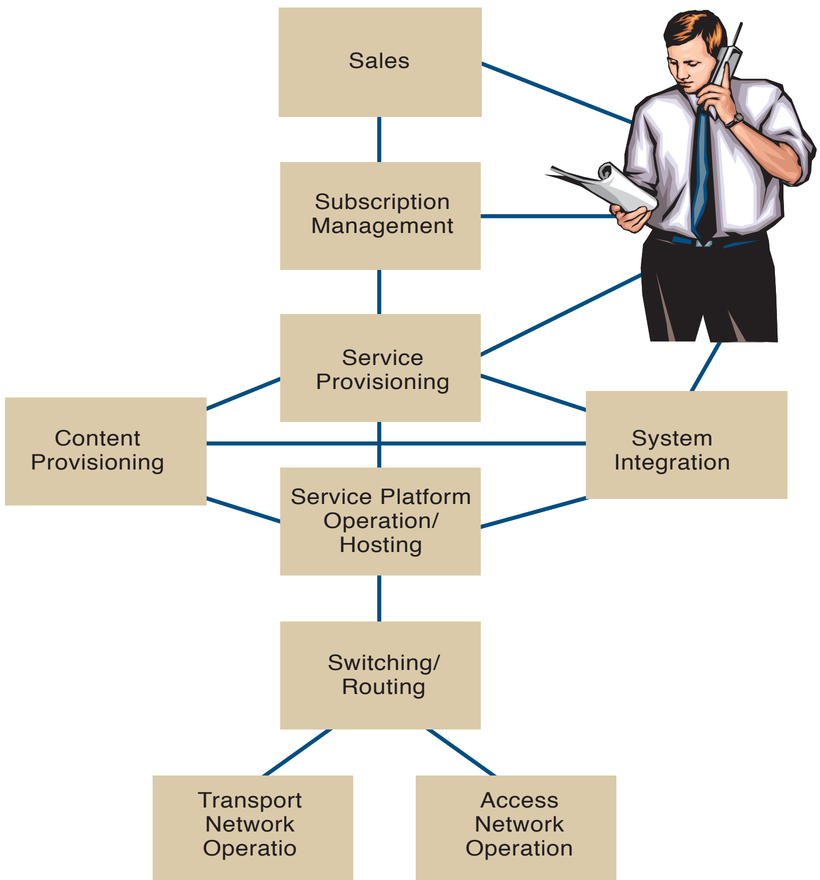
In a 2.5G and 3G world content will be of greater importance in mobile communication. Content provisioning is therefore included as a separate role in the model. Content provisioning relates to hosting of the content as well as to the services provided.

The last role included in the model is that of system integrator. This role comprises activities that integrate content and services into a whole in order to facilitate the customers' use of the services.

According to our definition, a player acting as an MVNO must at least fill the sales and subscription management roles. At the same time, an MVNO *cannot* fill the access network operator role based on a licensed radio network (but may operate unlicensed radio access networks – e.g. WLAN). All other roles in the model may or may not be filled by the MVNO.

Which combination of roles a particular player chooses, depends on his present business and on which assets he brings into the mobile communication business.

Figure 3 A generic business model



5 Analysis of Sustainability

Our hypothesis is that sustainability of the MVNO business models will depend on where the company setting up the MVNO business, originates from. We have grouped the companies into three groups:

a) Companies originating from outside the Information and Communication Technology (ICT) Industry;

b) Companies originating from inside the traditional telecommunication industry; and

c) Companies originating from inside the ICT industry, but not as a telecommunication network operator.

The three groups are called Retailer, Expander and Integrator respectively.

The Retailer

Companies grouped as "Retailer" provides mobile services to its own customers and can perform various roles such as sale, distribution, billing, and customer management. But the characteristics that differentiate the Retailer are that the Retailer does not enter the mobile industry from a position as a telecommunication company or from industries of the communication eco-system such as application provider or ISP. The motivation to enter the mobile industry can vary from obtaining a new "own brand" product in its portfolio of products to becoming a telecommunication company with own network elements.

The Retail business will tend to be a low profit industry due to the following main characteristics:

- The suppliers of the mobile network, the Mobile Network operator (MNOs), have large negotiation power due to the necessity of the input, concentration (small number of potential suppliers) and the fact that MNOs have their own business of mobile service provisioning (the MNO and the MVNO compete in the downstream market). The MNO will most likely use the power to set condition that will limit the MVNO's flexibility of pricing – for example through "retail price minus" condition – i.e. the price structure and the margin. In addition, the MVNO will not be supplied with higher quality of the network services and degree of functionality than the MNO itself. The types of agreement (set of conditions) offered are limited, often only to a choice of elements from a standard agreement.

- Low entry barriers. If the MNOs give access to their networks, they seem to be willing or obliged by regulation to give access to everybody accepting their standard agreement and fulfilling a set of minimum conditions.

- High degree of rivalry due to low degree of differentiation among the retailers, limited value added and a relatively high number of Retailers due to low entry barriers. Differentiation can be difficult to achieve due to the same underlying quality of network and lack of complementary activities in the "eco-system" of the ICT, e.g. provision of application or content. The option left to the Retailer is price as the mean of competition.

- The Retailer will hardly be in a position to enjoy increasing returns. Both supply-side and demand-side positive feedback is linked to the network and the MNO. Even if the retailer invests in network elements and/or manages to build a club of customers faced with switching cost, increasing returns benefits the larger operator.

The key success factors for the Retailer to be sustainable (earning a positive profit relatively higher than the rivals) seems to be:

- Differentiation through better value proposal to the targeted customer group given that the targeted group is large enough. There are some ways of differentiation such as product features, service, product mix and brand-name reputation. Brand-name reputation is often mentioned related to MVNOs. The best way to add value is building on the idea of common interest among members of a community with common communications needs and requirements. However, it is not easy to find a good example of an MVNO without other engagement of the ICT eco-system, such as application or content. Virgin of the UK is an example of company with a brand and with a product mix, but Virgin is a content provider as well. Uniqueness through trade-offs is difficult to copy.

- Capitalising on owned facilities such as billing systems, distribution chain, customer care system, group of customers etc. If the cost of adding a mobile service product-line is marginal, the MVNO can sustain low margin. But the margin will be smaller with the downward trend of end-user prices and of traditionally mobile services (voice) and of average revenue per user. Tesco of UK may be an example of a company with low added cost of introducing own brand mobile services.

- The agreement with MNO – value proposal to the MNO. Both the MVNO and MNO would like negotiated conditions that enhance its individual profit possibilities and power in the value system. Logically, the MNO should prefer MVNOs able to increase number of users and usage, complementary in market segments and user value to the MNOs own service provider and with potential to cannibalise the market share of the competing MNOs. The MNO's trade off is between loss in its service provider business and gain in other business levels. What matters to the Retailer should be the fit of negotiated conditions with its service concept, not necessarily the dept of access into the mobile network. To build and run a network with mobile switching centre, home location register and other network facilities requires high capital expenditure – high traffic volume to earn a profit – and higher competence level which may be a source of disadvantage compared to an experienced MNO. The MVNO's freedom to pursue individual strategies, such as pricing strategies, should be of high importance to the MVNO. The MNO and the MVNO may have common interest.

- Regulation. Without an obligation forced on the MNO by the regulator, the MNO may not wish to give access to its network. However, the MVNO may be better off with an agreement based on free will of the MNO.

The Expander

Companies grouped as "Expander" enter new segments or markets as a telecommunications network provider, e.g. fixed network operator expanding into mobile, mobile network operator expanding into a new geographical market.

The purpose of the Expander will be to get a better grip on the customer, to capitalize on resources such as competence and network facilities or to seek opportunities in new markets. The benefits and advantages to the expander depend on many factors, perhaps first of all added value to the customers, change of power and relationships within the Value Net and the company's uniqueness and defend ability. Synergies is a key word, because setting up a MVNO in a new marked with none or limited synergies, the new MVNO business will tend to be a stand alone "Retailer".

The key success factors for the Expander to be sustainable (earning a positive profit relatively higher than the rivals) seems to be:

- Increased returns. The move of the company should increase positive feedback, preferably both from the demand and supply side. In addition, increased functionality and pricing should increase switching cost locking in the customer.

- Increased value added to the customer making the customer pay more and/or increase number of customers and/or usage.

- Influence the game of business within the Value Net in light of the value network of layers of business landscape. The strategy of the Expander should be to build a defendable competitive position. The player should use the MVNO business as a strategic move to differentiate itself from the competitors – companies on the same layer performing the same or substituting roles. The MVNO business can be used as a tactical move as a response to competitors with a broader portfolio of substituting roles, e.g. bundling of various access technologies, or a move to become the broadest provider.

- Attitude of the MNO and regulation. The Expander would most likely prefer an agreement giving him access to the unbundled radio-network and make him able to control the routing of traffic, control the location of customer, provide technology roaming etc. The probability that the MVNO and the MNO will have different interest is greater than in the Retailer case. But Tele2 is an example of a telecommunications company with a MVNO business in Denmark, with access deep into Sonofon's (the MNO) network. The relation to the MNO can be a barrier to the Expander's business model. See section above regarding the Retailer case for discussion.

- Capitalizing on in-house resources such as network elements and competence of building and running a telecommunications operation.

- Other advantages such as brand, ref success factors of the Retailer case.

The Integrator

Companies grouped as "Integrator" enters other layers of the value network, e.g. an application provider or an Internet portal provider move into the mobile service layer.

The aim of the Integrator will be to get a better grip on the customer, enlarge the market / increase the total value to customers, influence the game between the companies of the value net to become relatively more powerful or to seek opportunities in new layers/markets. The benefits and advantages to the Integrator depend on many factors, perhaps first of all the actual position in the business landscape (relations and power within the Value Net), total added value to the customers, and the company's uniqueness and defend ability. Positioning through competence is the key for an integrator, because this will give a unique position, and might change the relations between the players, hence avoiding the new MVNO business to be just a stand alone "Retailer". The key success factors of the Integrator to be sustainable (earning a relatively high share of the revenue stream) seems to be:

- Secure and increase the grip on the users and secure the channel to the users and the revenues. The grip on and value added to the customer can depend on roles of various layers, e.g. functionality of the Internet portal service can depend on information from the mobile network and mobile terminal. A company or a partnership between companies performing roles of several layer of the Value Network (vertically integrated) can lock out other companies. The MVNO business can also be used to reduce the power of the company(s) of the mobile business layer, and in that way increase the power of its own core activity/layer.

- Increased returns. The move of the company should increase positive feedback, preferably both from the demand and supply side. In addition, increased functionality and pricing should increase switching cost locking in the customer. The MVNO should not be evaluated independent of the whole operation of the company or corporate group.

- Increased value added to the customer making the customer pay more and/or increase number of customers and/or usage.

- Other advantages such as brand, re success factors of the Retailer and the Expander.

6 Conclusion

The value of telecommunication services and products to the customers depend on complementary services and activities. The business model of a company have to give the company (or the corporate group) a defendable position in the net of various complementary and supplementary services provided by companies performing different sets of roles. In addition, the net can also be viewed as a complex set of relations between the playing companies and interests. Further, the position of the company/corporate group has to enable the company to defend – preferably increase – its share of revenue generated by the whole Value Net.

The main key success factors are:

- Take advantages of increasing returns and customer lock-in.

- Stimulate high total value of the whole Value Net. Aim to achieve a win-win situation with the MNO and other partners.

- Powerful position in the whole Value Net difficult to copy or bypass.

- Be in or manure into a position where a relatively large share of total revenues can be tapped.

The analysis show that there may be a large number of sustainable business models depending on where the company/corporate group came from, the relations to other companies in the Value Net and the characteristics of the influencing business landscape. But the winner(s) in the ICT business landscape will tend to be the companies and corporate groups that have business models building on the above success factors. The business model of the MVNO business unit should be assessed in relation to other business units of the company or corporate group.

In general, the Retailer tends to be a low profit business. The possible business models of the Expander and the Integrator are difficult to generalize, but high profit companies will tend to build on the above success factors.

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Why Should You Invest in MVNO?

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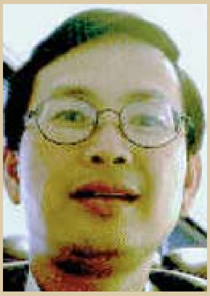

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In this paper we present an evaluation of the Discounted Cash Flow on Return on Equity of the Mobile Virtual Network Operator (MVNO) concept, which is an emerging business concept in the telecommunication sector. An MVNO is an operator offering mobile communications services without owning a radio infrastructure. The preliminary evaluation of Business Strategies, Designs of an MVNO, and Synergies between an MVNO and a Mobile Network Operator has been examined. Various Critical Success Factors have been examined within the context of a Business Case advanced by Ovum, and the financial analyses conducted in this paper show sound financial results confirming that the MVNO concept is deemed attractive from a shareholder's return on equity investment standpoint.

1 Introduction

With the strong and rapid growth in the mobile communications market reflected in the explosion of the number of mobile phones and the number of subscriptions, companies both inside and outside the telecommunication branch have been attracted to the mobile sector. Besides playing a passive role, i.e. investing in the mobile sector by acquiring stocks of mobile operator companies, a more aggressive and perhaps more profitable strategy would be to participate actively by becoming a mobile operator. The threshold of becoming a mobile operator was dramatically reduced with the introduction of the Mobile Virtual Network Operator (MVNO) concept. Indeed, it is possible to be an operator without having to invest in frequency spectrum license or in wireless network infrastructure and without having to build up competence in wireless technologies. In this paper a financial study of the MVNO concept is carried out. The goals are to identify and to create the values for the shareholders.

2 What is a Mobile Virtual Network Operator?

Although there is no consensus about the definition of MVNO [1,2] we choose to adopt the following definition:

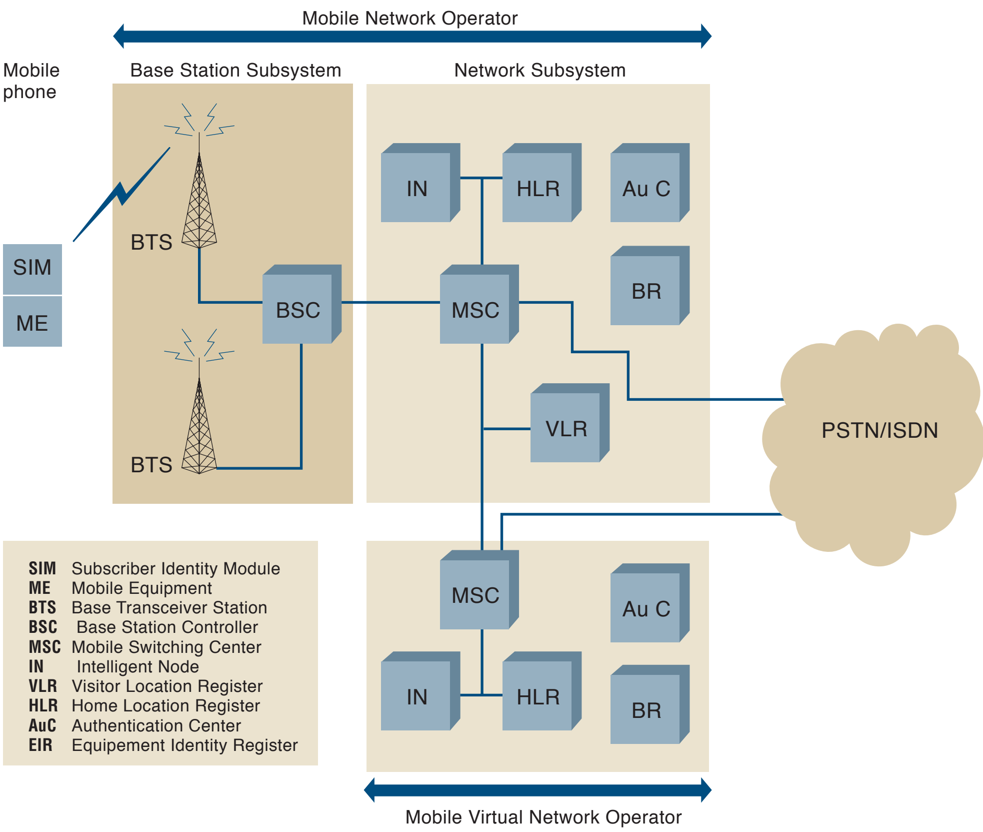

Figure 1 MVNO in GSM architecture

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An MVNO is an organization that is perceived by the customers as a regular mobile network operator, i.e. offering mobile communication services, but does not own a radio infrastructure.

In order to understand how this could be possible let us examine how the GSM system [9] works. As shown in Figure 1, the GSM system comprises three subsystems: the Mobile Station, the Base Station Subsystem and the Network Subsystem.

The *Mobile Station* (mobile phone) consists of the *Mobile Equipment* (the terminal) and a smart card called the *Subscriber Identity Module* (SIM). The SIM contains the *International Mobile Subscriber Identity* (IMSI), which allows the Mobile Network Operator to uniquely identify the subscriber. Indeed, The IMSI consists of three fields: the Mobile Country Code, The Mobile Network Code and the Customer ID.

The *Base Station Subsystem* is composed of *Base Transceiver Stations* (BTS) and *Base Station Controllers* (BSC) and is responsible for the radio link.

The *Network Subsystem* consists of the *Mobile service Switching Center* (MSC), the *Home Location Register* (HLR), the *Visitor Location Register* (VLR), the *Authentication Center* (AuC) and the *Equipment Identity Register* (EIR). Lately, the Subsystem may be strengthened with an *Intelligent network Node* (IN) that enables enhanced services such as Call forwarding, Voice mail, etc. The MSC is a switching node providing connection to PSTN/ISDN or other networks. The HLR contains subscriber information along with the current location of the mobile, i.e. the current VLR. The VLR contains selected information for each mobile station located on its service area. The AuC assists the HLR in the authentication of the mobile station. The EIR is a database containing a list of all valid mobile equipment (terminal).

In a mobile environment where the mobile stations (and the users) are moving constantly, it is crucial to determine their location in order to deliver services to them. The GSM network is organised hierarchically. At the lowest level, a group of cells corresponding to a BSC forms a *location area* in which the mobile phone can move without location updating.

At the next level, several location areas under the same MSC/VLR form a *service area*. When the mobile phone changes location area, it must register the new location to the current MSC/VLR but the HLR need not to be informed as long as the mobile phone is still in the same service area.

A registration towards HLR is only necessary when the mobile phone moves to a service area belonging to a new MSC/VLR. A location update message is sent to the new MSC/VLR, which records the location area information and then sends it to the subscriber's HLR. The identity of the HLR is resolved based on the IMSI, which contains the Mobile Network Code. After successful authentication, the HLR sends a subset of the subscriber information needed for call control to the new MSC/VLR and sends a de-registration to the old MSC/VLR. The HLR also records the identity of the new MSC/VLR.

A Mobile Network Operator (MNO) must own at least a Base Station Subsystem, a Network Subsystem and a SIM personification system (for issuing SIM cards to customers) in order to be able to offer communication services to the users (both its customers and visiting users) when they are within its service area. When the customer visits another MNO's service area, there must be a roaming agreement between the visited MNO and the home MNO that ensures service delivery to the customer. In this case the home MNO pays the visited MNO for outgoing calls and incoming calls initiated by or addressed to its customers (call origination and termination cost). In return, it will get paid for incoming calls from other networks and will also charge its customers extra, both for call delivery and call initiation at visited MNO.

According to our definition an MVNO does not own any radio infrastructure. Hence, it does not own any Base Station Subsystem. Consequently, it does not need to have a VLR since it is not capable of receiving any visitor. However, it may or may not own an HLR, an AuC, an EIR, an IN and a SIM personification system since outsourcing is always a possibility. An MVNO's customer is always on visit to another MNO's service area. Some sort of agreement is necessary. Such an agreement could not be a roaming agreement since an MVNO can never return the favour to an MNO that has offered services to its customers. It has to pay the MNO for both outgoing and incoming calls. It will get paid for incoming calls from other networks but cannot get paid extra from its customers for call delivery and initiation at visited MNO since they are always on visit to some MNO's service area. At first glance, it may appear that an MVNO has a very weak business case. However, with a good agreement with one or more MNO in one or more countries, an MVNO may be able to offer subscriptions with competitive prices and quality to its customers.

3 Business Environment of the Decade 2000

One of the most profound changes in business is that there is a new definition of success. Business is intrinsically different in the new millennium from what it has been in the past. Competition is becoming more intense as markets become global [3]. The widespread use of computer technology is altering ways in which one conducts their business. Competitive advantages are becoming more difficult to maintain while the international community has reached our backyard and competition has reached an all time high [10]. MVNO is one of the major drivers of these changes. The 1990s saw an explosion of telecommunication and the utilisation of cellular phones. The first decade of the new millennium will see a convergence of fixed and mobile services, and operators are keen to see a full range of telecom services. Since mobile spectrum is limited to spectrum constraints, Mobile Network Operators may be looking to negotiate commercial agreements with MVNO. MNO and MVNO can explore synergies as well as differentiate their services to service their customers [1]. The emergence and role of MVNOs will be essential in developing the market where the MNO's market share is weak and marginal, especially for an MNO during a market penetration phase.

4 Changing Nature and Intensity of Competition, hence Strategic Alliance

The envelope of competition is changing. Firms today should not deny the need to improve one's performance through greater performance and effectiveness. Business competition from across the globe; change brought to an organization through technological advances, and price competition are all examples of just some of the challenges facing businesses today [5]. Out of the five hundred (500) companies on Fortune magazine's 1990 list of the largest industrial companies in the United States, only 300 appeared on the 1999 list. Some were displaced by other companies with higher total revenues. Others disappeared in mergers, acquisitions or bankruptcies [4]. Drucker (1990) states that the only firms that survive are on the two extremes; those that set the standard and those that serve in a specialty area. The in-between position is neither desirable nor viable [6]. There are also new and fewer leaders in telecommunications due to industry consolidation. There is no longer national boundary for competition. The marriage of computing with telecommunications has made competition more intense than ever. For example, a know-how, specialty or scientific knowledge of an individual living in Russia can be made available via Telecommunication and Information Technology. The most obvious change is the intensity of competition in almost every facet of business [7]. The telecommunications industry is using a technique referred to as 'scenario planning' to explore possible future environments and determine whether or not their strategic plans will be appropriate in the coming years.

The very nature of competition is changing as we move into a service economy and into the information age. The emergence of MVNO represents that change. The global village has arrived for virtually everyone who sells goods or services. Advances in manufacturing, changing patterns of transportation, and social and political changes all contribute to changes in organisations. However, Mobile Network Operators' growth in telecommunication is not the only driver of change. It is the catalyst that underlies many other drivers. The dramatic growth rate of the number of mobile phone users in the last decade cannot continue indefinitely in the next decades. As a result, Mobile Network Operators will be competing with each other for existing

Box 1 Valuation

A project, a company or an investment can be valued using different methodologies. Assets can be measured by looking at its fair market value determined at an arm's length transaction. This process is however not applicable for an expansion project like an MVNO whereby shareholders are required to invest a large sum of money for capital expenditures plus incurring continuing expenses in a long run at a significant risk. The most common methodology used is a Net Present Value of Cash Flows. This requires development of pro forma projection using realistic assumptions to arrive at Statements of Earnings and Cash Flows Statements for future years (5 to 10 years). These streams of cash flows (Box 4) would be discounted at a cost of capital (defined in Box 2) to arrive at a Net Present Value (defined in Box 3). This Net Present Value would represent the valuation of the project, in this case, the valuation of the MVNO project. A project that yields a positive Net Present Value is deemed attractive, the higher, the better.

Box 2 Cost of Capital

Cost of capital is defined as the average cost that a company incurs in order to raise funds. Typically a company would raise funds through debt or through infusion of shareholder's equity, or most often through a combination of debt and equity. Cost of capital is defined as the after tax weighted average cost of debt (business interest expenses are tax deductible) plus the rate of return on equity desired by shareholders adjusted for risks.

Example: MVNO company A has a debt to equity ratio of 2 to 1. What this means is, for every 2 dollars of debt, there will be $1 of equity. Assuming that a company can borrow long-term interest rate at 7 % per year and the corporate income tax rate is 20 %. In addition, for shareholders to invest in MVNO company A, they would require an after tax return rate of 15 %; otherwise they would invest in a less risky project or a project of equal risk but with higher return.

In a simplified way cost of capital would be computed as follows:

Cost of capital = (75 % x (1–20 %) x 7 %) + (25 % x 15 %) = 7.95 % or roughly 8 %.

Box 3 Net Present Value

Net Present Value is defined as the net sum of negative and positive cash flow streams occurred during current and projected into future periods, discounted back into today's value at the cost of capital (defined in Box 2). This is necessary to recognize the value that a dollar today is worth more than a dollar tomorrow.

For example, at a cost of capital rate of 8 % per year, the following would be the discounting factor used to calculate a net present value:

Cost of Capital	Year 1	Year 2	Year 3
8 %	1.000	.857	.794

$1000 in today's dollar value, at 8 % cost of capital, would be worth $794 in year 3 or ($1000 x .794).

customers rather than for new customers in a mature market environment and for market development in third world countries [1]. Mobile Network Operators may soon realize that a strategic alliance with an MVNO may be the new industry norm to increase and to retain its market share in a global market.

5 New Paradigm for Business

In addition to the new global competitive nature for producers and the demands of customers and ultimate consumers, competition is further changed by the increasing demands of stakeholders [13]. Business success means meeting the needs of all stakeholders: workers, suppliers, customers, the community at large, the shareholders and the regulators. The need for rethinking how one views the organization and how it achieves goals and objectives is currently underway in the literature of business and management journals. Witness a new theory of organizational knowledge, or corporate epistemology provides a new way of interpreting that is gaining interest in journal articles [8]. Successful execution of strategies in today's highly competitive environment requires a sharp focus on customer needs and on new ways of managing talents and energies of all members in the organisation [5]. MVNO could offer a competitive edge beyond the short-term revenue, cost and profitability issues for a Mobile Network Operator. In today's increasing global competition, a constant focus on the ever changing needs of the customers with fast paced technological changes could require an MNO to team up with an MVNO to attain a sustainable competitive advantage. Above all, it means managing for flexibility to meet changing conditions, flexibility to take risks in order to serve the ever changing needs of the customers who may be spread out in a remote geographical areas.

6 Synergies versus Threats

New entrant MNOs would see the potential of synergies by partnering with an MVNO in entering a new market where initial market entry cost would be high. In a typical medium size European country, one third of total cost would be required for establishing the Base Station Subsystem. Utilizing the current excess capacity of an MNO would require the MVNO to pay for each year usage fee without incurring the large initial outlay of cash and thereby reducing the financial risk exposure. This would be very important for public companies whose debt to equity rating is very important in driving stock prices and shareholder's value. Reducing the outlay of capital investment would improve the cash flow position for a company in an aggressive growth position; sources of cash could be better used in more strategic areas. On the other hand, being an MVNO requires significant outlays of cash as operating expenses for marketing and business development purposes. Significant expenses would be required to be incurred for marketing and advertising expenses; free airtime and waiver of connection charges are standard costs that are incurred with delayed benefits before revenues can be generated. That is an area that would be of interest to an MNO to rely on the expertise of an MVNO. For example in UK, mobile operators spent $160 million in advertising costs. Orange operator spent an average of $240 to $480 per customer while the investment required would be $320 per customer. These data indicate a long-term payback for an MNO unless synergies can be explored between an MNO and an MVNO [1].

The partnering spirit between a new entrant or marginal MNO and that of an MVNO is quite different than that of a market leader who may look at an MVNO as a threat to their market share. A market leader would be unwilling to negotiate a commercial agreement with an MVNO and resist vigorously any attempt from regulators to regulate access to its market share [1].

Box 4 Cash Flows

Cash Flows are determined as the sources of funds (cash in-flow or cash receipts) and uses of funds (cash outflow or cash expenditures). It is different from Net Income or Net Earnings in many aspects, one of which, cash flows do not take depreciation expense or accruals of revenue or expenses into account. The reason that cash flows are used in the valuation of a project instead of Net Income because cash flows represent a project's ability to meet its obligation toward its debtors and shareholders, regardless of depreciation rules or convention which may vary from company to company.

7 Definition of Shareholder's Value and Measurement Yardsticks for MVNO (Present, Future)

Shareholder's value is often defined as the Return on Equity in terms of appreciation of value of capital invested to compensate the shareholders for risks and opportunity cost of money taking into account the inflationary impact on the value of money. The concept of shareholder's value creation is often associated with the long term building of residual value of the capital employed or the stock performance of the enterprise. Traditional accounting methods of measuring the benefits of an investment in a telecommunication in an MVNO in creating long term shareholder's value are often incomplete and short term in nature.

Accounting measurement of an investment in a Mobile Network Operator or an MVNO using common measurement yardsticks such as return on assets and return on investment are often misleading due to inconsistency and lack of uniformity varying from company to company. Different depreciation methods and depreciation life often lead to misleading results. To compensate for the shortcomings of the accounting yardstick of measurement, other methods such as present value of money using the cash flow derived from the project are discounted at the hurdle rate. In the case of an MVNO, discounting the present value of cash flow would not be sufficient due to the long payback. It would require a careful evaluation of the residual value beyond the explicit forecast using a perpetuity method to value a MVNO company.

8 Success when it Means Sustainable Competitive Advantage and Bottom Line

Various techniques exist to measure the benefits of an MVNO including:

Discounted Cash Flow and Net Present Value method. This method is widely accepted in the industry practice. The synergies that can be harvested between a fixed operator and a mobile network operator need to be identified and quantified.

Critical Success Factors method devised by John Rockart. Computer systems are developed to support a company's business objectives. Critical Success Factors need to be defined within the context of the MVNO's business objectives.

Valuation methods often vary from one business case to another and depend largely on data available. The most common methods used involve a weighted average on the three methodologies:

1 Discounted free cash flows at a cost of capital to arrive at a Net Present value;

2 Comparable data by using data of current public companies whose various multiple of EBITDA, earnings and sales can be readily available and computed;

3 Past transactions by relying on past transactions of public companies that were traded, acquired or merged with multiple of EBITDA, sales and net earnings.

Unfortunately, since MVNO is a new concept with no past or current history, the valuation method using the Comparable multiple method or multiple of Past transactions cannot be used. The only method available that can be used is the Discounted Cash Flow Present Value method

Pro Forma Income Statement/
Cash Flow: Assumptions: Initial cash outlay investment: ($4) Million

In 000's	Year 1	Year 3	Year 6
Customers	15	38	93
Revenues	$5496	$19,312	$43,079
Cost	($7,441)	$19,182	$33,962
EBIT	($1945)	$130	$3208
EBITDA	($1545)	$530	$3608

EBIT: Earnings before Interest and Taxes;
EBITDA: Earnings before Interest, Taxes and Depreciation

In 000's	Year 1	Year 3	Year 6
Customers	15	38	93
Revenues/customer	$366	$508	$463
Cost/customer	$496	$504	$465
EBIT/customer	($130)	$3.4	$35
EBITDA/customer	($103)	14	$39

Table 1 Pro Forma Income Statement and Cash flow

Table 2 Financial results

Financial Results/Sensitivity Study:

After Tax Cost of Capital	10%	12%
NPV	$15 Mil.	$11 Mil.
PAYBACK	5.2 YRS	5.2 YRS
DCF ROE	60 %	60 %

Financial assumptions: $4 million capital: 3 to 1 Debt to Equity ratio. Shareholder's equity investment: $1 million USD; $3 million USD loan amortization over 6-year period at 7 % per annum.

DCF ROE: Discounted Cash Flow Return on Equity

NPV: Net Present Value

Box 5 Payback

Payback is defined as a measure of risk with the number of years or months required for a project to generate sufficient cash flow to equal the original investment in capital expenditures plus any additional working capital. The quicker the payback period is, the smaller the risk of the project to the shareholders or investors.

using a Business Case approach with assumptions as advanced by the work done in Ovum – Virtual Mobile Services Strategies for Fixed and Mobile Operators by John Matthews and Susan Sweet [1]. These data and assumptions will be used in this paper with the largest unknown factor as delineated as the amount that an MVNO would have to pay an MNO. Since this is the most major cost for an MVNO and it varies from arrangement to arrangement, the profitability of an MVNO remains an uncertainty until an industry standard can be established. If the payment required were the operator's retail price minus a discount, the MVNO's cost would be significantly higher than if it is based on the cost plus basis. It would be extremely hard for an MVNO to generate a profit if it is charged at retail price minus a discount unless there is a very significant economy of scale. A reasonable assumption in the business case is that retail price minus discount is roughly 50 % higher than cost plus. It is therefore important for an MVNO to be able to convince that it can generate additional traffic, value-added services and market share for a physical operator in a competitive environment due to its marketing skills.

The following are data and summaries taken from the Business Case in Ovum-Virtual Mobile Services Strategies for Fixed and Mobile Operators by John Matthews and Susan Sweet [1]:

Residual Value: The calculation of Residual Value is essential to an MVNO valuation. The Business Case assumption in the Ovum study assumed a 10 % of Original Investment as Residual value in year 7. This assumption is arbitrary and does not follow a going concern entity concept from a valuation standpoint. The modified valuation method as proposed in this paper treats the Residual Value under a perpetuity method. This is extremely important and required given the infrastructure and nature of an MVNO. With an initial capital outlay assumed at $4 million dollars, once successful in acquiring favorable airtime rate from an MNO, the growth rate of an MVNO can be tremendous and is limited only to competition and market acceptance without requiring additional capital outlay. For this reason, in valuing an MVNO, a growth perpetuity method needs to be utilized which in this case would be calculated as follow: Last year Cash Flow divided by the Cost of Capital [12].

Another factor to consider is the sensitivity study using a range of Cost of Capital assumed. A strategic buyer or a larger firm with strong borrowing capacity would assume a lower cost of capital (for discounting Cash Flow purpose) while a non-strategic buyer or a smaller firm would have a higher cost of capital. A range of after tax cost of capital (10 %, 12 %,) would be used in this paper for valuation purposes instead of a fixed number as assumed by the Ovum study.

Discussion of Financial Results

Based on the above results, the investment in an MVNO is deemed financially very attractive with high risk since most of the value is realized in the later years. It would take 5.2 years payback on a present value of cash flow; most of the net present value is realized in the Residual value as the MVNO reaches its high potential after year 4 starting with 60,000 customers and reaching 93,000 customers at the outpost of the explicit forecast in year 6.

A Discounted Cash Flow After-Tax Return on Equity of 60 % is considered attractive given the risks associated with an MVNO. A Net Present Value varying from $11 Million to $15 million (net of Initial Capital Cash Outlay of $1 million in equity, debt of $3 million fully paid off after 5.2 years) is considered very attractive from a financial standpoint, creating significant shareholder's value.

Upside potential exists if customer growth can be acquired faster than assumed during the initial first three years or operating costs can be reduced and value added service revenue growth can be realized above the Business Case assumption levels:

Major Revenue Assumptions:
The starting point for these forecasts are the existing Ovum forecasts (assumed to follow an S curve) for overall subscribers and revenues.

- Assumed 1/3 market of MVNO customers & traffic-country size of Portugal. This would be 1.5 % of total mobile market;
- Call Revenues 65 % of Total Revenues;
- Interconnect Revenues 26 %;
- Value Added Revenues 6.5 %;
- Connection Revenues 3 %;
- Value added services 10 % of Call Revenue;

- Interconnection 40 % of Call Revenue.

Major Cost Assumptions [1]:

- Payments to MNOs for call termination equal to Interconnect Revenues;
- Payment to MNOs for call origination is 35 % of Call Revenues;
- Interconnect Payments equal to Interconnect Revenues;
- Churn rate 20 % – Effective corporate tax rate 20 %;
- Operating Cost decline as a proportion of Revenues as system grows, i.e. $1 million plus 5 % Revenues;
- Customer acquisition cost: $150/customer.

9 Supporting Business Strategy and Vision

In order for an MVNO to be successful, based on the Business Case assumptions above, it is essential that additional revenues can be derived either by expanding in niche markets, offering additional value added revenues and by reducing operating costs and capital costs. Brand management is essential in offering additional channels to market existing products and services [1]:

The following are Key Business Drivers of a successful MVNO:

- Implicit or explicit support from the public and regulators;
- Demand from users for more services and competition to keep prices low;
- Support from MNOs who will benefit from additional channels to market airtime;
- Ability to acquire mobile market penetration with lower risk and lower capital;
- Strong marketing, brand management skills;
- Value added services;
- Exclusive Cost plus airtime purchasing agreement;
- Manage to eliminate resistance from MNOs seeing MVNO as a threat to their business.

In order for various business strategies to work successfully, an MVNO has to be organized with a holistic business design and strategic approach taking into account the interests of all the stakeholders.

10 Holistic Business Design and Strategic Approach

Business requirements change as competition intensifies and as business and markets increase their geographic coverage. Business alliances change the structure of business processes and the information needed to support them [11].

Effective and efficient business processes are central to the success of every enterprise. When a company grows significantly or when its business or its markets change, the field of telecommunication must facilitate the changes required by business processes. It needs to consider the criteria of maximum local control flexibility in operations and ability to accommodate changes. Revolutionary change would require a complete redesign of a business process, in this case the creation MVNO in partnering spirit with an MNO as a catalyst for growth of market share. The new design process is called holistic design. Some of the important aspects of the holistic design include:

- Instead of looking at one aspect at a time, design all facets of the process concurrently involving all aspects of telecommunication.
- Needs of all stakeholders must be taken into account during process design.
- Support of business vision and strategy is a paramount design goal.

Overall, MVNO's holistic design should reflect all the aspects of the business working in partnering spirit with MNOs. It must support the business strategy and make communication channels more accessible. As the telecommunication global market consolidates into fewer and larger players, market leaders form an oligopoly market structure. The natural mergers and strategic alliance of physical operators and MVNO, the partitioning and rationalisation of market share from one country to another, a holistic business design of the MVNO are tantamount to long term and sustainable success. The synergistic of a holistic design is merely more than the sum of its parts [14].

12 Critical Success Factors

The following are summaries of critical success factors for an MVNO organization [1]:

- Understand brand management and consumer marketing.
- Mobile Network Operators with infrastructure in one country could explore a niche market as an MVNO in another market.

- MVNO's agreement with an MNO needs to find a win-win situation: Lower cost and additional revenues.

- MVNO obtains support from regulators or lobby for regulations.

- Obtain support from smaller MNOs to find common synergies which may benefit from additional channels to market airtime.

- MVNO negotiates for cost plus pricing versus market price negotiation with MNO.

- Use existing investment to reduce capital costs.

- Leverage on existing front or back systems to reduce costs.

- Reduce cost with lower churn rate.

- Explore value-added services not reachable by traditional MNOs such as providing channels to market additional products and services.

13 Conclusion

The preliminary evaluation of Business Strategies, Designs of an MVNO and Synergies between an MVNO and a Network Operator has been examined. Given a 60 % Return on Equity with 5.2 years payback on a $4 million USD capital with 3:1 debt to equity ratio, the MVNO concept as proposed appears to be financially attractive. Various Critical Success Factors have been examined within the context of a Business Case advanced by Ovum and the financial analyses have been conducted in this paper showing sound financial results and are deemed attractive from a financial investment standpoint. Critical Success factors remain in the regulatory aspects and/or a successful cost plus commercial agreement yet to be reached between an MNO and an MVNO. In summary, the creation of shareholder's value is possible with low initial capital outlay but it has to be carried out in a holistic approach taking into account the interests of all the stakeholders. Upside potentials exist to reduce the operating costs and capital costs as well as common synergies between an MVNO and an MNO in order to create substantial shareholder's value. Future studies may focus on a more detailed level of cost assumptions and revenues breakdowns of an MVNO operation. An update of a country specific of regulatory changes would also be useful as a platform for an initial MVNO launch. Studies of cases where an MNO in one country can operate as an MVNO in another country would also be possible with certain non-compete agreement. Future studies involving cross equity ownership between an MVNO and an MNO can also be explored to strengthen the strategic alliance of these two potentially complementary operations.

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Access to Mobile Networks

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A few months ago, Cullen International conducted a short study on national regulation of access to mobile networks. The countries covered in the study were Sweden, Finland, the UK, Denmark, Ireland, Netherlands, Germany, Italy and Spain. The study looked at a number issues on access to mobile networks and how regulators in those Member States covered had dealt with them.

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The scope of the study included

- Access to service providers/airtime resellers;
- Mobile call-by-call selection;
- Mobile carrier pre-selection;
- Mobile number portability;
- Mobile call termination rates;
- National roaming; and finally;
- Access for MVNOs.

The current EU telecom directives do not clearly address access to mobile networks. Of the above issues, only mobile termination rates are regulated at EU level. The ONP Interconnection Directive imposes an obligation on mobile operators with SMP on the national interconnection market to have cost oriented interconnection charges. The other issues have so far been left to the discretion of national regulators.

A new legislative framework for the electronic communications market is currently being discussed in Brussels. Many issues are yet to be solved not least and the consequences the new framework will have for the mobile industry remain uncertain. For instance, whether or not the new legislation would impose heavy cost orientation obligations on *all* mobile operators or regulation of international roaming prices. In addition, with the new, very broad definition of access, national regulatory authorities would be allowed, where they find a specific market not to be competitive, to impose a whole range of access obligations on operators with significant market power (SMP), be that on the fixed or on the mobile market. It is also more than likely that mobile number portability will become mandatory. Finally, it cannot be completely ruled out that NRAs under the new framework, at least in theory, would have the possibility to regulate retail prices.

But pending the adoption and the subsequent entry into force of the new framework, national regulatory authorities to a large extent remain free to regulate the mobile market.

Going back to the findings of the study, we found that out of the nine Member States covered, five had imposed obligations on mobile network operators to deal with *service providers/ airtime resellers*. First of all, high barriers to entry at the network level caused by the scarcity of radio spectrum, limiting the number of players, have triggered regulatory action. The presence of service providers is viewed as increasing competition in the provision of mobile services to end-users. And it is not good, from the point of view of competition, that the possibility to provide services should be restricted to those few operators with network infrastructure. The regulator thus supports a split between the provision of network capacity and services. Sweden is perhaps the country which has gone farthest in this direction. The four UMTS licenses, which were handed out by PTS at the end of 2000, are for the provision of UMTS network capacity "only". The PTS does not in fact require the license holders to provide services over those networks. In addition, mobile operators in Sweden have since July 2000 (following an amendment to the Telecommunications Act) been obliged to sell excess network capacity to service providers without their own networks. A recent report of the PTS shows that the Swedish market has seen the emergence of a number of new players during the last 12-18 months. The PTS says however that it is too early to say whether this change in market structure is due to regulatory changes.

In those countries where mobile service providers are left to the market, the regulators have either

- not seen any reasons to intervene since commercial agreements are already in place; or

- fear the effects mandatory access for service providers would have on network operators' incentives to invest in new mobile infrastructure. And less investment means less innovation.

What about access to mobile networks through *carrier selection*? (either on a call-by-call basis or through pre-selection). In six of the countries covered, regulators had imposed obligations on mobile operators with SMP to offer call-by-call selection (CS) while carrier pre-selection (CPS) had been mandated in four countries. In Spain and Finland, the options are available for international calls only. However, looking at the practical implementation, the picture changes. With the exception of the UK (check), neither call-by-call selection nor pre-selection has really taken off anywhere.

The regulators which have intervened argue that mobile CS and CPS would increase the choice for end users by allowing them to choose alternative carriers for outgoing calls. CS and CPS could also encourage new packaging of fixed/mobile services. On the other hand, regulators who have, at least so far, refrained, say that CS and CPS are more suitable tools for breaking up the fixed market where there normally is only one access network available. Also these regulators would consider regulating mobile CS and CPS if other types of intervention fail to deliver.

It is probably also fair to say that the incentive for regulators to impose obligations on indirect access to mobile networks has declined since there are no signs that the new EU legislation will cover it.

Mobile number portability is not a form of access since it only can take place between operators already established on the market. Still, the majority of regulators have mandated mobile number portability. Statistics show however that where it has been implemented, the effects so far have been insignificant even in those countries where the churn (the customer changes operator) is high. Mobile number portability is more than likely to be mandated in the future EU legislation.

As was noted in the beginning, the Interconnection Directive imposes an obligation on mobile operators with SMP on the national interconnection market to establish cost oriented interconnection charges. During the last couple of years, many regulators have been keen to scrutinise the *mobile termination charges* for fixed to mobile calls. This has in many cases led the regulator to set a maximum call termination charge. This rather intense activity shows that regulators today see mobile termination as a real bottleneck putting off competition, hence the inclination to intervene.

Recently, Oftel, the UK regulator, published a spectacular determination to strengthen the regulation of mobile termination rates. At present, BT Cellnet's and Vodafone's termination rates are subject to a price cap. But Oftel is proposing that for the period March 2002 to March 2006, the termination rates of *all* four mobile operators (i.e. also Orange and One2One) should be subject to a price cap. It is only in Austria where it has happened before that also non-SMP operators are being subjected to the cost orientation requirement.

Mandatory roaming between two 2G networks in the same country is relatively rare in the EU. Only a few countries have imposed compulsory 2G *national roaming*. One of the main reasons behind this hands-off approach is that the 2G networks in many countries have roughly the same geographical coverage. But the story will be a different one now that mobile operators are starting to roll out their 3G networks. Of the countries covered in the study, 3G-2G roaming has been mandated everywhere except in Germany.

The rationale behind this by and large parallel thinking is the idea of creating a level playing field for 3G new entrants and existing operators from the beginning. To achieve this, the new entrant must be given the right to use the network by the 2G operator while it is building out its own network. In most countries, thresholds have been set, for example that the 3G new entrant will only have the right to roam on existing networks after having covered a certain geographical percentage. In addition, 3G-2G roaming is generally required as a temporary, or "sunset" measure, to alleviate the initial inability of a new entrant to provide nationwide mobile services.

The last issue we looked at was the right of access for *mobile virtual network operators (MVNOs)*. The basic principle behind the MVNO concept is that the MVNO has not been allocated spectrum on its own and so must use the radio access network[1)] of one or more existing mobile networks to offer services to its own customers. The MVNO may choose to provide all other network elements itself[2)] or may choose to rent nearly all network elements from an existing network operator. In the second scenario the MVNO's ability to differentiate its own services from the network operator's services is reduced and the MVNO resembles a traditional service provider.

It is probably right to say that the lack of a clear-cut definition of MVNOs has complicated regulators' task on how to deal with MVNOs. It was

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[1)] *Radio spectrum and mobile base stations.*

[2)] *Including the long-distance routing of calls, running its own user location register, customer billing etc).*

the type of access that Sense Communications requested from the Scandinavian mobile operators' networks back in 1998 which launched the concept. Although Sense did not succeed back then, the attempt was useful because it forced those regulators to think in new terms.

Out of the nine countries we looked at, regulators in five countries have attempted to clarify the rights of MNVOs. The approach has taken various forms. In Denmark, for example, MVNOs have rights of access through the national roaming legislation. In Sweden, mobile operators have an obligation to sell excess network capacity, which could enable MVNO services. In Spanish regulation, the MVNO has explicitly been introduced as a new category of operator. In the UK however, where OFTEL chose not to regulate rights of MVNOs, several commercially negotiated MVNO agreements are in existence.

Two opposing arguments are repeatedly put forward in the MVNO debate. It is possible that one effect of mandating access for MVNOs could be to hamper mobile operators' incentive to invest in new infrastructure. It is also possible that the existence of more market players could generate more traffic over the mobile networks. Lower barriers to market entry for MVNOs could have larger benefits for consumers than traditional service providers because they are in a better position to differentiate their services from those of the mobile operators', also in terms of prices. But regulators may also ask themselves, how many players are necessary in the end to guarantee effective competition? Two or three is not enough, but what about four or five? And perhaps 3G new entrants will have an incentive to negotiate MNVO type agreements on a commercial basis to maximise traffic on their networks? The regulator may also sit back and wait for the effects of other measures before taking steps to mandate MVNOs.

The situation will inevitably differ from country to country, depending on how the regulator has dealt with other forms of access, the number of mobile licences, licence fees, availability of frequencies, degree of competition in the wholesale and retail markets etc. It is tempting to say that the safest way for mobile operators to prevent MVNO obligations is to negotiate commercial deals. But then the problem of non-discrimination could arise. Why would a mobile operate want to negotiate an innovative deal with a service provider if it would have to, subsequently, to offer the same terms and conditions to all the others?

Service Opportunities for Realistic MVNO Models

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1 Introduction

The intention of this paper is to define different MVNO models and discuss the related service opportunities. Ovum has analysed the term MVNO in a separate report [1]. From the management summary the following description of an MVNO is used:

- Offers mobile services to customers;
- Has its own mobile network code (MNC);
- Issues its own SIM card;
- Operates its own home location register (including mobile switching centre as an option);
- Does not have its own radio frequency (spectrum) allocation.

This interpretation of an MVNO is somewhat limited to GSM technology entities. We will in the following use a looser definition:

> *"An MVNO is an entity which provides mobile communication services to customer under its own brand, without a radio license."*

Based on this definition, further referred to as our MVNO definition, we have identified various shades of organisations, which might also be called MVNOs and investigated the possible service opportunities for the different models.

1.1 MVNO Models

Figure 1 shows to the left Resellers, Mobile Service Providers and the Ovum defined MVNOs (SIM/HLR with MSC option) that exist in the GSM-sphere. To the right we have introduced the GPRS extension, Mobile IP and WLAN IP zones together with an IP backbone to get a broader picture. The seven alternatives based on this figure all need to interconnect with one or more Mobile Network Operator (MNO) and/or IP backbone provider to produce mobile services to the customers. Further the MVNO will possibly have a relationship with content providers, application providers, Internet service providers, etc.

2 MVNO Possibilities and Constraints

As for all market players, it is important for an MVNO to be able to provide added value relative to what is already offered in the market. This is important in relation to the customer, but also in relation to the MNO (mobile network operator), in order to achieve the best possible MNO agreement. In this paragraph, four different aspects for creating value-adding opportunities are suggested. The value adding opportunities for a Mobile Service Provider is discussed separately in paragraph 3.

Sub-paragraph 2.1 deals with the extent of integration with the MNO's network (i.e. vertical integration), sub-paragraph 2.2 discusses possible WLAN deployment, sub-paragraph 2.3 discusses possible service opportunities with the GPRS extension and the scope of sub-paragraph 2.4 is to present possible technology roaming concepts.

2.1 Integration with Mobile Network Operator

Our MVNO definition, as presented in paragraph 1 above, focuses on the customer perception rather than the degree of equipment ownership. All the four roles indicated in Figure 1 (Reseller, MSP, MVNO1 and MVNO2) comply with such an MVNO definition, but the degree of equipment ownership (i.e. technical integration with the MNO) still governs which service capabilities the MVNO can offer.

In the following we have chosen to look at two of these cases, the Reseller and MVNO2 (controlling both MSC and HLR), because these are the extremes in terms of technical integration with the MNO. In the table below, some MVNO features and their dependability of the choice of MVNO model have been indicated. The table has been limited to the features that differentiate the models.

The two models and their associated characteristics are described in somewhat more detail in the following:

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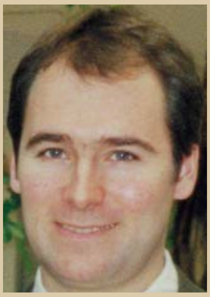

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2.1.1 Reseller

This model requires a "turn-key" traffic contract with an MNO. Without control over any network elements, the service capabilities are governed by that MNO. As shown in the table, in most respects, this can be considered a limiting constraint for the reseller. However, there are obvious advantages of sitting on the MNO's back as well; all roaming and interconnect agreements are already in place, all the MNO's services are available etc. For this reason, the reseller role should not require any significant amount of manpower on operational nor technical matters.

Also, as discussed in paragraph 3 below, there are many other ways for the Reseller to add value. The reseller role could suite major players in different (non-telecom) markets with an established brand, already populated customer database and existing customer relations. This could give a good negotiating position towards the MNO, which again may result in a cost advantage. The Reseller model is seen as a possible way into the mobile market for e.g. fixed network operators and ISPs.

2.1.2 Owning/Controlling MSC and HLR

In GSM this would equate to owing your own HLR and MSC. Having control over HLR, makes it possible to provide value added services based on HLR contents such as location data, logon status etc. Also, the options are wider (at least technically) with regards to special roaming arrangements, whether it is national or international roaming or roaming between different access technologies.

An MVNO of this type may build and operate its own backbone network in order to reduce costs on international traffic. This makes the model attractive for players that already control fixed network resources. On the other side, this model also requires more from the MVNO, in that it must make roaming/interconnect agreements on its own. To own the MSC makes it possible to provide value added services based on the call itself, e.g. IN solutions w/voice-prompt-menus, call routing, etc.

However, it is important to note that an alternative approach to own and operate the MSC and HLR is to negotiate access to and use of the relevant HLR-info and MSC functions with the MNO. This could provide a cost-efficient alternative, and potentially make the reseller model almost equally powerful as the MSC+HLR model, also when it comes to service capabilities.

2.1.3 Conclusion

It is more useful to use a loose rather than stringent MVNO definition with regard to equipment ownership. What is important is whether and how a particular player without a radio licence, by providing mobile communications, can add value for customers and partners. The Reseller model allows for a lot of value adding opportunities, even though service capabilities to a great extent are governed by the MNO. The MSC+HLR model allows for more freedom than the Reseller model with regards to service capabilities and more flexibility with regards to roaming and routing arrangements

2.2 GSM-GPRS Extension

With the introduction of GPRS (General Packet Radio Service) in the GSM network it will be possible to have always-on access to Internet and other data/IP services. The main drivers for the introduction of GPRS is:

- Efficient use of radio resources;
- Dynamic allocation of radio resources, (allocates channels only when data are transmitted);
- GPRS is designed for data and WEB/Internet applications – always on;
- Extend data-rates up to 40 kb/s in the first phase and up to 80 kb/s in later implementations;
- Offers billing on volume;
- Quality of service is specified in profiles to differentiate on customer-services.

Three different classes of mobile stations are defined:

- Class A: Supports both GPRS and circuit switched services, independent from each other. This is the most complex version.
- Class B: Supports both GPRS and circuit switched services, but not at the same time. It shall be possible to shift between the two services automatically. A packet transaction can be put on hold while an incoming speech transmission is handled and then continued when the speech is finalised.
- Class C: Supports both GPRS and circuit switched services, but not at the same time. A C-terminal could be realised as a packet data terminal only.

2.2.1 MVNO Opportunities

The equipment needed to operate a GPRS service will be more appropriate for introducing mobile Internet services. It is also believed that the interconnection towards the MNO's GPRS system will be more open and flexible than the MSC interface.

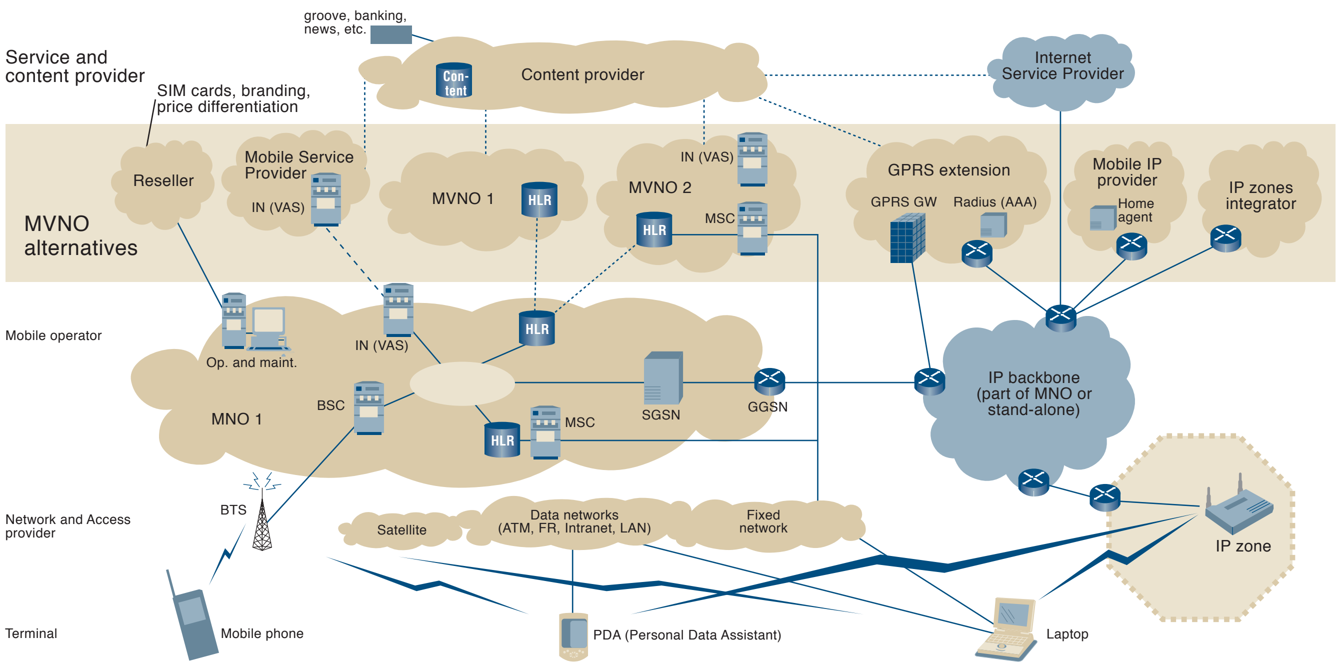

Figure 1 The network environment and possible MVNO alternatives

The GPRS subscription will be an add-on in the MNO's services provisioning portfolio. For an MVNO this can either be seen as an extension for the services offered in a vertical MVNO agreement (Reseller or MSC+HLR) or viewed as a possible stand-alone entrant strategy into the mobile business.

As a Reseller the customers will normally use the HLR of the MNO to get access to the GPRS service. The first optional move for an MVNO could be to negotiate a separate GPRS roaming agreement with other operators. You would then need an IP interconnection point, a MNC and a HLR. Further it should be possible to negotiate a separate GPRS interconnection agreement with your MNO, either to the GGSN (Gateway GPRS Support Node) or if possible deeper into the MNO's GPRS network with introduction of your own SGSN (Serving GPRS Support Node). This leave you as an MVNO, having a Reseller contract for the GSM part and an interconnect agreement for the GPRS part.

Initially the GPRS terminals will be of Class B. This means that the customers will not be able to handle circuit-switched services (voice) and packet transactions (e-mail, browsing) at the same time anyway. This split in operation will probably mean that the customer will feel no degradation on the service delivered from such an MVNO.

This suggestion will be very interesting when the focus of your operation is mobile Internet services bundled with commodity services like voice and SMS from the GSM world. Further this will probably give you a better position if

Feature / Model	**Reseller**	**MSC+HLR**
HLR and MSC	Does NOT own	Does own
GSM roaming	No freedom[1]	Possible
Technology roaming	Possible[3]	Possible
Call routing / interconnect	No freedom[1]	Flexibility[2]

Notes:

1 “No freedom” in the meaning “same as MNOM.

2 In the MSC+HLR case, the opportunity to control/own the backbone networks also exists.

3 It is possible for the reseller to support technology roaming if assuming a proprietary mobility management system (i.e. external to GSM network). However, the MSC+HLR model is more suitable because of the option to modify the HLR.

4 Value added services using HLR info such as logon status, position information, etc.; whereas value added services based on MSC could be IN-solutions, voice prompt menus, call routing logic, etc.

you want to negotiate a complete interconnection for all your services with the MNO. A GPRS interconnection will also be important for technology roaming solutions.

2.3 IP Zones Integrator

A business that wants to operate as an MVNO has an option in offering IP zone services in addition to the GSM/GPRS services. The following sections describe what an IP zone is and why IP zone offering is an interesting option. Challenges are how to quickly obtain sufficient coverage (to attract customers and to achieve a minimum system capacity), how to make a viable business model and how to defend against competing players. An IP zone is a term used for describing a geographical area that is covered by a Wireless Local Area Network (WLAN) combined with a connection to an IP network, most often the Internet.

2.3.1 WLAN as IP Zone

There are several technologies that can support wireless Internet access. A promising technology is referred to as WLAN. One could argue that WLAN is a generic term, but it is very closely associated with the IEEE-standard 802.11. WLAN is a semi-mature technology that heads UMTS by several years when it comes to deployment. In addition the WLAN operates in an unlicensed radio spectrum.

The beauty of WLAN technologies is that one can leverage on years of research and development in the fixed LAN-environment. Thus procedures for user Authorisation, and Authentication are already established. From a functional point of view there are very small differences between a wired LAN and a wireless LAN. The LAN environment has no tradition for charging the end user. The cost associated with operating a LAN has been a part of the company's overhead. For this reason there is no established business model for WLANs that can be leveraged on. Thus the major challenges for a company that tries to offer public WLAN-services is to build the right business model to support the operation.

2.3.2 Relevant Players in the IP Zone Context

A complete IP zone service delivery involves many roles, technically and business-vice. The below mentioned roles are a minimum of what is necessary for a complete service:

- Site owner: The site owner has property rights over the infrastructure (houses, buildings, arenas ...) in which the equipment is to be placed.

- Equipment owner: Somebody has to provide the necessary technical equipment (radio interfaces, antennas, hubs, routers, etc.).

- Access provider: To connect the IP zones we need a an access line from the site to the backbone network.

- IP backbone provider: To interconnect the IP zones and to provide Internet access we are in need of an Internet backbone provider.

- ISP: An ISP will deliver some Internet services, but most of all he is the business role responsible for giving out IP addresses to connected terminals.

- In addition to the above examples there is a need for a lot of functionality (security, accounting, billing, authorisation).

To make all this work, one can either take on all the roles oneself, or one can act as a clearing function for all the parties involved. Our challenge is therefore to find a role as an integrator and/or clearing house that has a long-term involvement.

2.3.3 Value for an MVNO

For IP zones operation to make sense to an MVNO there has to be value in it not only for the customer, but also for the MVNO and all other relevant players.

Negotiation Power – Entrance Strategy

By definition an MVNO does not hold its own licensed radio spectrum. Thus an MVNO needs an agreement with the (MNO) to be able to offer services. The MNOs have traditionally been reluctant to offer access into their networks. One obvious reason is that there is a large asymmetry between the MVNO and the MNO. The MNO's customers will under no circumstances send traffic into the MVNO's network, it is always the other way around. If an MVNO can offer IP connectivity in selected areas to the MNO's customer, the MNO is more likely to be willing to trade accesses. Thus an entrance strategy for a company could be to start out as an IP zone operator. After building an initial customer base the company could expand it's service portfolio to become an MVNO. The advantage of this increased negotiation power should not be underestimated. The biggest obstacle for MVNOs so far has been to negotiate fair deals with the MNOs. To bring this kind of negotiation power could be a significant competitive advantage compared to other MVNOs.

Value for the Customer

An MVNO is more attractive to the customer when complementing GSM/GPRS connectivity with a high-speed WLAN service. This is especially relevant when the user is moving within a small space (offices, airports, rests, ferry-ports and other mandatory waiting areas). WLAN plug-in cards are currently available, and can be used with laptops as well as PDAs, which are terminal types more suitable for business work and data applications than GPRS telephones. Following from low investment costs, a low price for the end user is anticipated, probably much lower than GPRS and UMTS.

Value as a Stand-alone Operation

Running an IP zone operation could very well be a good business in its' own right regardless of the increased negotiation power. This business opportunity of IP zones should be investigated as stand alone operation as well as value add to an MVNO-operation.

2.3.4 Conclusion

Introducing IP zones as a value added service in the portfolio of a MVNO, could be useful.

- It will increase the power in negotiations with the MNO and hence lead to a better deal.

- It will give the customer the experience of a better service, both on price and bandwidth, in the IP zone areas.

- It may be the feature of an MVNO that makes certain target customer segments willing to take on a MVNO subscription, due to specific needs.

2.4 Technology Roaming

2.4.1 Roaming between Different Access Technologies

Roaming is in telecommunication most often associated with enabling user access, service profile and charging capabilities across homogeneous networks. The GSM system is an example on a well performing roaming capability on a rather high level. Subject to roaming agreements between peer mobile operators, the users can roam between the mobile access networks with most service capabilities intact.

The roaming logic is implemented in the network entities and the users do not have to be aware of which underlying mobile operator is enabling the services. The handset is frequency compatible in the visited network and access is granted through authorisation and authentication procedures based on the SIM data provided. However, today's pricing regime in Europe often charge the end users specially roaming fees and premium calling rates when roaming in a foreign network.

Roaming between different access technologies could be somewhat more complicated than in the GSM case. First of all the basic user functionality has still to be catered for:

- Authorisation;
- Authentication;
- Service provisioning;
- Accounting.

But maybe even more basic when considering different networks is the physical interface between the user handset and the access network. In the GSM case it is implicitly given that the user is roaming with the same handset.

One roaming alternative is user roaming (typical SIM card roaming) where the user is able to insert his/ hers user profile in a different handset when roaming in a foreign network. This is the case when Europeans travel to US (or vice versa) and use their personal SIM card in a terminal compatible with the local frequency standard.

A more sophisticated roaming is when the handset supports two or more frequency bands (dual band, three band etc.) in combination with SIM authentication. With this solution available the roaming from one network technology to another could be implemented transparently as in the GSM case with homogenous networks. This is the case for roaming between the GSM-900 and GSM-1800 radio access in Europe today.

There are several challenges involved when considering roaming between different networks. At present there are several initiatives developing network solutions to allow mobility and enable transparency between various technologies. One of them is mobile IP, which is a standard developed by IETF [2]. The concept of Mobile IP is based around three network entities: The Mobile Node (MN), the Foreign Agent and the Home Agent (HA). The basic idea is that the MN gets access to visited networks (facilitated by the FA) and gets connected to its home data and applications. HAs are entities located on the MN's home network that are capable of tunnelling the mobile node's datagrams to it while it is away. This Mobile IP concept can also be applied to wireless network, and networks of different type.

While the Mobile IP concept is well defined, some challenges remain in order to make viable implementations for e.g. technology roaming concepts. One challenge is where to implement the FA; at the mobile or in a router in the visited network. Another challenge is how to implement the MN software on the mobile device, because relevant terminals such as laptops, PDAs and

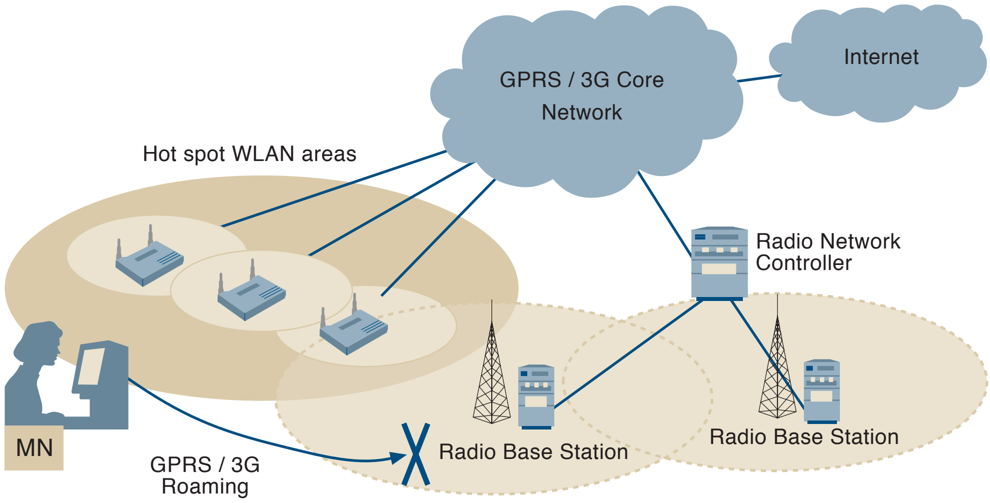

Figure 2 Roaming between GPRS/UMTS and IP zones with use of Mobile IP

mobile phones are rather closed platforms, requiring proprietary applications.

2.4.2 MVNO Opportunities

From an MVNO point of view roaming both within homogeneous networks and heterogeneous networks is considered important. The GSM roaming capability implies that an MVNO needs a service agreement with only one mobile operator and still provide large service coverage.

Roaming in between heterogeneous network might introduce new opportunities for a virtual operator. There are several scenarios, which might be promising:

1 Fixed net operators might extend their business with mobile services by enabling roaming, thus cater for a complete product offering.

2 Mobile services combined with WLAN hot spots might attract a mobile customer segment with large capacity needs to communicate out of office.

3 Mobile services supporting several local mobile standards, thus enabling real interregional coverage.

3 Service Provider

To summarise the possible MVNO alternatives and the related service opportunities so far, we have:

- Reseller;
- MSC+HLR;
- GPRS extension;
- IP zones integrator;
- Technology roaming.

All these alternatives share one common characteristic – they are MNO or technology centric. The two first seek to negotiate an agreement with the MNO to get a suitable vertical integra-

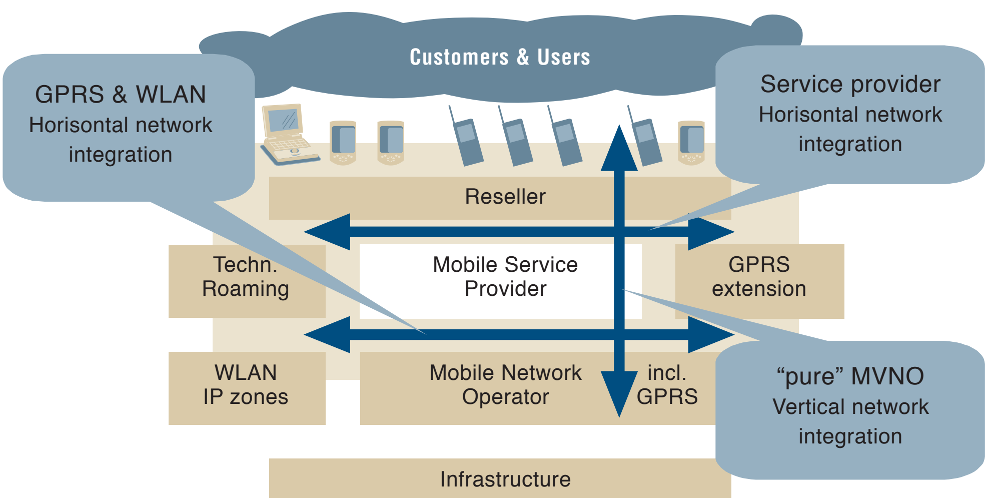

Figure 3 MVNO room of options (pink background) with indication of "pure" MVNO vertical network integration, GPRS & WLAN horizontal network integration (lower arrow) and Service Provider horizontal service integration (upper arrow)

tion point for making business. The three last seek to find some alternative business and/or market entrance strategies horizontal to the MNO via alternative technical solutions. Looking at the MVNO definition in paragraph 2.1.1, we recognise the customer approach. The glue for combining these two will be the Service Provider role, shown as the upper horizontal arrow in Figure 3.

There are many service opportunities that are available to an MVNO regardless of the choice of one of the models indicated by Figure 1. Some such opportunities are:

- Branding;
- Billing;
- Customer support;
- Exclusive application/features for terminal/SIM;
- Exclusive service/features in the network;
- Collaboration with partners such as content providers, application providers, Internet services providers, etc.

The possibilities for an MVNO when merging a Reseller role with a Service Provider will be to continue to handle the three first ones in a proper way and search for some uniqueness in a combination of the three last.

3.1.1 Whole Products

Actors in the telecommunication market strive to fulfil their user needs by offering complete services, thus being the only communication provider towards the customer. A Service Provider approach would make sense to a lot of actors that today only provides partially services. Typical candidates could be fixed net providers, CATV providers, ISP's. These actors would complement their existing service portfolio by introducing resold mobile services or IP zones, dependant on their customers needs and own capabilities.

3.1.2 Customer Mobility Needs

Customers have different service needs with respect to mobility. Many segments are very predictable and mobile within a limited area: Home, work, local community, commuting in between and from time to time a holiday or a business trip outside the primary roaming space. Such services needs might be well served by a Service Provider capable of identifying the customer mobility and combing access technologies accordingly. Work and home is suitable for IP zones whereas GSM/GPRS comprises the commuting and ad hoc coverage.

3.1.3 Time to Market

Time to market is in many cases vital to a company's success. The Service Provider approach is on several areas a relatively fast way to launch services since little or no physical build out is needed. However, this might only be the case if the strategy is based on "me too" thinking. Most

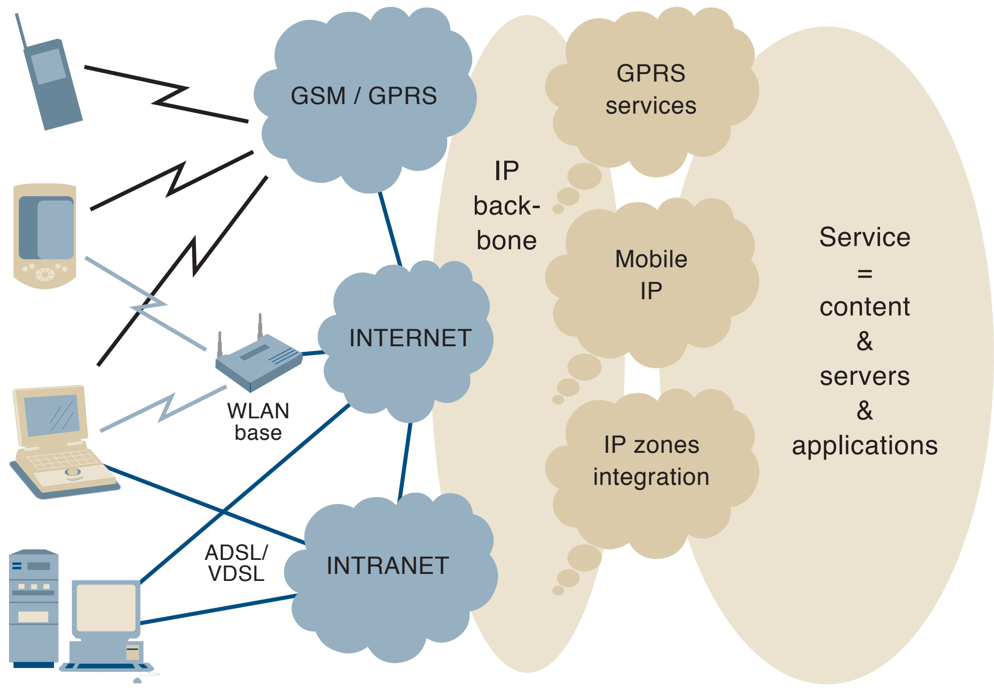

Figure 4 Horizontal service integration – Access and network independence

companies tries to stand out from the crowd, create a competitive edge, by offering something unique. Each unique entity or service feature has to be developed and here there are no shortcuts for a Service Provider. The benefit will then be to focus on just this uniqueness and not the network related developments and trade-offs.

3.1.4 MVNO Opportunities

The idea behind an MVNO is to deliver mobile services to the customer without building your own mobile access network. This means lower cost and higher flexibility with regard to business focus. As a Service Provider this idea is taken even further – trying to be independent of not only the MNO but the network and radio access over all, see Figure 4.

The strategy will then be to decide where to negotiate the interconnection and reseller deals and what services and application to develop and/or bundle in the product offer to the customer.

4 Conclusion

MVNO was initially defined as sitting on top of the MNO, serving the customers with mobile services without its own mobile access licence. The experience from several markets is that the Reseller model makes it handier for the MNO to control the vertical integration.

The focus for MVNOs as we see it will shift from this vertical integration view, to investigate alternative MVNO models. One approach is to look for alternative technologies to deliver the same services or at least the interesting art of the services for your business. WLAN IP zones and GPRS extension seems to be the candidates with the highest potential for the moment. When we combine them, we also build the basis for service provisioning across access technologies – technology roaming.

Further it has been recognised that one of the main drivers for the MVNO, the mobile service offering to the customer, points in the direction of focus on the Service Provider role. This horizontal integration providing mobile services to the customer, possible also in combination with a WLAN or GPRS service, can give an MVNO the needed strength when dealing with different network operators.

5 References

1 *Virtual Mobile Services: Strategies for Fixed and Mobile Operators*. Ovum Ltd., 2000.

2 IETF. *IP Mobility Support*. (RFC 2002.)

How do the Price Agreements Affect the Business Case of an MVNO?

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1 Introduction

Mobile communications markets contain several kinds of players who offer mobile services to customers. Some of them do not own the entire infrastructure necessary to deliver the services, including a license to utilize the radio spectrum. A useful overview of these kinds of operators is given in Ovum 2000.

In August 2000 we witnessed the appearance of the first mobile virtual network operator (hereafter MVNO or virtual operator) in the world when Tele2 signed an agreement with the mobile network operator Sonofon in Denmark. A year later Tele2 signed another MVNO agreement,[2)] this time with Telfort in the Netherlands. Mobile network operators (hereafter MNO or network operator) in the Netherlands do not have an obligation to give access to MVNOs. In Denmark mobile network operators are obliged to provide access to their networks, including MVNO access, but merely on the basis of commercially negotiated agreements. Apparently, both the mobile network operators and Tele2 have found the MVNO concept commercially interesting.

In this paper we discuss what might influence the parties' incentives to voluntary enter into an MVNO agreement. We emphasize particularly the effect of prices and price structures between the host MNO and the MVNO. A comparison will also be made between accessing the MNO network as a service provider and as an MVNO.[3)]

The rest of the paper is organised as follows: In section 2 we give a brief overview of the relationship between a network operator and a mobile virtual network operator. In section 3 we take a closer look into the MNOs' choice of how to market their infrastructure-based products. We then go on to discuss the effects of different price structures offered to potential third party market organisations, like service providers (SP)

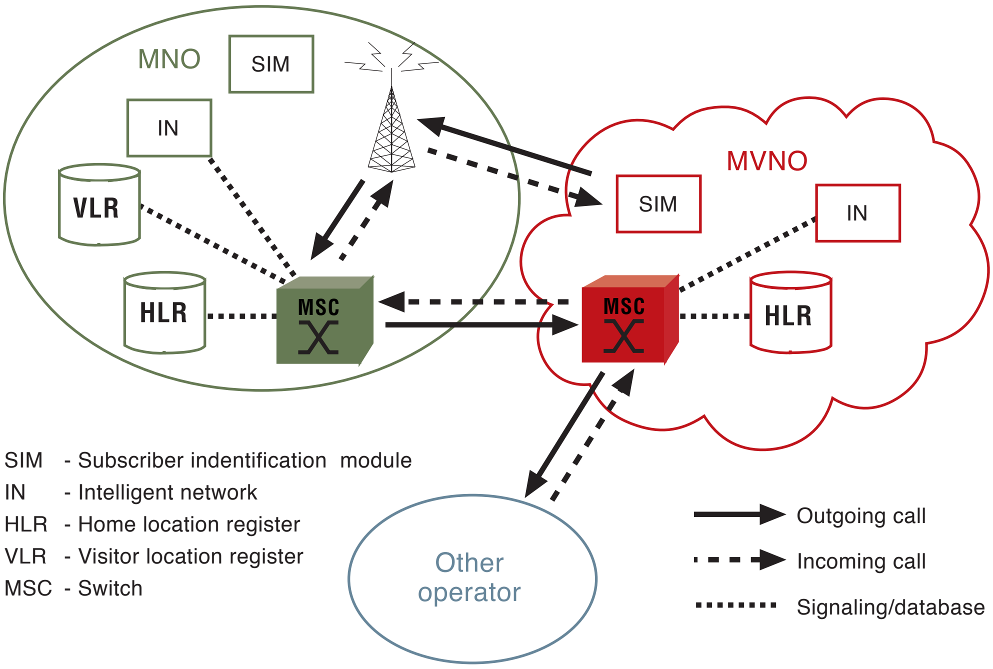

Figure 1 A mobile virtual network operator's customer – making and receiving calls

1) *We thank Petter Bliksrud, Thor Gunnar Eskedal, Øystein Foros, Bjørn Hansen, Steinar Sandbu and Lone Semmingsen for helpful comments and discussion. None of these are responsible for remaining shortcomings and possible errors in the paper.*

2) *See press release http://www.bit.se/bitonline/2001/08/24/20010824BIT00230/08240023.htm or http://www.Tele2.com*

3) *In the following, the term Service Provider (SP) will be used to describe all commercial entities that offer mobile services to its customers by means of an MNO's infrastructure but do not issue their own SIM cards.*

and virtual operators in sections 4, 5 and 6. Section 7 offers some concluding remarks.

2 The MVNO – MNO Relationship

A mobile network operator controls the whole chain of values needed to produce mobile telecom services. It holds a radio spectrum license, issues its own SIM cards, owns and operates the infrastructure including the base stations, switches and the gateway with the home location register (HLR). It is in full control of marketing, branding and pricing, as long as it stays within the regulatory framework. A mobile virtual network operator offers mobile services to customers, but does not hold a spectrum license and has to make an agreement to access an MNO's radio network. However, the MVNO issues its own SIM cards, has its own switch, HLR and service platforms, and has a full customer-care and billing system.

Figure 1 illustrates the structure of these two operators and demonstrates the routing of a call made by an MVNO customer to a customer in another network (black arrows) and vice versa. For the outgoing call, the nearest base station of the host MNO first accepts the MVNO customer's SIM card, and the call is routed to the MNO switch and then on to the MVNO's switch. This operation will be referred to as 'roaming out' in the following. Finally, the call is routed to the network of the other operator. The dotted arrows depict the routing of an incoming call. The part from the MVNO's switch to the terminal (SIM) of the MVNO customer is referred to as 'roaming in'. A call from one MVNO customer to another (not illustrated in the figure) is the combination of roaming out and roaming in.

3 The Network Operator's Choice of Market Channel

An MNO faces several options on how to market their infrastructure-based products. It might choose to let its own market organisation sell the final products; it might choose to use a third party such as a virtual operator or a service provider, or it may choose a combination of these.

As pointed out by e.g. Foros and Hansen (2000), the strategy of the MNO towards such third parties depends on the business stealing and the volume effects: Does the network operator simply face a new competitor who steals customers from their own core business, or will the third party contribute positively to the revenues by making the old customers buy a larger quantity or by bringing in new customers.

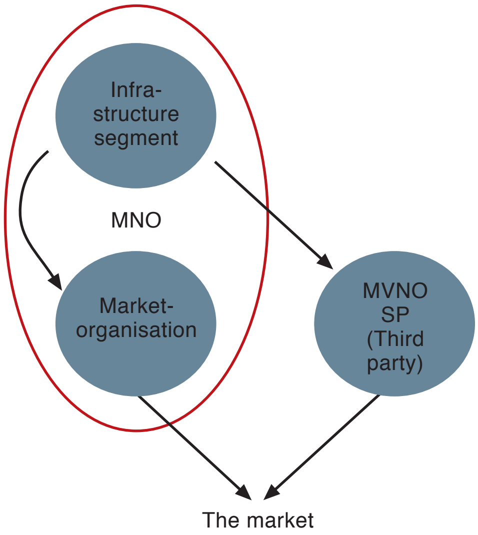

Figure 2 The choice of the MNO on how to market their infrastructure-based products[4)]

Even if the third party does not add value through the volume effect, the network operator may choose to use the third party as a market channel. If the third party can run the market operation more effectively than the MNO,[5)] total profits will be larger if the former runs the market operation. If the two parties are able to agree upon a contract that splits total profits such that both parties are better off, an outsourcing of the market organisation could be realised.

A network operator with a small customer base will probably have higher incentives to give access to a third party than one with a large customer base. The reason is twofold: Firstly, the smaller network is more likely to have idle capacity than the larger, and hence is more likely to avoid congestion when connecting the third party customers. Secondly, the business-stealing effect for the smaller network operator will be less because the third party will capture more customers from the larger network. The fact that neither Sonofon in the Danish market, nor Telfort in the Dutch market are the largest operators in their respective markets lends support to our assertion that small players relative to large players, indeed have larger incentives to give access to third parties.

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4) *The figure is from Foros and Hansen (2000).*

5) *Normally this will not be the case because most existing operators will have a larger customer base than the third party and hence lower cost through enjoying economies of scale in the network operation and/or the market operation.*

	Payments from (+) to (–)		
Call:	Customer of the MVNO	MNO	Other[8]
From MVNO to MNO	t_1	$-(p_1 + p_3)$	-
From MVNO to MVNO	t_2	$-(p_1 + p_2)$	-
From MVNO to Other	t_3	$-p_1$	$-m_1$
From MNO to MVNO	-	$q_1 - p_2$	-
From Other to MVNO	-	$-p_2$	q_2

Table 1 Income and costs from calls. MVNO[7]

	Payments from (+) to (–)		
Call:	SP customer	MNO	Other
From SP to MNO	s_1	$-r_1$	-
From SP to SP	s_2	$-r_1$	-
From SP to Other	s_3	$-r_2$	-
From MNO to SP	-	-	-
From Other to SP	-	-	-

Table 2 Income and costs from calls. SP

As described in section 2, an MVNO issues its own SIM cards and controls its own switch. This puts it in a far better position to introduce advanced services on its own service platform compared to a service provider. Thus, it may be easier for an MVNO to add value by introducing new services, complementary or independent to the MNO's services. On the other hand, the MVNO may choose to offer services in direct competition to the network operator's service portfolio. In the next section we take a closer look at the price structure between the host MNO and potential third parties and discuss how the network operator may set prices to balance the business stealing effect and the volume effect.

4 Third Party Price Structures

Tables 1 and 2, together with Figure 3, give an overview of the structure of the end-user prices, and the roaming and interconnect price components that need to be specified for the call portfolio of an MVNO and a service provider (SP).[6] The structure is partly based on the observed MVNO agreement beween Tele2 and Sonofon, and on the general agreements the Norwegian network operators Telenor Mobil AS and NetCom GSM have made with their service providers, see Sonofon and Tele2 (2000), Telenor Mobil (2001), and NetCom (2001) respectively. Nevertheless, the structures are quite general, and provide a fairly wide-range description of the core business models of an MVNO and an SP.

A positive symbol denotes an income for the MVNO/SP, and a negative symbol a cost. Hence, if all price elements were scalars and the subscribers of the MVNO make x calls to subscribers of the MNO, the MVNO makes a surplus of $(t_1–(p_1 + p_3))x$ from these calls. However, each element will in general comprise a vector of prices. Thus, the end-user prices, t_i and s_i, $i = 1,2,3$, will contain all the elements in the price menu the MVNO/SP offers its customers. Normally this would include monthly subscriptions, connect charges, and airtime tariffs. The same goes for the elements in the last two columns. At least, most MNOs would require different airtime tariffs for peak and off-peak periods. Furthermore, the prices may or may not contain connect charges and subscription.

For a call made from one MVNO customer to another MVNO customer, the MVNO would pay the MNO p_1 for transmitting the signal from the call-originator's terminal to the MVNO's MSC (roaming-out), and p_2 for transmitting it from the MNO's MSC to the receiving MVNO customer (roaming-in). The price p_3 is the MNO's termination price. For a player with significant market power, the regulatory authority may determine the level of this. Thus, although the roaming in and termination services are technically identical, the prices p_2 and p_3 may differ for a network operator that is free to set its own MVNO access prices. For calls made from the

[6] *For simplicity, the tables do not contain the tariffs when an MVNO/SP customer roams on another network but its host MNO. The MVNO has to negotiate these roaming agreements itself, while the SP inherits the roaming agreements made by the host MNO.*

[7] *This table is based on IMSI-routing, that is the routing used in the MVNO agreement between Tele2 and Sonofon in Denmark. IMSI-routing means that the call is routed based on an analysis of the A-number. Thus the call is routed directly from the MNO's network to the MVNO without analysis of the destination of the call (B-number). It is possible to use ordinary routing, i.e. analysis of the B-number as in international roaming, however IMSI-routing has been preferred in MVNO concepts.*

[8] *By "other" we mean another operator in the market, i.e. another mobile network operator, a fixed network operator or another MVNO.*

MVNO to a customer subscribing to any other network, the MVNO would pay p_1 for roaming-out to the MNO, and m_2 in transport and interconnect charges to the terminating network. The MVNO itself must negotiate its interconnect charges with other networks. Finally, for incoming calls, the MVNO must pay p_2 for the roaming-in service provided by the MNO. In addition it receives q_1 and q_2 in whatever interconnect charges it manages to negotiate with the parties.[9]

The price structure for the SP is much simpler. It pays r_1 to the MNO for calls terminating in the MNO's network, that is calls to MNO customers and other SP customers. Furthermore, it pays r_2 to the MNO for calls terminating in other operators' networks. Thus, the SP 'inherits' all the interconnect agreements (including roaming) of the host network operator, and does not receive or make any payments to other network operators than its host MNO. This simple structure reflects the fact that the service provider is re-selling the services provided by the MNO. In contrast, the MVNO controls its own facilities, as illustrated in Figure 1. The latter, issuing their own SIM cards, will have to negotiate their own international roaming agreements and interconnect agreements.[11]

5 SIM Card Ownership and Second-Degree Price Discrimination

The difference in SIM card ownership between an MVNO and an SP gives rise to a key difference in the MNO's ability to price discriminate. The MVNO issues its own SIM cards, while the SP does not, although it may re-badge, and even put in some additional features in the SIM cards it rents/buys from the host MNO. Thus, the MNO knows the subscription type of the SP customer and can set the prices in r_1 and r_2 according to the kind of subscription of the SP customer.

This means that the MNO to a large extent (but restricted by regulatory practise) can influence the price structure the SP chooses to offer its customers. In the Norwegian case, the MNOs offer their SPs the prices r_1^H and r_1^L. The SP must, for each customer, choose whether he should belong to r_1^H or r_1^L. The r_1^H price bundle comprises a high fixed monthly subscription rate and a low airtime tariff, while the r_1^L bundle has a low monthly subscription rate and a high airtime tariff. Hence, the structures r_1^H and r_1^L resembles the MNO's own end-user prices, designed to make the customers self-select to a 'high-end' subscription or a 'low-end' subscription. The SPs, facing the same market as the MNO, choose to offer similar price structures as the MNO.

Consequently, the MNO can prevent the service operators from stealing the attractive high-end customers, that is, to capture these customers without having to pay an accordingly high total (subscription + airtime) amount to the MNO. The MNO does not know the subscription type of the MVNO customer. This is due to the fact that the SIM card is foreign and accordingly, prices, p_1, p_2 and p_3 must be set uniformly for

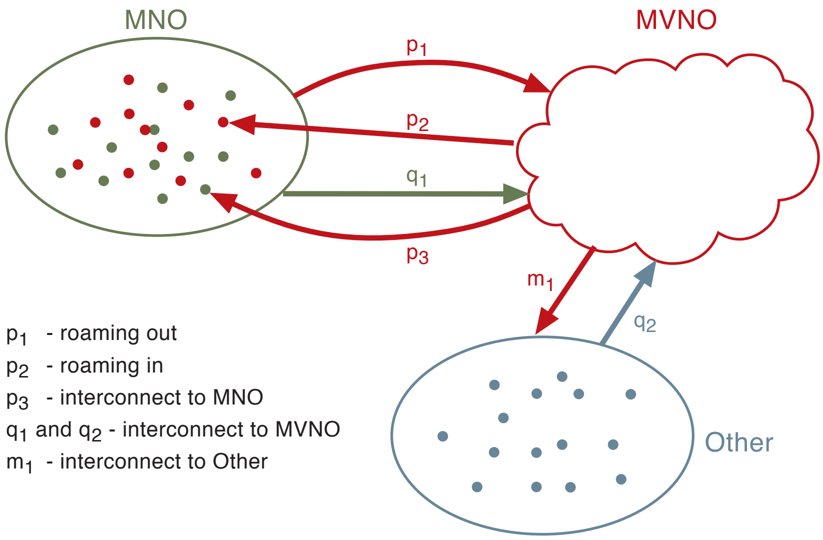

Figure 3 Payments between different telecom operators[10]

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9) *The Sonofon/Tele2 agreement exhibits a very simple structure which we think may be replicated in future MVNO agreements: Firstly, the roaming-in price equals the roaming-out price, i.e.* $p_1 = p_2$. *This probably reflects the fact that the MNO's marginal costs of providing these services are equal, and that the MVNO in general will have a balanced call pattern. For calls from one Tele2 customer to another Tele2 customer, Tele2 gets a 25 % discount on* $(p_1 + p_2)$. *The termination charges,* p_3 *and* q_1 *are not specified in the agreement. We expect that* q_1 *is at least as large as* p_1, *otherwise the MVNO would incur a loss every time an MNO customer called an MVNO customer. Finally, the agreement does not specify a fixed monthly payment per subscriber from the MVNO to the MNO.*

10) *Figure 3 describes the streams of payment for a regular voice service between an MNO, an MVNO and another telecom operator ("other"). The MNO is host of the MVNO. The MVNO's subscribers are consequently part of the MNO's network, indicated by red dots in Figure 3. The red arrows indicate payments made by the MVNO, the green arrows payments made by the MNO and the blue arrows payments made by the other operator. Payment to the MNO are marked by* p, *while* m *marks payment to the other operator and* q *indicates payment to the MVNO. The direction of the arrows shows how the call is routed.*

11) *This may be difficult and costly for a virtual operator 'starting from scratch' since it cannot offer reciprocal roaming possibilities.*

all subscribers. Thus, the MNO can continue its second-degree price discrimination towards SP customers but not towards MVNO customers.[12)]

6 The MVNO Price Agreements and Entry

As described above, the prices for the MVNO customers' use of airtime must be set independently of subscription type. In general, this gives the virtual operator more freedom to segment the market according to its own will, compared to the second-degree price discrimination case described above. However, a network operator anticipating this may set the roaming-in – roaming-out prices such that the business stealing effect is minimized. For instance, a network operator that has most of its customers in the high-end segment could offer a price structure (set the price) with a low subscription fee and high airtime rate. Any virtual operator that accepts this price structure is forced to operate in the low-end segment only. (Conversely and theoretically, a network operator with most of its customers in the low-end segment could offer a price structure with a high subscription rate and a low airtime rate, forcing the virtual operator to serve the high-end segment only.) Thus, in practise, the great price flexibility of an MVNO emphasized by several sources, see e.g. Ovum (2000), may be quite exaggerated.[13)]

A network operator with a balanced assortment of high-end and low-end customers and giving access to an MVNO is forced to accept either business stealing in the high-end segment or intense competition in the low-end segment. For such a network operator, and for an entrant that wants to serve both ends of the market, the service provider concept may be the preferable solution.

Finally, players that control some infrastructure in other parts of the telecom business may be well suited to become MVNOs. Well-known examples include fixed network operators which may add value by converged fixed-mobile services, and MNOs in other countries utilizing their existing international roaming agreements.

7 Concluding Remarks

Summing up the insights from the previous sections we may picture the archetypical MVNO constellation: The host MNO is a small operator with a competitive disadvantage in the low-end market. The MVNO is a pan-European, mobile and fixed operator with a highly competitive mass-market organisation. Not coincidently, this case fits well with the observed constellations today.

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12) *See Varian 1989 for a discussion of the various forms of price discrimination.*

13) *In addition, to plan its own network activity it is obviously important for the MNO to get estimates on the MVNO's minutes of usage. In the Sonofon/Tele2 agreement, the MVNO is punished if the actual usage is 15 % above or below prognosticated usage. If the usage is above prognosticated level no tariff adjustments are made, but adjustments in network quality may occur: "Traffic amounts exceeding the prognosticated level will be handled provided that the quality of other subscriber groups are not affected", see Sonofon and Tele2 2000, ANNEX IV, page 7. Thus, to a certain extent, the MNO can restrict the MVNO from running unannounced very aggressive price campaigns, by refusing to handle traffic above prognosticated levels (a similar point is made by Foros and Hansen 2000).*

An Entrant Strategy for an MVNO Based on Communities

KENTH ENGØ, EIRIK BEFRING AND KENNETH TILLEY

The purpose of this paper is to explore a possibly alternative entrant strategy into the telecommunication market as a mobile virtual network operator (MVNO). We seek new trends and models that can give complementary models for the development and deployment of telecommunication services. In particular we explore the community concept as an alternative way of segmenting the market, and explicitly using tight connections and the relations in such communities to ignite a network externality effect in order to lock-in customers. A possible mathematical model of the sought networks is the so-called small-world network. These networks can be characterized by the fact that the average number of connections to get from one arbitrary node to another is very small compared to the total number of nodes, and that there is high local clustering, that is; many local connections among the nodes. The practical implication of this is that information can spread fast, despite high local connectivity. We outline a possible entrant strategy that an MVNO operation can use based on the community approach, and we discuss some example communities to illustrate the ideas.

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1 Introduction

Distance is dead!

In earlier ages the people in a person's physical proximity defined communities. We are now living in the Connection Age! People can travel to any place in the world in matter of hours. People on opposite sides of the Earth can talk to each other like they were sitting next to each other. Teenagers nowadays have close friends not just down the street, but also in other cities and other countries, obtained through chatting, e-mail, and mobile communication. In the digital age people are collaborating over huge distances, and the obstacle of physical separation has for all practical purposes vanished. Our thesis is that communication will totally transform society as we know it today, and physical distance is dead in the Connection Age!

The new era will give new meaning to the concept of community. We have already seen examples of virtual communities on the Internet: social networks coming into existence despite the physical separation of the members. The future will explode into new types of communities, new ways of collaborating and new ways of living and interacting with each other. This will fully transform our society rightfully into the Connection Age [10].

A possible way to implement market segmentation is to address the communities themselves as target markets, with the goal of trying to utilize some of the inherent structure in the communities to create a business opportunity. One possible attribute to opt for is the network externality effect [2] – also called positive feedback [3]. This can be extremely powerful, since the customer will experience lock-in, and the winner takes it all. We will look at the possibility of using this as a possible entrant strategy for an MVNO. The incumbent that owns the network infrastructure will generally dictate the terms in the negotiations with a possible MVNO, and will be able squeeze the latter on margins. Hence, the MVNO will need a strong business opportunity to leverage the negotiations with the network operator (NO) in order to create a win-win deal.

This paper is organized as follows. In the next section we will discuss communities and a mathematical model of communities based on so-called 'small-world' networks. The linkage between the community concept and the mathematical model will aid us in the understanding of observed phenomenon and supply us with a possible description of observed communities. We also reflect upon adoption and adaptation rates in these communities. In Section 3 we address the emerging virtual telecommunication operators – Mobile Virtual Network Operator (MVNO). There is no rigid definition of what an MVNO really is, and hence we need to make precise our particular meaning of the concept. Section 4 describes an entrant strategy based on communities and triggering network externalities. The approach is general of nature, and we detail out the strategy in the case of a possible MVNO operation. The paper is concluded with some general remarks.

2 Communities and Networks

A community or personal network is any collection of people sharing some interest, like a hobby, a social framework, etc. Hence, every one of us is "members" of thousands of networks, depending on time of the day, geographic location, surroundings, your own choice, and many other factors. A person belongs to some networks out of free will. However, the vast majority of networks we belong to are of such a

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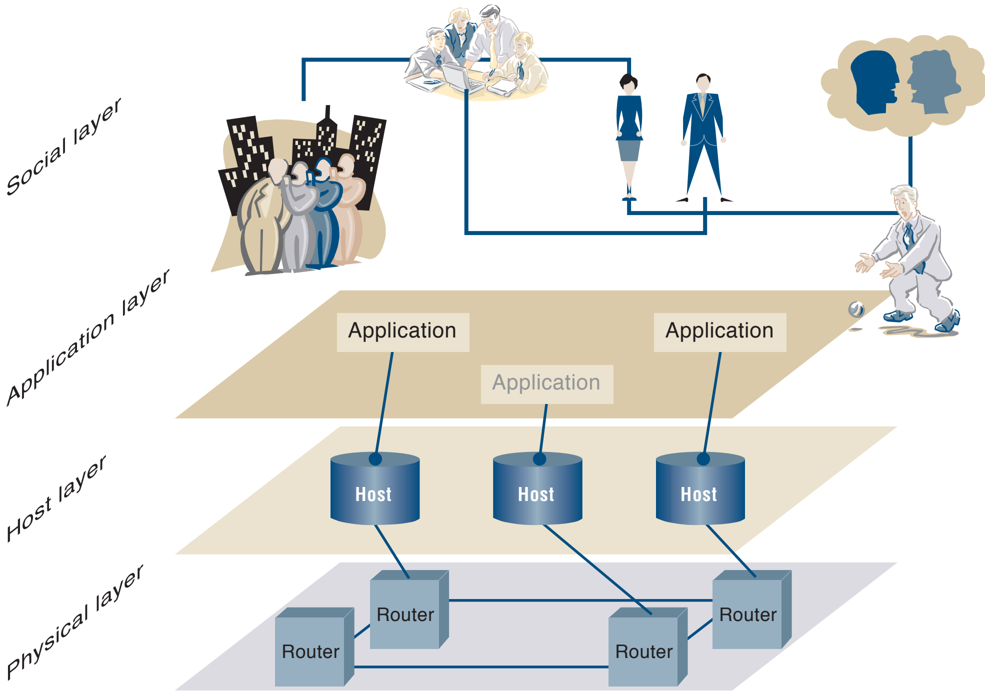


Figure 1 Different layers of networks

character that the membership is inflicted upon us by "external" reasons. Everybody living in Norway belong to the same geographic network "People in Norway". The criteria defining this network are the geographic location of the person. Whereas, the network of teenagers is defined by individuals aged 13 to 20.

Networks defined by external characteristics are not very interesting, since these networks are intrinsically static. The defining character is beyond the "control" and influence of the members, and this again lead to no or only marginal interaction/communication between the members. The phenomenon of network externality will probably never occur in such static networks. The reason for this is that the definition and value of the network to each of the members is not of the positive feedback type [2] or increasing returns type [3].

We will exclusively focus on networks of the free will type, so-called communities. In these networks the individual itself has full control over the memberships, and also exercise some influence on the dynamics in the network. The chances of experiencing network externalities are greater in these types of networks, because there is interaction between the members, and the whole community is possibly gaining value from the addition of any new member. In business; communities of practice is seen as a possible reinvention of the earlier team-approach for organisations, giving groups of people informally tighter bound by sharing their expertise and passion for a joint enterprise [4].

Characterizing communities is not an easy task, and the result depends on your goal in mind.

We believe that communities can be an appropriate setting for triggering network externalities. We do not only want to observe the phenomenon, but also use it in a constructive manner, in order to possibly launch new, ubiquitous, telecommunication services. One example community is the tourist segment. Only 18 % of total international travel is business related, and over 60 % are leisure! Of the total international travel some 10 % is pure backpackers; people constantly on the move, going from place to place, staying a week or two, and using more money per day than the average Japanese tourist [11,12].

Small-World Network Models

Everybody on this planet is separated by only six other people. Six degrees of separation. Between us and everybody else on this planet. The president of the United States. A gondolier in Venice ... It's not just the big names. It's anyone. A native in a rain forest. A Tierra del Fuegan. An Eskimo. I am bound to everyone on this planet by a trail of six people. It's a profound thought Ö. How every person is a new door, opening up into other worlds." From John Guare's play *Six Degrees of Separation* (1990).

One way to analyse communities mathematically is graph theory. However, graph theory has, as of today, not matured enough to cope in full with the problems we want to analyse, successfully. Intense work is carried out on devising

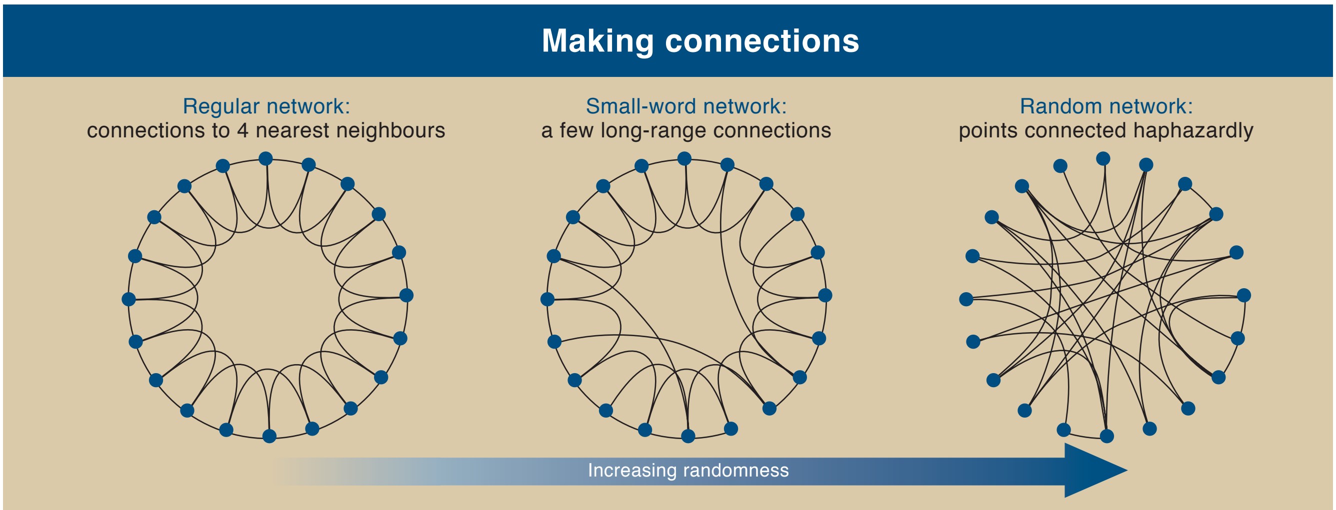


Figure 2 Regular, 'small-world', and random networks

new models for networks incorporating the complex random structure that is observed in real life [6]. The regular – lattice – graph is a graph model with well-defined and regular connection patterns. More promising models are found among refinements of random graphs, the so-called 'small-world' networks [1].

One can consider two extremes of networks. The first are regular networks, where "nearby" nodes have large numbers of interconnections, but "distant" nodes have few. The second are random networks, where the nodes are connected at random. See Figures 3 and 4.

Regular networks are highly clustered, i.e. there is a high density of connections between nearby nodes, but have long path lengths, i.e. to go from one distant node to another one must pass through many intermediate nodes.

Random networks are highly un-clustered but have short path lengths. This is because the randomness makes it less likely that nearby nodes will have lots of connections, but introduces more links that connect one part of the network to another.

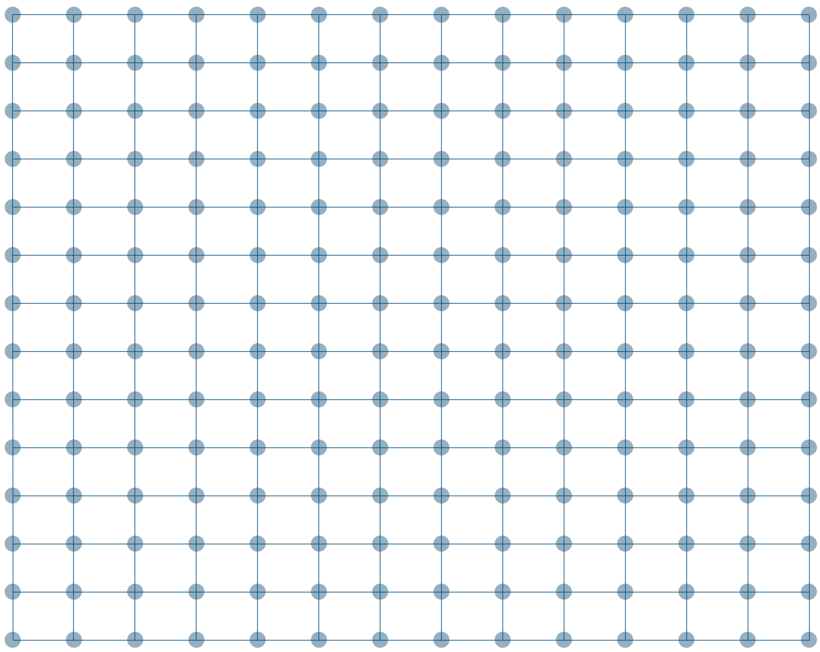
In [1], Watts and Strogatz studied what happens between these two extremes. They started with regular networks and "re-wired" the nodes. That is, they decided whether to leave each edge connecting a pair of nodes in place, or to change it to connect the starting node to a different ending one, chosen at random. This decision was made at random, with probability p for each edge. Thus, if $p = 0$, the original regular network is unchanged, but if $p = 1$, the resulting network is completely random. Introducing a relatively small number of random connections dramatically changed the character of the graph. That is, for small values of p, the graphs retained their properties of being highly clustered, but the average path lengths dropped dramatically. For example, for $p = .001$, (so that only 0.1 % of the edges in the graph have been randomly changed), the "clustering coefficient" is over 95 % of what it would be for a regular graph, but the "characteristic path length" is less than 20 % of what it would be for a regular graph, see Figure 5.

In a sense, locality is violated in 'small-world' networks, since the 'shortcuts' in the network realize action at a distance.

Adoption and Adaptation Rates

The role of the telecommunication business in personal communication is to interconnect parties not in physical reach. This task can be fulfilled in at least two ways: by on-line telecommunication services or delaying the service.

Figure 3 A regular grid with nearest-neighbour links (196 nodes)



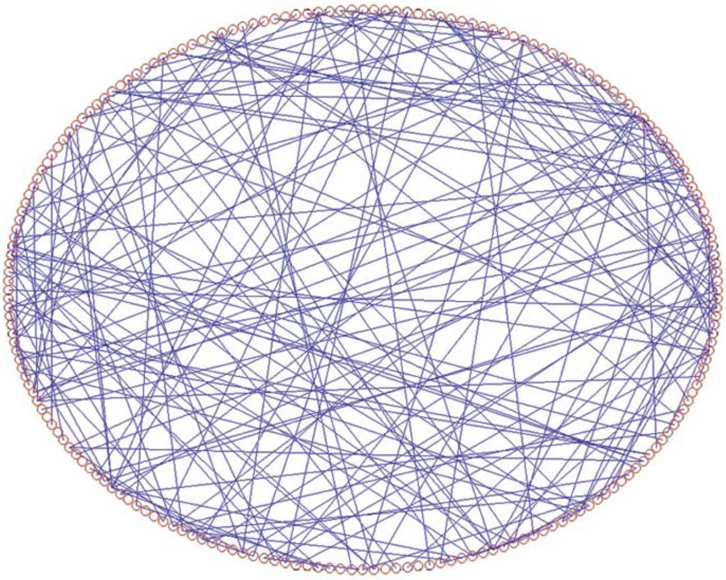


Figure 4 A random graph (200 nodes), with link probability p = 0.01

The last option means storing the communication need as some sort of information.

The Tipping Point is the name given by epidemiologists for the dramatic moment in an epidemic when everything can change all at once.

In his work [14] Malcom Gladwell puts up an elegant framework of how social epidemics emerges. The theory of tipping points explains why we have trouble estimating dramatic, exponential change.

Gladwell's premise is that in addition to applying to viruses, this type of pattern is observed in many other situations. The book is filled with far-reaching examples, from the resurgence of Hush Puppies shoes to the popularity of Sesame Street to an epidemic of teen suicides in Micronesia.

Based up on the research of Stanley Milgram, the small-world problem, Gladwell identifies three principles of an epidemic, witch provides us the tools we need for how to go about reaching a tipping point.

The Law of the Few

is a law which states that only a few people matter. There are people who are more socially connected than others, and thus have a much greater effect on the spread of an epidemic. In the case of a social phenomenon, they know the right people to talk to, or they cross social boundaries, living comfortably in several worlds at once, or they are just good salesmen. Their presence makes an idea contagious.

The Stickiness Factor

is the second law, meaning the length with which an idea or disease stays with you. The longer it does, the more time you will propagate it. People who hear about a new idea actually remember it, and in some way do something about it. Gladwell suggests that little changes in the presentation of ideas, designed to make the ideas stickier, can have big effects. Gladwell takes an interesting angle on this phenomenon by examining the success of Sesame Street.

The Power of Context

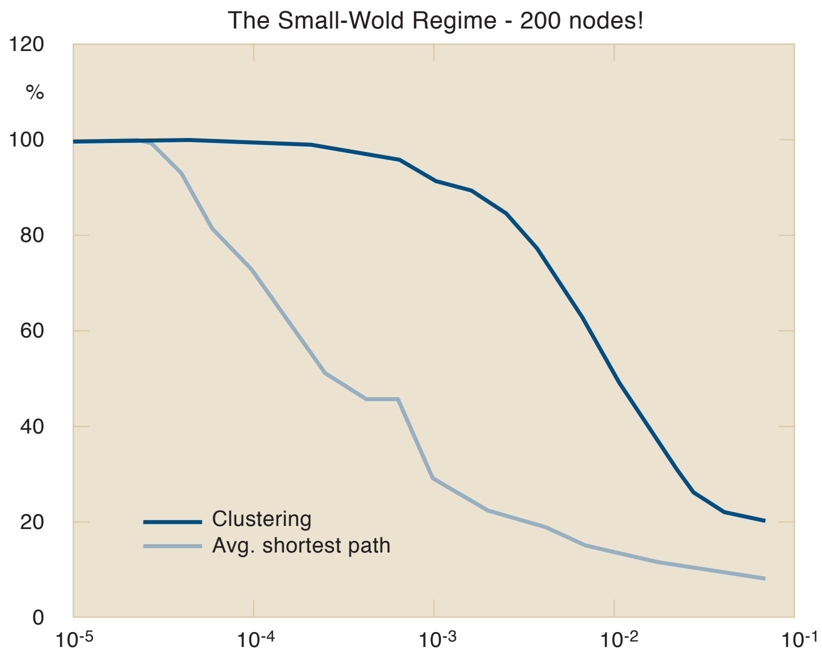
The last law is the Power of Context, stating that environmental influences play a far greater role than we give them credit for.

One section of the book that we found especially interesting was a chapter in which the author draws a parallel between the tipping point and the chasm described in Geoffrey Moore's *Crossing the Chasm* [15]. The premise of the chasm is that during the introduction of discontinuous technological innovations, a chasm exists because the majority of users are unwilling to accept the recommendation of very early users (innovators).

The need for technical tools or terminals to do either the on-line communication or transferring the stored information will give us different adoption (buying the device) and adaptation rates (using the device). The simple voice terminals of today have high adaptation to adoption rates, whereas the communication services on a PC have low rates. This means that the technical tool/terminal in itself will have some level of barrier to utilise the service offered.

We believe that somehow igniting the network externality in free-will communities will possibly decrease terminal barriers. Along with

Figure 5 Clustering and shortest path in a small-world graph (200 nodes)



proper support functions this can result in much higher adaptation rates and service efficiency for the customers and communities. It is further postulated that the communication needs of communities, technical tool adoption and adaptation rates on a local scale is linked to global characteristics through chaos theory [5] and small-world network [1].

Targeting communities modelled as 'small-world' networks can be prolific in this setting. One of the characteristics of the 'small-world' networks – the average distance between to arbitrary nodes is small – can be interpreted, as the spread of information is more efficient in these communities. Then the adaptation of new services is faster once the terminal has been acquired.

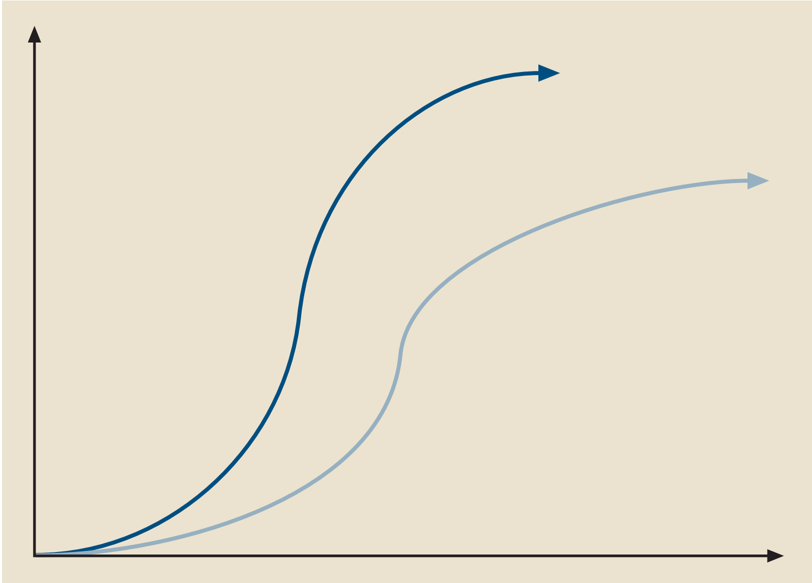


Figure 6 Different adoption rates vs. time

3 The Relation to an MVNO

We believe the above 'theoretical approach' to communities enriches the view of communication needs interesting for the telecommunication business. The focus on both communities and terminal adoption and adaptation rates gives us a direct link to the phenomenon network externality that is seen as one of the major characteristics for the telecommunication service deployment today and in the future. Possible services that enable the forming and growing of such networks will be characterised by high adoption/adaptation rates and probably high mobility factors – both personal, terminal and service mobility. Technically, this means services independent of the existing core networks, service platforms, access networks and terminal operating system. Based on this an agent driven service platform must be developed to link the terminal user interface, service production and databases needed to run the service.

What is an MVNO?

A Mobile Virtual Network Operator (MVNO) is a mobile operator that does not own its own radio spectrum and usually does not have its own network infrastructure. Instead, MVNOs have business arrangements with traditional mobile operators to buy minutes of use (MOU) for sale to their own customers. Business agreements can be done with one or more network owners operating in the same market.

The question we want to ask is: Why carry out virtual community development through an MVNO?

According to Rheingold [13] "Virtual communities are cultural aggregations that emerge when enough people bump into each other often enough in cyberspace". The communities in cyberspace are more than self-sufficient and in their virtual interactions are able to get similar, if not truly the same, experiences as a social interaction.

- The MVNO adds value such as brand appeal, distribution channels, and other affinities to the resale of mobile services. It may be significant initial factors in community development.

- The MVNO usually offer no significant difference in service or network performance, but offer some special affinity to their customers. MVNOs can offer a product mix, or bundling mix, that incumbent mobile operators cannot match. Both the product and the bundling mix may differ from the incumbent, and favour community building.

- The MVNOs are well-known companies, with marketing and financial strength, and sufficient agreements with existing operators to provide a good service coverage area.

- Some leading providers are actually deploying their own Mobile Switching Centres (MSC), Service Control Points (SCP) and mobile IN infrastructure in order to facilitate the means to offer value-added services. In this way, MVNOs can treat incumbent infrastructure such as radio equipment as a commodity.

- Offering value-added services helps differentiate the MVNO versus the incumbent mobile operator, allowing for customer acquisition and preventing the MVNO from needing to compete on the basis of price alone. An MVNO may cultivate core competency and focus areas like customer centricity, community service development, more than an incumbent.

- MVNOs can have full control over the SIM card, branding, marketing, billing, and customer care operations, but the entry cost is low. Flexibility makes the MVNO able to take the first mover advantage.

- The major benefit to traditional mobile operators co-operating with MVNOs is to broaden the customer base (sell additional MOUs) at a zero cost of acquisition

Implementing a communication solution for communities like tourists and backpackers is a huge challenge. A potential operator must eventually obtain worldwide coverage, and the solution should preferably be a mobile communication system – that is if the traveller is to rely on his/her own mobile terminal. An MVNO strategy now naturally enters. This is self-evident because no single operator can build a worldwide mobile phone system with the costs that such an operation will incur. This is just learning from several bankrupt satellite systems, and the enormous cost of acquiring UMTS licences in certain countries.

Lonely Planet has established collaboration with ekit.com, a self-proclaimed MVNO that will exercise the above-announced strategy. Their current solution is limited to commodity services for people out travelling.

4 An Entrant Strategy into the Telecommunication Market Based on Communities

There is a tight connection between the market approach and the task of entering a market.

The market entry strategy consists of:

1 market approach, marketing strategy, and

2 partnerships and who to join when approaching a market.

In the market strategy we utilize the network externality phenomenon. Network externality is the effect usually described as the increase in value for the people belonging to a community/network as a new member joins the population [2]. This can loosely be paraphrased as follows; the consumer is forced into using a specific product by addressing the consumer's peers in a way as to leave the individual without choice as what to choose.

Telecommunication network operators have not yet targeted this as an intentional market strategy, although the telecommunication business has for a number of years been the archetypical example of a business with an intrinsic network externality effect.

Partnership deals should be negotiated with companies that supplement and enhance your own approach. This indicates that an entrant should seek partnerships with market participants that are reasonably modern in their customer handling and treatment.

Several ways of approaching the customer has characteristics that presumably will support the network externality products in a better way than ordinary broadcast marketing.

The Tupperware model is a classical peer-to-peer type of spreading a product portfolio. The basis is a "franchise" model where ordinary people sell to friends and neighbours. This model exploits normal everyday networks among people, and the there does probably not exist a person that has not been invited to a Tupperware party by a friend or colleague. Exploiting the "Tupperware" network effect in a mobile communication setting should be the goal of the entrant.

Hotmail has used a modern electronic alternative to the Tupperware party. Hotmail specializes in free Internet-based email. On every email sent from a Hotmail subscriber there is a WWW link that takes the receiver directly to a signup service that lets you get your own account. It thus becomes a short and personal link between the producer of the service, the communication channel and the target(s). It is also a necessity for the receiver to have an email service not too dissimilar from the sender's service. In a lot of instances the receiver has to at least get a service similar to the one already deployed.

A distinct possibility for any new entrant into a telecommunication market is to target the business or consumer market. In our concept this can be viewed as a road map to an integrated market, not only one target in it self. The Japanese I-mode concept is realized through the consumer market with good fortune. It has been followed up by a B-mode targeted towards a more business type segment. The standard European way is to establish the enterprise market as its first (and only (?)) target segment. This is a historic phenomenon that might not be the most valid way of approaching markets in the future.

The MVNO Case

An MVNO entering into the telecommunication market with a new service must acquire a customer base – or exploit an existing customer base. If the MVNO is in the unfortunate situation of starting from scratch, this acquisition should be done fast and in a fashion exploiting the natural network externality intrinsic to telecommunication services. Following the idea introduced in this paper about 'small-world' networks, peer-to-peer communities are then a natural target community. The key issue is to address the way people communicate, mostly in a dynamic group fashion, and use this as a basis for technology, interface and marketing strategies. This is essential knowledge in starting up an enterprise like an MVNO. One of the most important assets of an MVNO, being situated close to the customer, can be knowledge of the customer communication.

Hence, the communication solution should expand the total market of telecommunication services, in order not to cannibalize the market for the network operators that own the infrastructure. As an MVNO you will be dependent on the incumbent operators, and you should avoid a situation where you compete on margins. You have to introduce something new when entering the market as an MVNO, and the overall goal is to create a win-win deal with the incumbent operator. This should be a healthy symbiotic relationship, versus a deadly price war on the services.

5 Conclusions

In this paper we have discussed the above community/network framework as a possible entrant strategy for an MVNO into the telecommunication market.

Communities that are suitable candidates for an MVNO initially entering into a market will typically have high adoption and adaptation rates, giving the entering MVNO the possibility of creating a customer base fairly fast for the preferred customer network. The above ideas are not solely restricted to the case of an MVNO entry, but can also be applied in other situations where one is faced with the discouraging task of entering a new market segment with no previous or similar customer base.

Stochastic graph theory offers the strategic option of analysing potential market segments in a different way than traditional demographic analysis. We believe this to be important, because it offers a more dynamic analysis of communities. This should however not be understood as demographic analysis not being important.

With the graph theory approach we have the option to analyse aspects such as formation and evolution of personal networks and communities, which are rather intractable issues in demographic studies. Hence, using stochastic graph theory we can try to better understand the inner workings of the phenomenon of network externality. This addresses the need for understanding the phenomenon and how to utilize it, rather than just observing it. The literature is full of the latter; examples of economic webs that display positive feedback, but random graphs and small-world networks are some of the first attempts in trying to understand the intricate and non-linear inner workings of network externalities.

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Modelling Market Uncertainty and Competition in Telecommunication Environment:
Network Providers and Virtual Operators

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In this paper we describe a methodology for making optimal strategic decisions in the presence of uncertainty directed specifically to telecommunication environment. We concentrate on the case when a part of the uncertainty results from the actions of other actor(s) that pursue their own aims. This is especially important issue in the telecommunications where uncertainty about market development is coupled with emergence of new actors and new business roles. Our approach blends established methodology for decision support under uncertainty known as stochastic programming with selected ideas of game theory. The basic ideas are illustrated through the case study that involves relationship between network providers and virtual operators.

We provide numerical examples and economic interpretations for static and dynamic cases under various assumptions about such parameters as market sensitivity or quality of knowledge about the competitor's policies.

1 Introduction

In this paper we describe a modelling approach, which provides decision support for evaluation of the strategies of an industrial agent that finds itself in complex relations of competition and collaboration with other agents belonging to the same industrial environment. This is exactly the situation in which many telecom service providers find themselves now, with deregulation process and convergence between telecommunications, computer industry and content provision being well under way. The objective is to provide a set of quantitative decision support tools which would enhance the quality of strategic and tactical decisions, like decisions about product mix, pricing, and investment. Interplay between established network providers and virtual operators is an important particular case of this situation, when the necessity of quantitative decision support is particularly evident.

Microeconomic theory [MW95] provides important theoretical insights in these issues, especially when the system under study finds itself in conditions of equilibrium. Unfortunately, equilibrium is a feature which is conspicuously lacking in the current telecommunication environment which makes many established approaches inapplicable. Another weak point of the classical theory is often inadequate treatment of uncertainty, another central feature of today telecommunications. This is the reason why we have employed techniques which were specially designed to incorporate uncertainty and dynamics in decision models, and in particular stochastic programming [EW88, BL97]. On the theoretical level, this methodology was under development for a few decades, but only relatively recently the state of software and hardware allowed large-scale applications. We supplement it by selected ideas of the game theory [Bin92] because the part of uncertainty confronted by a given decision maker results from the actions of other decision makers.

Provision of services in telecom between two or more parties requires that bits can be transported and routed from one party to the other. In Internet, this is the purpose of IP (Internet Protocol). The service itself is offered transparently between the parties in the packet structure offered by the transport layer protocols TCP (Transmission Control Protocol) and UDP (User Datagram Protocol). The service itself is not visible in the network but hidden by the transport protocols. Offering services is thus a two-stage business: first, offering transport and routing of bits and, second, offering the application that exists between the communicating parties. The first capability is offered by the network operators. The second capability may be offered by any other party, including the users themselves.

More precisely, e-mail is a service that exists above TCP and is thus not directly visible to the network. The network simply makes use of the mail address to identify the areas where the communicating users are located. The mail service is embedded in terminals and mail servers. The service may be offered via independent operators increasing the value of the service beyond that of routing and delivery. Such offers can be security in terms of access control and filtering, creation of SMS messages for alerting the user on a mobile phone that a mail has been received, and extending a LAN to incorporate home office solutions and mobility.

The operator primarily offering the service may also want to market the network support. This is of course no problem if the service operator and the network operator are the same. If they are

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different, the service operator must lease network connectibility from operators owning the network. There are many reasons why this can be a consistent business logic. However, we shall not consider these aspects here.

We introduce this approach through the case study which describes relations between network provider, virtual operator and a population of customers; see Figure 1. We develop a decision model for this situation which is decomposed in three sub-models: *customer model*, *network provider model* and *virtual operator model*. For the sake of transparency a number of simplifying assumptions are made in these models, although they are not essential and a number of more specific details can be incorporated easily. In the simplest case we consider two providers that offer the same type of service to a common market. This service is based on a telecommunication network and the network capacity is utilised for its delivery.

Whereas one of the providers, which we call Network Operator (NO), owns the network, the other provider is Virtual Network Operator (VNO) not possessing her own network facilities. Therefore she must lease capacity from the Network Operator to be able to produce service. She sends a request for a needed amount of capacity to her rival and has to pay a price for the received capacity units.

Customers in that market can subscribe to each of the providers for delivery of service and pay a price for it. For the sake of transparency this price has a simple and non-differentiated structure, although arbitrarily complex price schemes can be incorporated in the similar manner considering several customer types. We assume that the providers fix their prices at the beginning of a time period for the whole period. The whole time horizon under consideration consists of several such periods.

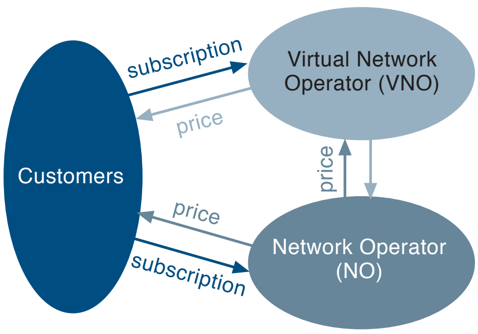

Figure 1 Relations between service providers and customers

The *customer model* assumes that the number of customers wishing to purchase service from one of the providers at a given time period is based on the customer number in the previous period. It is corrected by the customer flow resulting from migration between the providers, unsubscription or arrival of the new subscribers due to the price differences between providers and/or the price changes between periods made by the same provider. This flow consists of a fixed and a variable part: some customers will (un-)subscribe to or from service or migrate between providers regardless of price levels, whereas a (usually bigger) number decides on movement dependent on price changes. Feedback dependent on network effects can be also important for customer decisions: a greater amount of customers will provide more utility to these customers and thus attract even more subscribers. Other approaches are also conceivable so that the customer model itself could be seen as a module providing detailed input for the complete model.

Important part of the *provider model* for the Network Operator (NO) deals with the policy for determination of the service prices and the prices for capacity leasing within bounds determined by the regulation authorities. Another important part of his policies deals with investment in the infrastructure. The Virtual Network Operator's decisions cover service prices and the amount of capacity to lease. Both operators' objectives are to maximise their profits, to increase their market share or to serve some other goals.

The usual economic view on a market is "from above", i.e. a general welfare function is formulated that will maximise the total welfare of this market [MW95]. We do not follow this approach here because the objective is to provide decision support tools for a given industry actor. Therefore we adopt the point of view of one of the operators, and develop the decision model accordingly. For the purpose of this case study we take the view of the Network Operator, although the point of view of the Virtual Network Operator can be considered similarly. Naturally, his main interest lies in maximising his own welfare (or market share), while the general welfare is secondary. To achieve this goal he formulates the model describing customer behaviour and he has to predict his rival's decisions as optimal responses to his price policy. These models depend inevitably on a number of parameters with uncertain values. Therefore the adequate treatment of uncertainty becomes of paramount importance here.

In the subsequent sections we develop this approach in more detail. In the next section we consider more formally the general structure of the model. After that the simplest possible case is considered which deals with one time period and a deterministic set-up. It is assumed for now that the providers follow a profit maximising price policy. Later this model is extended by allowing for uncertainties both about the network owner's decisions and about the customers' behaviour or "external" entities like opportunity costs. A further extension is made by introduction of a multiperiod model. Theoretical considerations are supplemented by results of numerical experiments.

Quantitative decision models for competitive telecommunication environment recently became a subject of intensive research effort. An alternative and complementary approach is constituted by simulation models of systems of interacting agents known as *agent nets* [BEG98, Gai98, Gai99]. Different models which utilise the game theoretical concepts were proposed in [LS92, QR01, SL88]. The distinctive feature of the approach presented here is the utilisation of stochastic programming methodology for adequate treatment of uncertainty and the absence of equilibrium coupled with selected notions of the game theory.

2 Top Level Description of Modelling Approach

Seen from point of view of the Network Operator, the decision model consists of three blocks: enterprise model, customer model and competition model shown on Figure 2.

Each period the decision process of the Network Operator consists of the following steps:

- Predict the customer response for a given decision and a given competition response using the *customer model*;
- Predict the competition response for a given decision using the *competition model*. In this particular case study the Virtual Network Operator constitutes the competition;
- Select the optimal policy from the *enterprise model* using as an input the predictions of customer and competition response obtained on the previous two steps.

The following notations are utilized here:

y – decisions of Network Operator (NO). These decisions are the price y_1 for service provision to own customers and the price y_2 for capacity leased by his rivals.

z – decisions of Virtual Network Operator (VNO). They comprise the price z_1 for service provision and the amount z_2 of capacity leased from the NO.

$n = (n_1,n_2)$ – the total number of customers of NO and VNO respectively. These numbers depends on their respective decisions y and z.

$F_2(y,z,n)$ – the objective function of the VNO, it depends on respective decisions y and z of providers and on the number of customers $n = n(y,z)$ obtained from the customer model. Examples of such a function are profit, market share, etc. Note that this function incorporates the knowledge of the network operator about the aims of his rival, namely the NO thinks that the VNO chooses his decisions from maximization of this function. More formally, the Network Operator takes as predictions $z(y)$ for decisions of the Virtual Network Operator the solution of the following problem:

$$\max_{z \in Z} F_2\left(y,z,n(y,z)\right)$$

where Z is the set of admissible decisions of the VNO.

$F_1(y,z,n)$ – objective function of the NO, it depends on respective decisions y and z of the providers and on the number of customers n obtained from the customer model. Examples of such a function are profit, market share, etc. Prediction $z(y)$ of response of the VNO yielded by the competition model and prediction $n(y) = n(z(y),y)$ of the customer number provided by customer model are utilised for computation of its value for fixed decision y. Consequently, decision y is selected by maximisation of this objective function solving the problem

$$\max_{y \in Y} F_1\left(y,z(y),n(y)\right)$$

where Y is the set of admissible decisions of the NO.

In what follows we develop specific models using this general structure paying special attention to uncertainty and dynamics.

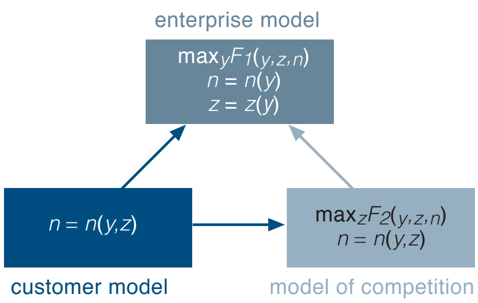

Figure 2 General structure of decision model

3 Single Time Period

We start with the simplest possible case, which involves the single decision period and assumes that the Network Operator has full information about different parameters which define the customer model and the competition model. This case will be used as a benchmark for more complex cases also because it allows an analytic solution.

3.1 Deterministic Case

The Network Operator's profits consist of the revenue from the service provision and the revenue from the capacity leasing diminished by the costs of service provision. These costs for service provision consist of a fixed and a variable component. Similarly the profits of the Virtual Network Operator consist of revenue obtained by service provision, diminished by costs of service provision and by costs of leasing capacity.

We assume now that the virtual operator has the full knowledge about the price policy of the Network Operator. The amount of capacity available to lease and the VNO's service prices have to be chosen within some limits. Furthermore, it has to be taken into account that this provider must lease enough capacity to serve all demand of her customers (Quality of Service constraint). Then the Virtual Network Operator's response to the Network Operator's prices and the assumed customer behaviour can be determined as the profit maximising solution of her problem. This solution can be stated explicitly.

The Network Operator knows that the Virtual Network Operator settles her policy as a profit maximising response to his own prices. Taken this into account he too will choose his decisions for a maximal profit and solves the same model as the VNO. Thus he knows this provider's decisions which he can substitute in his own model. Under certain assumptions to ensure concavity of the goal function we can derive an explicit solution also for this model of the Network Operator.

Let us describe the model more formally, following the structure defined in the previous section.

3.1.1 Customer Model

We describe this model for the multiperiod case. For the sake of simplicity we assume that the customer behaviour is governed by price considerations only. Schematically the customer decision process is described by Figure 3.

In order to describe the decision process mathematically, we need to introduce indexes for each of the operators. With the Network Operator we associate index $i = 1$, while with the Virtual Network Operator we associate index $i = 2$.

Here $q_i^t, t = 0,1,\ldots$ is the price charged by operator i at time t for its service and $n_i^t, t = 0,1,\ldots$ is the number of customers by the end of period t who utilise a service provided by operator i. This number depends on the prices q_i^t charged by operators and is structured as follows

$$n_i^{t+1} = n_i^t + m_i^t + m_{ij}^t \qquad (1)$$

where m_i^t is amount of the first time customers subscribed to operator i at time t, and m_{ij}^t is the amount of customers that switch from operator j to operator i at time t. Both m_i^t and m_{ij}^t depend on prices q_i^t. In the general case this dependence is derived from price/demand relationship shown on Figure 4.

Here $f(h)$ is the total demand for service in the case if the unit price is h and d^0 is the value of demand which corresponds to some reference price h_0. We linearise this curve in the vicinity of the point h_0, which gives the following approximate relation between price and demand

$$d = d^0 - ch$$

where c is a coefficient to be estimated from the market statistics. Using this approach we obtain the approximate linearised relations between the number of customers and the price increments,

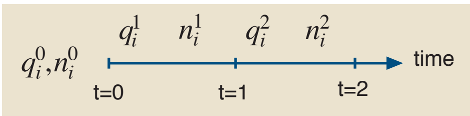

Figure 3 Customer decision process

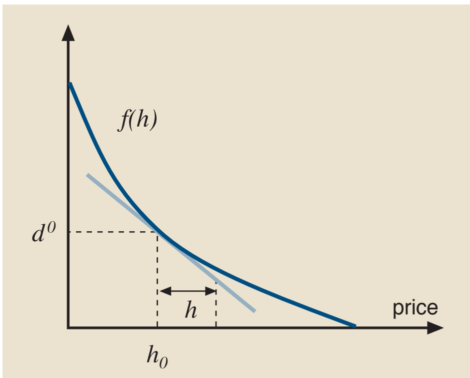

Figure 4 Price/demand relationship

which are valid in some vicinity of the reference price under conditions that the average service utilisation by a single customer remains constant. This last assumption can be easily relaxed by considering a "physical" customer consisting from several "logical" customers. This leads to the following relations:

$$m_i^t = k_i^t + c_i\,(x_i^{t-1} - x_i^t) \tag{2}$$

$$m_{ij}^t = k_{ij}^t + c_{ij}(x_j^t - x_i^t) \tag{3}$$

where the price structure is the following:

$$q_i^t = q + x_i^t$$

Here q is a reference price, x_i^t is a price increment of operator i at time t, k_i^t is the amount of new customers which would subscribe to the service of operator i at time t in the absence of price change, k_{ij}^t is the number of customers which would migrate from operator j to operator i in the absence of price difference between services offered by these operators, and c_i^t, c_{ij}^t are coefficients to be estimated from the market data. Through k_i^t and k_i^t it is possible to model different aspects of the customer behaviour besides the response to the price change.

In the case of a single period it is convenient to denote $y_1 = x_1^1$, $z_1 = x_2^1$ which together with the relations (1)-(3) will yield the following expression for the number of customers n_1 and n_2 of operators 1 and 2 (the NO and the VNO) respectively:

$$n_1 = k_1 - r_1 y_1 + r_{12} z_1 \tag{4}$$

$$n_2 = k_2 + r_{12} y_1 - r_2 z_1 \tag{5}$$

where parameters $k_1, k_2, r_1, r_2, r_{12}$ can be expressed through parameters found in (1)-(3).

3.1.2 Competition Model

This is a profit model for the Virtual Network Operator as seen by the Network operator. The profit is defined as the difference between the revenue and costs which are the costs for leasing the network capacity and the cost of service provision. Denoting

y_2 – price to charged by the NO for a unit of leased capacity;

z_2 – amount of capacity leased by the VNO;

Revenue and costs of the VNO can be expressed as follows:

Revenue. Given that the price charged by the Virtual Network Operator for its service is $q + z_1$ and the number of his customers is given by (5) his revenue is

$$(q + z_1)(k_2 + r_{12} y_1 - r_2 z_1)$$

Costs. They are composed from two components:

- Cost for leasing of the network capacity $y_2 z_2$;
- Cost of service provision $g_2 + e_2(k_2 + r_{12} y_1 - r_2 z_1)$, where g_2 and e_2 are respectively the fixed service provision costs and the variable service provision cost per customer for the VNO.

Therefore the expression for profit of the Virtual Network Operator is

$$(k_2 - (q - e_2) r_2 + r_{12} y_1) z_1 - r_2 z_1^2 - y_2 z_2$$

There are two decisions of the VNO that affect his profit in this model:

- The price difference z_1 between the reference service price and the price charged by the VNO;
- The amount of the network capacity z_2 to lease from the NO.

In order to predict these decisions the Network Operator assumes that the Virtual Network Operator maximises his profit under constraints on the quality of service. Therefore he obtains the prediction $z(y)$ as the solution of the following optimisation problem:

Find z_1 and z_2 which maximise

$$(k_2 - (q - e_2) r_2 + r_{12} y_1) z_1 - r_2 z_1^2 - y_2 z_2$$

subject to constraints

$$z_2 \geq d(k_2 + r_{12} y_1 - r_2 z_1)$$
$$k_2 + r_{12} y_1 - r_2 z_1 \geq 0$$
$$-\Delta \leq z_1 \leq \Delta$$

where d is the average amount of capacity required for the service provision for one user with admissible service quality and Δ is the bound for the price change. Note that the solution of this problem depends on the price decisions y_1 and y_2 of the Network Operator. In the case when the solution lies within these bounds, it can be expressed analytically as follows:

$$z_1(y) = \frac{k_2 - (q - e_2)r_2 + dr_2 y_2 + r_{12} y_1}{2r_2} \quad (6)$$

$$z_2(y) = \frac{d}{2}\left(k_2 + r_{12} y_1 + (q - e_2)r_2 - dr_2 y_2\right) \quad (7)$$

which means that the decisions of the VNO depend linearly on the decisions of the NO.

3.1.3 Enterprise Model

This model describes aims of the Network Operator and how these aims depend on the decisions of customers and competition. In order to be specific we consider the profit model similar to the competition model described in the previous section, which requires a definition of revenue and costs of the Network Operator.

Revenue. It is composed from two components:

- Revenue from the service provision to the customers. Given that the price charged by the Network Operator for its service is $q + y_1$ and the number of his customers is given by (4) this part of revenue is

$$(q + y_1)(k_1 - r_1 y_1 + r_{12} z_1)$$

- Revenue from the leasing of capacity to the VNO:

$$y_2 z_2$$

Costs. They are the costs of the service provision:

$$g_1 + e_1(k_1 - r_1 y_1 + r_{12} z_1)$$

where g_1 is the fixed cost of service provision and e_1 is the variable cost of service provision per customer for the network owner. There are two decisions of the NO which affect his profit in this model:

- The price difference y_1 between the reference service price and the price charged by the NO;
- The price y_2 charged to the VNO for a unit of leased capacity.

Besides, his profit depends on the decisions z_1 and z_2 of the VNO. Now the Network Operator can use the predictions of decisions taken by the Virtual Network Operator from (6)-(7). Substituting these predictions into the expression for profit and assuming that the Network Operator makes decisions which maximise his profit we obtain the following optimisation problem:

Find y_1 and y_2 which maximise

$$-\left(r_1 - \frac{r_{12}^2}{2r_2}\right) y_1^2 + dr_{12} y_1 y_2 - \frac{d^2}{2} r_2 y_2^2 + a_1 y_1 + a_2 y_2$$

subject to constraints

$$k_1 - r_1 y_1 + r_{12} z_1 \geq 0$$
$$-\Delta \leq y_1 \leq \Delta$$
$$0 \leq y_2 \leq U_1$$

where a_1 and a_2 are expressed through parameters introduced before, Δ is the bound on the service price change and U_1 is the upper bound for the price charged for the leased capacity fixed by the regulation authorities. It is assumed here that the Network Operator has unlimited amount of network capacity, later we will dispense with this assumption.

This problem is a simple quadratic programming problem which can be easily solved analytically if it is concave. This, however, is not always the case and concavity conditions should be derived from the parameters which describe the customer and competition behaviour.

This simple model is used as a benchmark and as a starting point for development of more advanced and realistic models.

3.2 Allowing for Uncertainties

It is very likely that the Virtual Network Operator has no such a broad knowledge about the situation as assumed in the previous section. There can be several sources of uncertainty like

- Pricing policy of the NO;
- Customer behaviour as described by the coefficients for the customer flow;
- Customer behaviour with regard to demand. There may exist different customer types, each with a specific demand pattern, demand may change over time, the demand behaviour may be not clear to the operators, etc.;
- Costs for the provision of service.

In the next model the first two sources of uncertainty are taken into account. Both operators are uncertain about the customer behaviour (market sensitivity, the amount of customers that are (un-)subscribing for service). Since at the decision moment the operator has no exact knowledge about the customers' behaviour, the needed amount of capacity cannot be predicted exactly. We still assume that the Network Operator has unlimited amount of capacity available, but the Virtual Network Operator may face the problem that some demand remains unserved. Therefore opportunity costs may occur and have to be included in her model. We assume that the VNO is also uncertain about the exact level of these opportunity costs.

Furthermore, the Virtual Network Operator can only estimate pricing decisions of the Network Operator to a certain extend. However, we still assume that the Network Operator has the complete knowledge about the decision behaviour of the VNO. As described previously, the NO wants to find out decisions of his rival. Then he can choose his policy such that he can maximise his expected profits given the response of the VNO on his decisions that will maximise her profits too. Observe that only average or expected profits can be maximised due to the described uncertainties. Therefore the Network Operator describes how the Virtual Network Operator perceives the NO's decisions by help of uncertain parameters and his actual price. But we have to bear in mind that revenue and costs are caused only by those customers that are actually served. This number is limited by the amount of available capacity. Furthermore there is a constraint ensuring nonnegative customer numbers. When he has solved this problem of predicting his rival's response the Network Operator again can substitute this solution into his own profit maximisation problem and solve it to find his best decisions under the given response.

4 Two Stage Model

Now the described model will be extended by the second time period. However, it represents an intermediate stage between the one period model and a general two period model: at the beginning of the first period all pricing and leasing decisions are made and remain unchanged also throughout the second period. But, when the demand becomes known after the first period, the Network Operator has the possibility to extend capacity. This means that the number of decision variables of the Virtual Network Operator remains the same, at the beginning of the first time period she decides about service prices and amount of leased capacity. However, the Network Operator decides at the beginning of the first time period about the service and capacity prices and amount of capacity he makes available for leasing. The introduction of the latter decision variable gives a new quality of the contract between the two providers: so far, only the VNO has determined how much capacity she wants to lease; an upper bound was settled by an "outer force" like a regulation authority. Now also the Network Operator can intervene by setting an upper bound on capacity he has available for leasing. At the beginning of the second time period he has to make a further decision: whether to extend the network and to what extent.

For the Network Operator the available capacity in the second period depends also on a possible network extension. This has to be taken into account when formulating the new objective function. Then the decision process proceeds as depicted before: the NO tries to predict how his decisions are perceived by his rival and which strategy the rival chooses as response to his policy for formulating his own prices accordingly.

Since the decisions depending on the other part's policy remain constant throughout all time periods, both prediction and the decision problem can be solved as a combination of both period's problems by the use of a discount factor.

5 Mathematical Description of Modelling Approach: General Case

In this section we describe formally our modelling approach for the general multiperiod case with uncertainty. In order to simplify our exposition only two periods are considered, but extension for the case of more periods is straightforward. For the case of two periods the decision process is presented on Figure 5.

We introduced here the following notations:

ω_t, $t = 1,2$ – uncertain parameters from the point of view of the NO at time period t. These parameters describe the quantities from customer and competition model about which the Network Operator has uncertain knowledge. The information about these parameters which are available for the Network Operator is described by probability distributions. It is assumed that the values of these parameters become known at the end of period t.

y_t, $t = 1,2$ – decisions taken by the NO at the beginning of period t before the values ω_t of uncertain parameters become known. These decisions are taken with the aim to improve the values of some enterprise performance criterion, like profit or market share, averaged with respect to the values of uncertain parameters.

z_t, $t = 1,2$ – reaction of competitors to decisions of the NO. This reaction is forecast by the Network Operator using the model of competition.

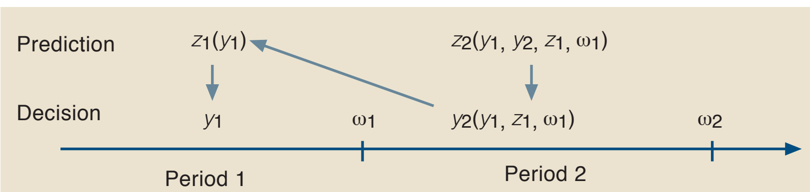

Figure 5 Decision process for two periods in the presence of uncertainty

The Network Operator assumes that the competitors take decisions with the aim to improve the values of some enterprise performance criterion, averaged with respect to the values of uncertain parameters.

The decision that is going to be implemented immediately by the Network Operator is y_1. In order to take this decision it is necessary to foresee its influence on the decisions taken in the subsequent periods by the Network Operator, competitors and customers. This is done through the decision/prediction process depicted on Figure 5, which consists of the following steps. We present it here in the most general form, while a more specific model is considered in the next section.

1. Prediction of competitor's reaction during Period 2

For given y_1, y_2, z_1, ω_1 obtain prediction $z_2(y_1, y_2, z_1, \omega_1)$ for decision of competitors during Period 2 by solving the following problem.

Find $z_2 \in Z_2$ which minimizes

$$E_{\omega_2} F_{20}\left(y_1, y_2, z_1, z_2, \omega_1, \omega_2\right)$$

subject to constraints

$$F_{2i}(y_1, y_2, z_1, z_2, \omega_1) \le 0,\ i = 1 : m_{22}$$

where $F_{20}(\bullet)$ is the enterprise performance criterion of competition for Period 2 and the functions $F_{2i}(\bullet)$ define different constraints on decisions of the competition like, for example, quality of service constraints.

2. Finding optimal decision for Period 2

For given y_1, z_1, ω_1 and prediction $z_2(y_1, y_2, z_1, \omega_1)$ for decision of the competitors during Period 2 find the optimal decision $y_2 = y_2(y_1, z_1, \omega_1)$ for Period 2 by solving the following problem.

Find $y_2 \in Y_2$ which minimizes

$$E_{\omega_2} f_{20}\left(y_1, y_2, z_1, z_2\left(y_1, y_2, z_1, \omega_1\right), \omega_1, \omega_2\right)$$

subject to constraints

$$f_{2i}(y_1, y_2, z_1, z_2(y_1, y_2, z_1, w_1), \omega_1) \le 0,\ i = 1 : m_{21}$$

where $f_{20}(\bullet)$ is the enterprise performance criterion of the NO for Period 2 and the functions $f_{2i}(\bullet)$ define different constraints on decisions of the NO. Let us denote the optimal value of the performance criterion by $Q(y_1, z_1, \omega_1)$.

3. Prediction of competitor's reaction during Period 1

For given y_1 obtain the prediction $z_1(y_1)$ for decision of the competitors during Period 1 by solving the following problem.

Find $z_1 \in Z_1$ which minimizes

$$E_{\omega_1} F_{10}\left(y_1, z_1, \omega_1\right)$$

subject to constraints

$$F_{1i}(y_1, z_1) \le 0,\ i = 1 : m_{12}$$

where $F_{10}(\bullet)$ is an enterprise performance criterion of competition for Period 1 and the functions $F_{1i}(\bullet)$ define different constraints on the decisions of competition.

4. Finding optimal decision for Period 1

Having a prediction $z_1(y_1)$ for decision of the competitors during Period 1, find the optimal decision y_1 of the NO for Period 1 by solving the following problem.

Find $y_1 \in Y_1$ which minimizes

$$E_{\omega_1}\Big(f_{10}\big(y_1, z_1(y_1), \omega_1\big) + Q\big(y_1, z_1(y_1), \omega_1\big)\Big) \quad (8)$$

subject to constraints

$$f_{1i}(y_1, z_1(y_1)) \le 0,\ i = 1 : m_{11} \quad (9)$$

where $f_{10}(\bullet)$ is the enterprise performance criterion of the Network Operator for Period 1 and the functions $f_{2i}(\bullet)$ define different constraints on decisions of the NO. Observe that the integrated criterion which is optimised incorporates criteria for both periods.

This decision process looks fairly involved. However, given the present state of the art in the optimisation methods and related software it is feasible to build a decision support system based on this approach. It is in this connection that the numerical approaches developed in the field of stochastic programming become pivotal. One possible way to proceed consists of the following steps.

- Approximate probabilistic distributions of the uncertain parameters by a finite number of scenarios that take the form

$$\left(p_{1i}, \omega_1^i\right), \left(p_{2ij}, \omega_2^{ij}\right), i = 1{:}N, j = 1{:}M_i \quad (10)$$

where it is assumed that ω_1 takes the value ω_1^i with probability p_{1i} and ω_2 takes the value ω_2^{ij} with probability p_{2ij} under the condition that ω_1 takes the value ω_1^i.

- Construct the so-called *deterministic equivalent* of the problem (8)–(9) [EW88,BL97] which makes the problem amenable to solution. A specific form of the deterministic equivalent depends on the structure of the problem and one example can be found in the next section.

- Use commercial software as building blocks for the solution of the deterministic equivalent and for the development of a decision support system.

Alternative stochastic programming approach allows working directly with continuous distributions by application of sampling techniques and stochastic gradient methods [Gai88].

6 Two Period Model with Uncertainty and Investment in Infrastructure

Let us develop now a specific decision model for the Network Operator in the presence of Virtual Network Operator(s) using the approach from the previous section. This model includes the models which were described informally in sections 3.2 and 4 and constitute the further development of one period deterministic model from sections 3.1.1 – 3.1.2. Notations remain essentially the same with some changes due to the consideration of scenarios and two time periods.

We start by describing decision variables that in the case of the network operator include also the possibility to invest in the infrastructure.

Decisions of the Network Operator:
$y_1 = (y_{11}, y_{12}, y_{13})$ – decisions during Period 1;

y_{11} – price to charge for its service to customers during Period 1;

y_{12} – price to charge for capacity to the VNO during Period 1;

y_{13} – maximal amount of capacity to lease to the VNO during Period 1;

$y_2 = (y_{21}, y_{22}, y_{23}, y_{24}, y_{25})$ – decisions during Period 2;

y_{21} – price to charge for its service to customers during Period 2;

y_{22} – price to charge for capacity to the VNO during Period 2;

y_{23} – maximal amount of capacity to lease to the VNO during Period 2, we assume that $y_{23} \geq y_{13}$;

y_{24} – amount of capacity to add at the beginning of Period 2, this additional capacity is available during Period 2;

y_{25} – binary variable which equals 1 if decision to add capacity is taken and 0 otherwise.

Decisions of the Virtual Network Operator:
$z_t\ (z_{t1}, z_{t2})$ – decisions during Period t, $t = 1,2$;

z_{t1} – price to charge for its service to customers;

z_{t2} – amount of capacity to lease from the NO.

Next, let us define uncertain parameters ω_t, $t = 1,2$. These are the parameters that define the customer model and the competition model from sections 3.1.1 and 3.1.2. More specifically,

$$\omega_t = \left(r_1^t, r_2^t, \eta^t\right), r_1^t = \left(r_{11}^t, \ldots, r_{19}^t\right),$$
$$r_2^t = \left(r_{21}^t, \ldots, r_{26}^t\right), t = 1,2$$

where r_1^t and r_2^t describe the uncertainty related to enterprise and competition model respectively. Here $r_{11}^t, r_{12}^t, r_{22}^t$ are taken from the relations

$$n_1^t = k_1^t - r_{11}^t y_{t1} + r_{12}^t z_{t1}$$
$$n_2^t = k_2^t + r_{12}^t y_{t1} - r_{22}^t z_{t1}$$

that describe the customer model in the case of two periods similar to the model (4)-(5) and $r_{21}^t = r_{12}^t$. Besides,

$$r_{13}^t = k_1^t - r_{11}^t\left(q - e_1^t\right), r_{14}^t = r_{12}^t\left(q - e_1^t\right),$$
$$r_{23}^t = k_2^t - r_{22}^t\left(q - e_2^t\right), r_{25}^t = k_2^t$$

where e_1^t, e_2^t are the variable cost of service provision per customer taken from the profit expressions for operators

$$g_1^t + e_1^t\left(k_1^t - r_{11}^t y_{t1} + r_{12}^t z_{t1}\right)$$
$$g_2^t + e_2^t\left(k_2^t + r_{12}^t y_{t1} - r_{22}^t z_{t1}\right)$$

which are similar to the ones presented in sections 3.1.2 and 3.1.3 devoted to the enterprise model and the competition model respectively. Other parameters have the following meaning:

r_{15}^t – the opportunity cost of not meeting one unit of demand for NO during Period t;

r_{16}^t – the variable cost of adding a unit of capacity;

r_{17}^t – the fixed cost of adding capacity, this parameter together with r_{16}^t is defined only for $t = 2$;

$$r_{18}^t = k_1^t - \frac{b}{d_1^t}, r_{19}^t = \frac{1}{d_1^t}, r_{26}^t = \frac{1}{d_2^t},$$
$$r_{10}^t = q - e_1^t, r_{28}^t = q - e_2^t$$

where b is the current network capacity of the NO and d_1^t, d_2^t are the amounts of capacity required to satisfy a demand from one customer for the NO and the VNO respectively;

r_{24}^t – the opportunity cost of not serving one unit of demand for the VNO during Period t;

Variable η^t is used to describe uncertainty in the knowledge that the Virtual Network Operator has about the decisions of the Network Operator as seen by NO. More precisely, if decision of the Network Operator is y_t then he assumes that the Virtual Network Operator thinks that this decision is

$$\hat{y}_t = y_t + \eta^t$$

and uses this value in his competition model.

Generally, uncertain parameters ω_t are described by continuous probability distributions. Following the scenario approach outlined at the end of the last section, we approximate the possible values of uncertain parameters by a finite number of values with given probabilities as in (10):

$$\omega_1^i = \left(r_1^{1i}, r_2^{1i}, \eta^{1i}\right), \omega_2^{ij} = \left(r_1^{2ij}, r_2^{2ij}, \eta^{2ij}\right),$$
$$i = 1{:}N, j = 1{:}M_i$$

In accordance with the framework described in the previous section, decisions of both providers in period 2 depend on the values of random variables ω_1. In the case of a finite number of scenarios $i = 1{:}N$ they will depend on the index of a scenario. Therefore we denote

y_2^i – decision of the NO in Period 2 under scenario i;

$z_2^i = z_2^i\left(y_2^i\right)$ – prediction of the response of the VNO to decision y_2^i of the NO in Period 2 under scenario i.

1. Decision Model for the Network Operator

Now we are ready to describe the deterministic equivalent of the decision process outlined in the last section for the case of an environment consisting of the Network Operator and the Virtual Network Operator. We start by defining the integrated decision model of the NO that combines decision models for both periods. Its objective is to find the optimal decision y_1 of the Network Operator for Period 1 and his optimal decisions y_2^i for Period 2 and scenarios $i = 1{:}N$ having predictions $z_1(y_1)$ and $z_2^i\left(y_2^i\right)$ for decisions of the VNO by solving the following problem.

Find y_1 and $y_2^i, i = 1{:}N$ which maximizes

$$f_1\left(y_1, z_1\left(y_1\right)\right) + \alpha \sum_{i=1}^{N} p_{1i} f_2^i\left(y_2^i, z_2^i\left(y_2^i\right)\right) \qquad (11)$$

subject to constraints

$$-\Delta \le y_{11} \le \Delta, \qquad (12)$$

$$-\Delta \le y_{21}^i \le \Delta, i = 1{:}N, \qquad (13)$$

$$0 \le y_{12} \le U_1, \qquad (14)$$

$$0 \le y_{22}^i \le U_1, i = 1{:}N, \qquad (15)$$

$$0 \le y_{13} \le b, \qquad (16)$$

$$y_{13} \le y_{23}^i \le b + y_{24}^i, i = 1{:}N, \qquad (17)$$

$$y_{24}^i \le Y_{24}^i y_{25}^i, i = 1{:}N, \qquad (18)$$

$$k_1^{1i} - r_{11}^{1i} y_{11} + r_{12}^{1i} z_{11} \ge 0, i = 1{:}N, \qquad (19)$$

$$k_1^{2ij} - r_{11}^{2ij} y_{21} + r_{12}^{2ij} z_{21} \ge 0,$$
$$i = 1{:}N, j = 1{:}M, \qquad (20)$$

Similarly to (8), the objective function in (11) consists of two terms. The term $f_1(\bullet)$ describes the profits of the Network Operator during Period 1. Function $f_2^i(\bullet)$ describes the profits of the NO during Period 2 under scenario i. Therefore the second term describes average profits of this operator during Period 2 discounted with the discount coefficient $\alpha \le 1$. Function $f_1(\bullet)$ can be expressed as follows.

$$f_1\left(y_1, z_1\left(y_1\right)\right) = \left(\bar{r}_{13}^1 - \sum_{i=1}^{N} p_i w_{1i}\right) y_{11} -$$
$$\bar{r}_{11}^1 y_{11}^2 + \left(\bar{r}_{14}^1 + \bar{r}_{12}^1 y_{11}\right) z_{11}\left(y_1\right) + y_{12} z_{12}\left(y_1\right) -$$
$$\sum_{i=1}^{N} p_{1i}\left(r_{15}^{1i} + r_{10}^1\right) w_{1i}$$

where w_{1i} are potential customers of the Network Operator which are lost due to the lack of capacity for the service provision during Period 1 under scenario i:

$$w_{1i} = \max\left(0, r_{18}^{1i} - r_{11}^{1i} y_{11} + r_{12}^{1i} z_{11}(y_2) + r_{19}^{1i} z_{12}(y_2)\right)$$

and $\bar{r}_1^1$ are expected values of uncertain parameters r_1^1:

$$\bar{r}_1^1 = \left(\bar{r}_1^1, \ldots, \bar{r}_{19}^1\right) = \sum_{i=1}^{N} p_{1i} r_1^{1i}.$$

The first part of the expression for $f_1(\bullet)$ (everything except the last sum) is the profit defined as the difference between the revenue from the service provision and the leasing of capacity minus service provision costs exactly as it was defined in the enterprise model of Section 3.1.3. Since the revenue stems only from those customers that are actually served, the number of served customers is determined as the number of potential customers diminished by the number of customers that cannot be served due to the lack of capacity. Function $f_2^i(\bullet)$ for profit during Period 2 is very similar to $f_1(\bullet)$ and can be expressed as follows:

$$\begin{aligned} & f_2^i\left(y_2^i, z_2^i\left(y_2^i\right)\right) = \\ & \left(\bar{r}_{13}^{2i} - \sum_{j=1}^{M_i} p_{2ij} w_{2ij}\right) y_{21}^i - \bar{r}_{11}^{2i}\left(y_{21}^i\right)^2 + \\ & \left(\bar{r}_{14}^{2i} + \bar{r}_{12}^{2i} y_{21}^i\right) z_{21}^i\left(y_2^i\right) + y_{22}^i z_{22}^i\left(y_2^i\right) - \\ & - r_{16}^{2i} y_{24}^i - r_{17}^{2i} y_{25}^i - \\ & \sum_{j=1}^{M_i} p_{2ij}\left(r_{15}^{2ij} + r_{10}^2\right) w_{2ij} \end{aligned}$$

where w_{2ij} are the potential customers of the Network Operator which are lost due to the lack of capacity for service provision during Period 2 under scenario j provided that the uncertain parameters during Period 1 followed scenario i:

$$\begin{aligned} w_{2ij} = \max\Big(0, & r_{18}^{2ij} - r_{11}^{2ij} y_{21}^i + \\ & r_{12}^{2ij} z_{21}^i\left(y_2^i\right) - r_{19}^{2ij} y_{24}^i + r_{19}^{2ij} z_{22}^i\left(y_2^i\right)\Big) \end{aligned}$$

and $\bar{r}_1^{2i}$ are expected values of uncertain parameters r_1^{2i} conditioned on scenario i of Period 1:

$$\bar{r}_1^{2i} = \left(\bar{r}_{11}^{2i}, \ldots, \bar{r}_{19}^{2i}\right) = \sum_{j=1}^{M_i} p_{2ij} r_1^{2ij}.$$

Observe that the costs for the infrastructure upgrade are taken into account in the profit calculation for Period 2 through the variables y_{24}^i and y_{25}^i.

Constraints (12)–-(20) consist of five groups. Constraints (12)-(13) define the bounds for the service price change during Periods 1 and 2 respectively, while (14)-(15) define the bounds for the price charged for the leased capacity. Constraints (16)-(17) fix the bounds on the amount of the leased capacity which assures that it does not exceed the total network capacity. Constraint (18) assures that the amount of newly built capacity y_{24}^i will be positive only when the decision to expand capacity is taken, namely $y_{25}^i = 1$. Parameter y_{24}^i is the maximal amount of capacity increase under scenario i. Constraints (19)–(20) ensure a nonnegative customer number.

Predictions $z_1(y_1)$ and $z_2^i\left(y_2^i\right)$ of decisions of the Virtual Network Operator which enter this model are obtained through prediction models for Periods 1 and 2.

2. Prediction model for Period 1

For a given y_1 obtain a prediction $z_1(y_1)$ for decision of the VNO during Period 1 by solving the following problem.

Find z_1 and $v_1 = (v_{11}, \ldots, v_{1N})$ which maximizes

$$\begin{aligned} & F_{10}\left(y_1, z_1, v_1\right) = \\ & \left(\bar{r}_{23}^1 + \bar{r}_{21}^1 y_{11} + \sum_{i=1}^{N} p_{1i} r_{21}^{1i} \eta_1^{1i} - \sum_{i=1}^{N} p_{1i} v_{1i}\right) z_{11} - \\ & \bar{r}_{22}^1 z_{11}^2 - \left(y_{12} + \sum_{i=1}^{N} p_{1i} \eta_2^{1i}\right) z_{12} - \\ & \sum_{i=1}^{N} p_{1i}\left(r_{24}^{1i} + r_{28}^1\right) v_{1i} \end{aligned} \tag{21}$$

subject to constraints

$$\begin{aligned} & v_{1i} + r_{22}^{1i} z_{11} + r_{26}^{1i} z_{12} \geq \\ & r_{25}^{1i} + r_{21}^{1i} y_{11} + r_{21}^{1i} \eta_1^{1i}, i = 1:N, \end{aligned} \tag{22}$$

$$v_{1i} \geq 0,\ i = 1:N \tag{23}$$

$$-\Delta \leq z_{11} \leq \Delta, \tag{24}$$

$$0 \leq z_{12} \leq y_{13}, \tag{25}$$

$$k_2^{1i} + r_{21}^{1i} y_{11} - r_{22}^{1i} z_{11} \geq 0, i = 1:N \tag{26}$$

where v_{1i} are potential customers of the VNO which are lost due to the lack of capacity for the service provision during Period 1 under scenario i. The structure of the profit function $F_{10}(y_1, z_1, v_1)$ is very similar to the one period competition model from Section 3.1.2. The new elements are the sums which contain parameters η_1^{1i} and η_2^{1i} which are used to model imprecise knowledge of the Virtual Network Operator about decisions of the Network Operator. Besides, the last term is appeared which represents average opportunity costs for not meeting demand.

Constraints (22)–(23) connect the amount of unserved demand with total demand and available capacity. Constraint (24) fixes bounds on admissible price changes, while (25) assures that the leased capacity does not exceed capacity that the Network Operator is ready to lease. Constraint (26) ensures a nonnegative customer number.

3. Prediction model for Period 2

For a given scenario i of the Period 1 and a given decision y_2^i of the Network Operator during Period 2 obtain a prediction $z_2^i\left(y_2^i\right)$ for decision of the Virtual Network Operator during Period 2 by solving the following problem.

Find z_2 and $v_{2i} = \left(v_{2i1}, \ldots, v_{2iM_i}\right)$ which maximize

$$F_{20}\left(y_2^i, z_2, v_{2i}\right) = \left(\bar{r}_{23}^{2i} + \bar{r}_{21}^{2i} y_{21}^i + \sum_{j=1}^{M_i} p_{2ij} r_{21}^{2ij} \eta_1^{2ij} - \sum_{i=1}^{N} p_{1i} v_{1i}\right) z_{21} - \bar{r}_{22}^{2i} z_{21}^2 - \left(y_{22}^i + \sum_{j=1}^{M_i} p_{2ij} \eta_2^{2ij}\right) z_{22} - \sum_{j=1}^{M_1} p_{2ij}\left(r_{24}^{2ij} + r_{28}^2\right) v_{2ij} \tag{27}$$

subject to constraints

$$v_{2ij} + r_{22}^{2ij} z_{21} + r_{26}^{2ij} z_{22} \geq r_{25}^{2ij} + r_{21}^{2ij} y_{11} + r_{21}^{2ij} \eta_1^{2ij}, j = 1 : M_i, \tag{28}$$

$$v_{2ij} \geq 0, j = 1 : M_i \tag{29}$$

$$-\Delta \leq z_{21} \leq \Delta, \tag{30}$$

$$0 \leq z_{22} \leq y_{23}, \tag{31}$$

$$k_2^{2ij} + r_{21}^{2ij} y_{21} - r_{22}^{2ij} z_{21} \geq 0, \quad i = 1 : N, j = 1 : M_i \tag{32}$$

where v_{2ij} are potential customers of the VNO, which are lost due to the lack of capacity for the service provision during Period 2 under scenario i of Period 1 and scenario j of Period 2. The structure of the profit function and constraints (28)-(32) is very similar to the prediction model for Period 1.

Observe that both prediction problems are quadratic programming problems which are easily solvable with standard software.

7 Implementation and Numerical Experiments

The methodology described above underlies a decision support system for analysis of strategic and tactical decisions in a competitive telecommunication environment, which is currently under development. The top-level architecture of this system is depicted in Figure 6. It consists of the following main components.

- *Spreadsheet front*. It is used for data entry and communication with user.
- *MATLAB engine*. It provides connection between blocks, common implementation platform, quick prototyping capability for new models, and customised top-level algorithms for model solution, scenario generation and postprocessing.
- *Model suite*. Contains a set of models based on the approach described in the previous sections.
- *Problem solvers*. This block utilises commercial and custom developed solvers for model solution and analysis, in particular commercial linear and non-linear programming solvers.

We present here some results of experiments with several models from the Model suite of this system. All models are variants of the models presented in sections 3,4,6 and are implemented in Matlab. The quadratic programming solver necessary for solution of prediction models of virtual operator (21)–(26) and (27)–(32) was taken from Matlab optimisation toolbox.

We illustrate here several capabilities of the system and in particular

- Graphical presentation of enterprise performance and other important characteristics as the function of decisions. This can help considerably in the decision process because it allows analysing the impact of decisions on

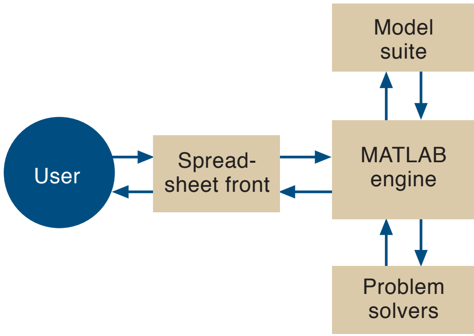

Figure 6 Top-level architecture of decision support system

performance having much more information than just the optimal values of decision parameters derived from the solution of model (11)–(20).

- Analysis of dependence of results on different important characteristics of the decision problem. Some examples of such characteristics are market parameters, degrees of uncertainty, and parameters of enterprise and competition models. This analysis is particular important due to the imprecise nature of the input data.

Two sets of numerical experiments with two models are presented here: the single period stochastic model and the two period stochastic model with capacity expansion.

7.1 Single Period Stochastic Model

This is the model which is obtained from the model described in Section 6 by discarding all the elements which refer to the second period.

In particular, in the objective function (11) the second term is eliminated together with the prediction model of the second period (27)–(32). Results are presented on Figures 7–11. They show the effect of the Virtual Network Operator's uncertainty about the Network Operators' price decisions and of customers' sensitivity to both providers' prices.

Price uncertainty denotes the quality of information flow in the market, in this case the knowledge of the virtual operator about the network owner's prices. It is expressed by the random parameters that represent uncertain knowledge of the VNO about the Network Operator's service price and his price for leasing capacity. This uncertainty enters the prediction model (21)–(26) through the parameters η_1^{1i} and η_2^{1i}.

Market sensitivity is expressed by customer flow from or to operators in dependence of the single operators' prices. This customer flow is determined by the help of parameters in customer model denoting the amount of customers migrating between the operators, the new subscribers or those which abandon the service. In terms of the model of section 6 these are the parameters $k_1^t, k_2^t, r_{11}^t, r_{12}^t, r_{22}^t$. A highly sensitive market is characterised by the high values of these parameters.

The figures show dependence of the profit of the Network Operator (in the upper left sub-graph),

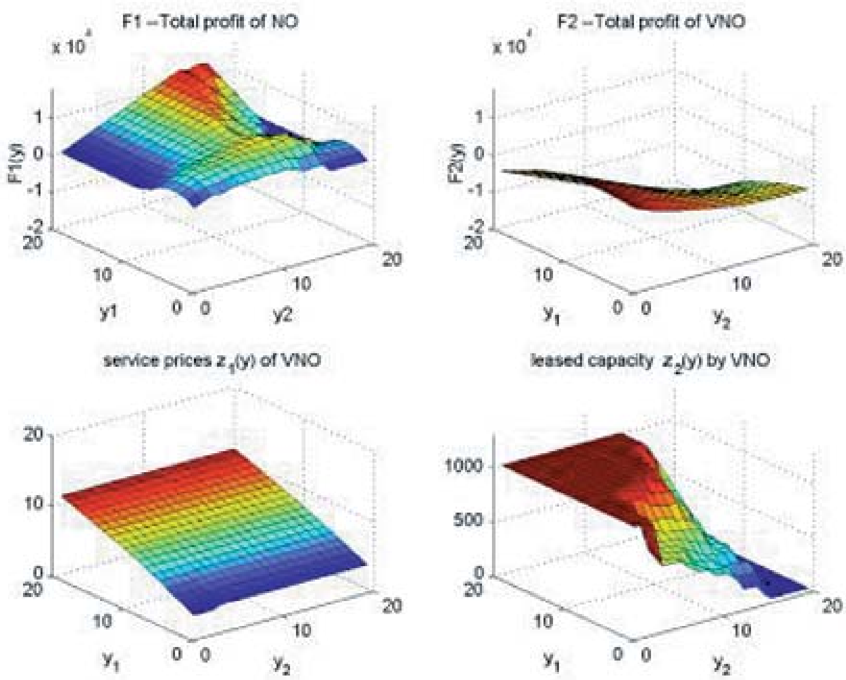

Figure 7 One stage stochastic model: the reference parameter set

profit of the Virtual Network Operator (in the upper right sub-graph), the VNO service price (in the lower left sub-graph) and the amount of leased capacity (in the lower right sub-graph) as functions of the service price y_1 of the Network Operator and of his leased capacity price y_2. We fixed the reference values of the model parameters and changed the level of the price uncertainty and market sensitivity with respect to the reference values.

Figure 7 shows the results for the reference parameter set. Figures 8 and 9 show the results with the same parameter set with the exception that the values of the market sensitivity parameters were increased and decreased respectively. The values of the market sensitivity parameters were fixed again to the reference level in the experiments reported on Figures 10 and 11, but the level of price uncertainty was increased and decreased respectively.

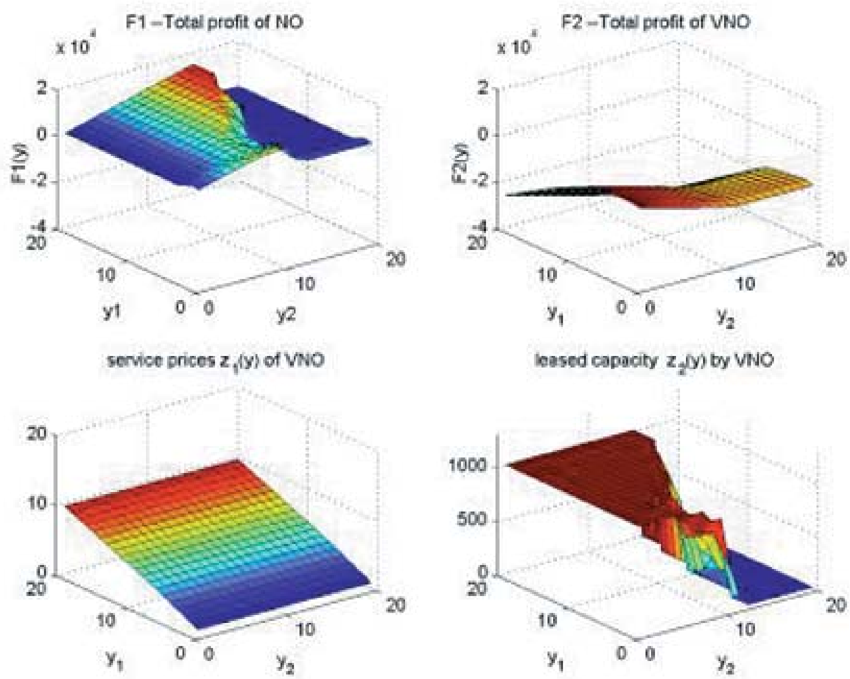

Figure 8 One stage stochastic model: the case of high market sensitivity

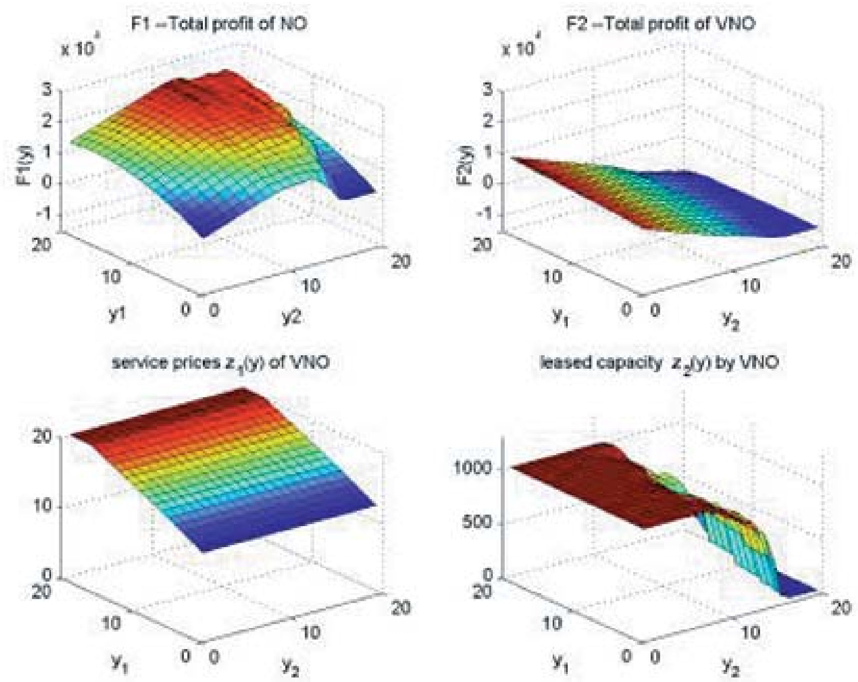

Figure 9 One stage stochastic model: the case of low market sensitivity

We will now have a closer look on the four sub-graphs in each of the figures. Our explanation is based on Figure 7, but similar analysis can be easily made also for all the other figures.

Let us consider the uppermost left sub-graph, which depicts the profit of NO as the function of his service price y_1 and leased capacity price y_2. The profit functions of NO consist of two main components: service provision and capacity leasing. Whereas the profits caused by the capacity leasing part depend mainly on the Network Operator's capacity prices, the profits of service provision depend on the Network Operator's service prices. This means we can give the following description of the main areas in the upper two sub-graphs:

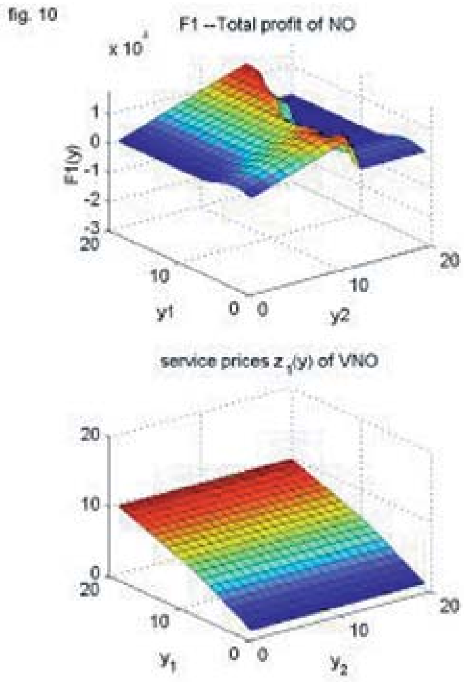

Figure 10 One stage stochastic model: the case of high price uncertainty

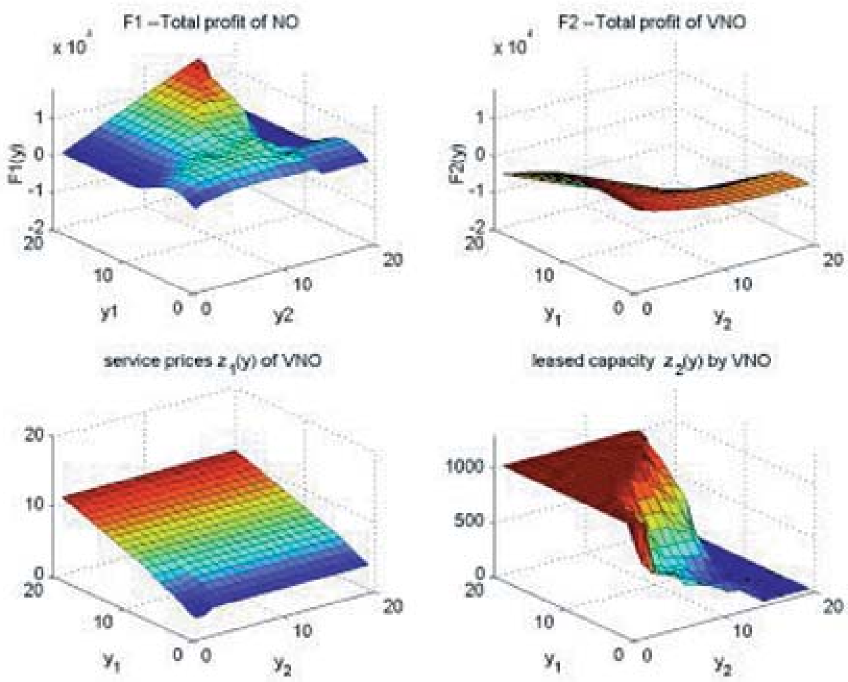

Figure 11 One stage stochastic model: the case of low price uncertainty

- VNO leases capacity, NO has positive customer number (the front part in the graph which corresponds to low service prices y_1 and low capacity prices y_2 of the NO). This is the mainstream situation.

- VNO leases capacity, NO serves no customers (left part of the graph, for high service prices y_1 and low capacity prices y_2 of the NO). This corresponds to the case when the service price difference between two operators is so high that all customers go to VNO and NO obtains his profit only by leasing capacity to VNO.

- VNO leases no capacity, NO has positive customer number (right part in graph display, for low service prices y_1 and high capacity prices y_2 of the NO). This corresponds to the situation when VNO is driven out of the market by NO, who applies prohibitive leasing price.

- VNO leases no capacity, NO serves no customers (back part, for high service prices y_1 and high capacity prices y_2 of the NO). This corresponds to the situation when technology is not capable yet to provide a service at reasonable price and the service does not take off.

These areas and the respective dependencies can also be found in the graph of the Virtual Network Operator's profit function (upper right sub-graph).

A look at the service price decision z_1 of the Virtual Network Operator (the lower left sub-graph) shows that she nearly always offers her service at a lower price than the Network Operator; with increasing prices y_1 of the Network Operator this price difference even increases. The model of customer behaviour includes among others customer migration due to the price differences between the providers. A comparison of the customer numbers of each operator shows that the Network Operator has a positive customer number and the Virtual Network Operator has no customers to serve when the Network Operator charges low service prices whereas these relations are reversed when the Network Operator charges high service prices. However, the Virtual Network Operator maybe cannot serve all demand of the customers because she has only limited amount of capacity. For this demand that she cannot meet, she faces opportunity costs that diminish her profits. This effect is especially visible in the rear part of the graph depicting the VNO profit function (upper left sub-graph): The Network Operator capacity prices are so high that the VNO does not lease any capacity anymore and thus can not serve any customers. The only component in her profit/loss function is then the opportunity costs.

The profit functions show now only the profits of the Network Operator and the Virtual Network Operator that would be obtained for certain pricing decisions of the Network Operator. With the given set of parameters we observe that the VNO often has a negative profit. This means he could stay on the market only for low capacity prices and high service prices. With another set of parameters (e.g. a higher general price level q or other opportunity costs) the area of nonnegative profits of the VNO could be extended, so that she takes part in the market also when the Network Operator charges higher prices for capacity.

The amount of capacity leased by the VNO for a certain pricing policy of the Network owner is influenced by a trade-off between costs for lost customers and the costs for capacity leasing. For low capacity prices the virtual operator would lease even more capacity but she is limited by the decisions of the Network Operator.

This capacity limit also gives some effect on the VNO decision on her service prices; the edge visible in the sub-graph depicting the service price decision coincides with the limits on the amount of capacity available for leasing.

The irregularities that are visible in the graphs illustrating the Network Operator's profits (upper left sub-graph) and the decision of VNO about the amount of the leased capacity (lower right sub-graph) are due to the fact that uncertainty about opportunity costs, customer movements, price uncertainty etc. was represented by a finite number of scenarios. Continuous distributions will give smoother graphs, but will create problems with numerical solution of related optimisation problems.

Reasonable economic interpretations can be found also for finer details on the graphs. Let us look again at the upper left sub-graph, which depicts the profit function of the Network Operator. The crate visible approximately in the middle of the graph depicts the highest possible profit that can be obtained by leasing capacity to rivals. If the capacity price is chosen higher the Virtual Network Operator will decide to lease less capacity. The saddle in the fore right area of the graph denotes the service price which will cause highest possible profits obtainable from service provision to own customers. When the Network Operator chooses a higher service price he will lose customers to his rival. Even here the different parts of the graph will change with another choice of the parameter set, so that for example the maximum profit obtainable by capacity leasing and the maximum profit obtainable by the service provision show different relative height.

7.2 Simplified Two Period Stochastic Model

This model is informally described in Section 4. It is obtained from the model of Section 6 by fixing the second period price decisions of the Network Operator to his prices during the first period. Figure 12 shows the results with the reference parameter set where the network extension was fixed to zero, while in the case shown on Figure 13 the network extension was fixed to a given positive number.

7.3 Analysis of Results

The profit function of the Network Operator as depicted above is influenced by several components and has therefore a complicated shape that makes a mathematical treatment difficult. The important effects that come into play are

- Number of customers purchasing service from the NO;

- Amount of capacity leased by the VNO.

Market sensitivity. The easier customers will move between the single providers the more capacity is reserved to meet the demand and the lower are the service prices. This strategy will ensure to obtain as many customers as possible. The highest profits for the Virtual Network Operator are achieved at a low level of market sensitivity with high service prices and low capacity prices. In the case of highly sensitive market the Network Operator obtains highest profits by choosing high capacity and service prices. In the case of low market sensitivity the part of the profits due to the service provision becomes more important since the customers are more loyal to him even in the presence of higher service prices.

Price uncertainty. In the case of higher price uncertainty, i.e. bad information flow in the market, the Virtual Network Operator will lease somewhat more capacity than in the case of lower uncertainty and better information flow in the market. However, her decision about the service price will be affected only marginally. The level of service price will always be below the Network Operator's prices, except for very low values of the Network Operator's service prices. Besides, the Network Operator can obtain higher profit in the case if the VNO knows less about his policies. In the case of a longer time horizon with two decision periods these observations are reinforced.

Some additional observations which can be given as advice to the Network Operator for choosing a profit maximising policy for the given set of model parameters:

- The case of low market sensitivity: choose capacity price at approx. 75 % of the limit and a high service price;

- The case of good information flow, i.e. low price uncertainty of the VNO: choose high service price and medium capacity price;

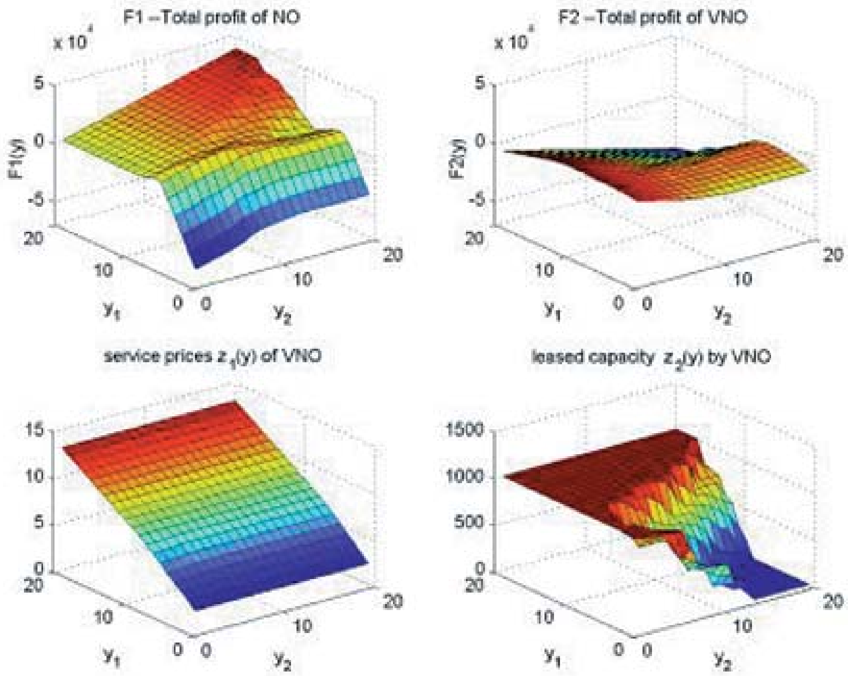

Figure 12 Two periods, reference parameter set, no network extension

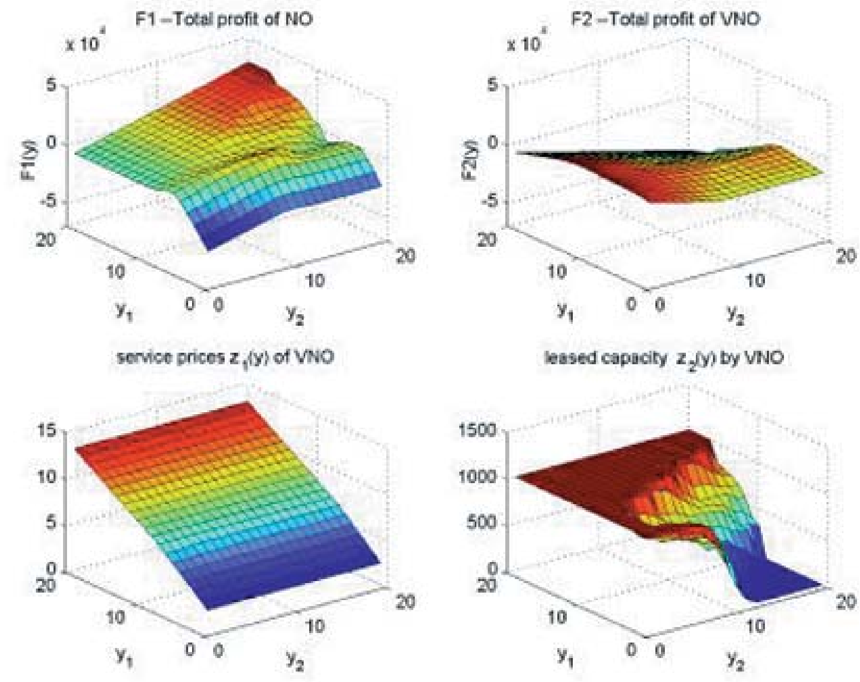

Figure 13 Two periods, reference parameter set, network extension by 5000 units

- The case of the very bad information flow / high uncertainty: choose capacity price approximately at the middle of the region, choose the service price either high or low. In the first case the profits are obtained by leasing capacity, in the latter case by service provision to own customers.

These considerations are given here as an example of the kind of recommendations the decision maker can get by using modelling system. For different values of the model parameters these recommendations may change.

8 Maximising Market Share

It is conceivable that the service providers pursue some other aims than the maximum profit. One of such aims may be the largest possible market share. Generally, it is defined as the sales of a company in a defined market compared with total sales in that market. Therefore, here the market share is based on the amount of service sold to the single providers' customers, i.e. the served demand. The models, which are similar to the models in the case of the profit maximisation, can be formulated. For example the enterprise performance measure of the Network Operator will have the following shape for the single period case:

F_1 = *Number of customers served by Network Operator / Total number of customers served by both operators*

The Virtual Network Operator's market share function is constructed similarly. Besides of the different objective functions the models are set up on the same premises as for the models with profit maximising operators. However, we have to bear in mind that in the case of uncertainty the operators have to estimate also the number of customers of their rival in order to determine their own market share. Thus the Network Operator's model for the prediction of the VNO strategy includes a term for her estimated customer number and a term for the NO customer number perceived by the VNO. The total number of served customers may therefore be estimated differently by both operators depending on the quality of information flow in the market.

The models as formulated here are purely market share oriented, there is no dependency on the capacity price anymore and all economic aspects were put into background. To be more realistic a combination of both presented ideas may be appropriate. Another important feature of the market share approach is that the goal functions are not quadratic anymore, and a solution technique will therefore be more complicated.

9 Conclusions and Future Work

A framework was developed for modelling of complex competition relationships and evaluation of strategic decisions in the telecommunication environment. Its methodological foundation draws upon selected ideas of the game theory and the stochastic programming.

Decision support system based on this framework is under development. In this paper we utilized it for analysis of interactions between network operator and virtual operators. Although at present the models have a quite simple structure, they allow obtaining fairly interesting and non-trivial insights into this situation.

The further work that we are planning is organized along the following interrelated directions.

- Further development of the model suite. It includes development of more sophisticated customer models with feedback and more differentiated pricing structures.
- Study of the mathematical properties of the modelling framework. This will provide insights into the structure of the optimal strategies and facilitate the development of efficient solution techniques.
- Implementation of the architecture of the decision support system. The objective is to create a user friendly and robust tool suite for evaluation of strategic decisions in a competitive telecommunication environment.

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The Future of Virtual Network Operation
Lessons from the ICT-Industries

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This article describes and analyzes critical conditions for achieving net benefit from opening the value-chain in telecom by introducing virtual network operators (VNOs). These are facility-less operators that outsource most of basic service production, while focusing on a smaller core business consisting of intelligent network operation, innovative services and creative marketing. Whereas granting the VNO significant influence both over service offerings and price margins is one essential condition for profitable return, this is far from a sufficient one. Not only should technical interfaces between networks and between higher and lower technology layers be standardized to facilitate trade in the use of such resources, but contracts should also be designed that combine (i) incentives for future network investment and service provision among facility-based network operators with (ii) conditions that do not place undue service and pricing restriction on facility-less operators when renting those networks. The major argument for designing such contracts, however, is not primarily transaction cost minimization in the static sense, although this is also an issue, but rather the subsequent learning and industrial dynamic effects released by such contracts. By servicing a broader range of demanding external service provider customers, facility-based operators will also be exposed to a broader range of service related problems, stimulating the search for more innovative and customer friendly network solutions. Facility-less network operators, on the other hand, may develop into market-led service providers that no longer can rely on subsidies from their facility-based sister affiliates, but will be forced to develop profitable service and marketing solutions for a wide range of demanding end customers.

1 Introduction

The purpose of this paper is to analyze how operators and customers may benefit from opening the value-chain in telecom and establishing virtual network operators (VNOs). Virtual network operators are facilities-less service providers that own and control only a smaller core of selected network devices and service applications, while contracting out the remaining network and application services that are necessary to provide the final service bundle to customers as promised. Although net social benefit may be positive, incumbent will generally benefit less and consequently be less receptive to virtual network operation than customers and new entrants. If all were likely to benefit, virtual network operation should emerge naturally. Since some stand to benefit more than others, virtual operation will not appear as viable strategy until facilitating regulation and appropriate operating conditions have been established. In this paper our focus will be more on operating conditions than on facilitating regulation.

First of all, to profit from virtual business practice, the price difference between final user price and rental price must cover more than the VNO's own service production cost. Generally, this margin is meagre, and the chances for extra profit smaller, when prices and services are tightly controlled by the network operator than when they are less tightly controlled and correspondingly more influenced by the VNO itself (or by the regulator on behalf of the VNO). Under certain conditions concerning service transactions, production resources, organizational capabilities, competition and governance (to be further laid out below), this separation may contribute both to more efficient utilization of existing network resources, and to more efficient development of new networks and services. Many still tend to believe, however, that the net benefit of virtual network operation is highly uncertain and probably negative.[1] The main reason for such scepticism seems to be the expected negative incentive effects that such a regulation may have on investment in future networks such as in 3rd generation mobile network (UMTS network), combined with weaker infrastructure competition. Although these negative incentive and competition effects will be moderated by the positive effect that such regulation will have on service innovation and competition, sceptics (most incumbents and some regulators) expect positive effects to be outweighed by negative ones. However, the negative incentive effects on infrastructure investment will depend on both the financial arrangement chosen for building and operating such networks and the industrial dynamics released by opening the value-chain in general, and introducing virtual network operators in particular. My intention

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1) *This was the conclusion reached by the British regulator Oftel and Norwegian Department of Communication that recently evaluated the concept of virtual operators in mobile communication.*

with this paper is to start a more open and critical assessment of this difficult, but very important question.[2)]

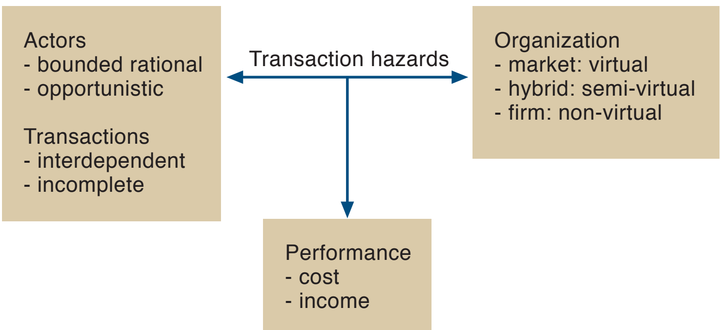
2 The Essence of Virtual Business Practice

2.1 The Core Issue of Separation

As indicated above, the crucial question is whether basic network services and enhanced (advanced) services are technologically separable, and if separable, whether they still are too interdependent to justify full corporate separation. On the other hand, if basic and enhanced services are technologically separable, but only moderately interdependent, what could then be the most efficient mechanism for safeguarding the underlying investment in physical infrastructure, supplementary resources and service capabilities? Would simple contracting suffice, or would more hierarchical structures be required such as strategic alliances or long-term exclusive contracts? Transaction cost economics, the premier theoretical approach in analyzing such problems, will serve as our theoretical guide, here applied in a somewhat more resource-centric and dynamic fashion than usual (Williamson, 1991).

As indicated in Figure 1, positive cost and/or income performance is achieved by aligning transacting actors who differ in their personal and transactional attributes with organizational forms (market, hybrid, firm) which differ in their governance mechanisms (incentives, administrative control and contract laws). Compared to the firm (as one out of three alternative generic forms), the market will be characterized by stronger economic incentives, weaker administrative controls and stronger reliance on the court system as conflict resolution mechanism (Williamson, 1991). Hybrid forms such as joint ventures fall in between firms and markets.

Figure 1 The core issue



In general, transaction hazards arise when incomplete contracting is carried out between opportunistic, bounded rational and interdependent actors. As interdependencies and the associated transaction hazards decrease, integrated firms (fully integrated facility-based operators) are gradually replaced by hybrid forms and arm's length contracting. That is, facility-less "virtual" network operators that buy basic network services from facility-based "non-virtual" operators will normally do this under incomplete contracts that specify some, but not all the obligations under some, but not all future conditions. Instead of specifying every possible future decision and condition, difficulties are dealt with, and conflicts resolved, as the future unfolds. This may work reasonably well under most ordinary supply contracts as long as problems are simple and easy to solve and potential losses from switching partner are small. In situations where problems are more difficult to solve, and switching costs are large, simple contracts will no longer suffice. Should one of the parties, due to possible failures or defects by the other party wish to exit from the relation, this may not only lead to time-consuming and costly conflicts, arbitration and possible litigation, but also to the loss of all the non-redeployable assets. To avoid such transaction costs, simple contracts should be replaced by more complex contracts with stronger safeguards, such as long-term contract, joint ventures or fully integrated corporations, dependent on the level of contractual difficulty and the size of potential losses from separation (the choice of integrated corporation being reserved for the most difficult cases with highest loss potential).

2.2 Defining Virtual Network Operators

Virtual network operators (VNOs) are operators that own and control a minimum of higher-layer network infrastructure while contracting out the remaining lower-layer infrastructure (cables, switches, etc.). Alternatively, a VNO may be defined as an enhanced service provider that owns and controls only those facilities that produces the enhanced features that may differentiate its services from those of its competitors, whereas all the remaining basic infrastructure is

[2)] *The more general question of outsourcing also apply to upstream activities such as network building and mobile tower operation as reported by TELECOM A.M., a daily news bulletin from Warren Publishing Inc: "Nextel signed a master lease agreement November 5 with Crown Castle International valued at $250 million over 10 years for colocation on 1,264 wireless sites on Crown Castle's towers. Colocation will begin immediately and continue over three years, with Crown Castle expecting annualized leasing revenue of $23-$27 million under the 25-year contract, the companies said. As part of the contract, Crown Castle said it will provide installation services for all the sites. The agreement with Nextel comes after a series of contracts that Bell Atlantic, BellSouth, Powertel and the U.K.'s One-2-One have signed with Crown Castle to outsource their tower networks,"(TELECOM A.M., Vol. 5, No. 215. November 8, 1999).*

rented, or the associated network service bought, from facility-based operators. Since intelligent facilities and service applications are the primary means by which VNOs make revenue and profits, these facilities and applications should also be owned and controlled by VNOs. Normally, expected profit margins will be lower on transport and access service that virtual operators only rent or buy, than on intelligent nodes and application that the operators privately own and actively manage, unless prices are set below cost by the regulator.

Physically, the VNO's own network devices and service applications can either be hosted by the incumbent or by the VNO. In the latter case, VNO devices and applications are connected to those of the incumbent across more or less standard interfaces, making the former more or less independent of the latter. To create a virtual network operation, access not only to the incumbent's physical network but also to his Operational Support Systems (OSS) is required. These are computer databases and systems that provide services and network management, administration, planning and repair functions, as well as functions related to customer operations, such as customer care and billing. In other words, whereas network facilities and service applications are the hardware and software needed to produce and deliver telecom services to final users, interface standards are specifications that more or less seamlessly interconnect the hardware and software of the VNO with those of the incumbent or other complementary network operators, making the former interoperable with the latter. In this respect, a full and unconditional opening of the value-chain essentially means turning previously closed and proprietary interfaces into open and non-proprietary ones, while simultaneously offering network facilities and service applications that newcomers can afford to rent or buy. Under exclusive contract, the value-chain is closed to all except the selected partner, whereas the underlying core technology with associated interface may still be more or less proprietary. Except for the renting and pricing issue, opening the value-chain in telecoms is strikingly similar to opening the value-chain in the computer industry. In particular, as telecoms converge with computing, lessons from the computer industry may increasingly become relevant for the telecom industry.

Also facility-based operators are forced to buy network services from each other in situations where subscribers of one network call subscribers of other networks. By renting or leasing networks, costly duplication is avoided, existing infrastructure more fully exploited, and services provided at lowest possible production costs per unit (economies of scale). Only substantial increases in transaction cost between competing network operators should prevent such renting and leasing contracts from replacing network duplication. Thus, virtual network operators that own only a minimum of infrastructure will only survive to the degree such economies of scale from higher utilization of the larger network can be attained just as well by selling to external as to internal service providers; that is, by separating network operation from service provision. Since this cannot be excluded, some incumbents have already started to explore the profitability of VNOs more systematically, especially in foreign market where the roles are reversed, and the need for an alternative VNO-strategy is more pressing.[3)]

2.3 The Separation Issue

Dividing integrated telecom enterprises into distinctive businesses, separated by technical and contractual interfaces, has for quite a while been the standard approach for introducing competition in the telecom sector, strongly promoted by regulator and new entrants, and gradually excepted by incumbents. Considerable differences still exist, however, concerning which activities to separate and to what extent. While regulators and new entrants seem to prefer that technologically separable activities should also be organized as independently owned businesses, most incumbents are strongly against this. Their objection would generally be that most activities that seem to be technologically separable, are considerably less so, and of those that are, many are still too interdependent to justify full corporate separation. Forcing corporate separation between activities sharing the use of common non-redeployable and/or non-tradable assets would simply cause transaction costs to exceed the associated separation benefit (positive competition effects). Incumbents have therefore been considerably less reluctant in accepting the location of interconnection points outside systems of highly interdependent or non-tradable resources than inside these systems as illustrated by local loop unbundling and mobile network roaming initiatives (Ulset, 1998a).

Recent interconnect arrangements, especially of the less intervening kind, have not only made it easier for telecom brokers and resellers to buy and sell excess capacity, but also enabled new entrants to seamlessly interconnect their smaller network with the larger network of the incumbent. Now, as the telecom technology has turned more complex, higher technical layers have been

[3)] *This led Telenor and BT to develop a business plan for a software-based telco, named Facet, which illustrate perfectly the VNO concept (Halbo et. al., 1999a, 1999b).*

added to the basic infrastructure, and more specialized service and support functions have developed, the question of separation has also been extended to include these layers, services and functions. Dividing the infrastructure into independent layers would help to create technology-independent services and service-independent technology. It would also make it possible for independent operators to specialize on different layers and to combine their services, under some kind of bundling contract, into more or less customized packages for sale to final users.

Whereas the regulator have regarded corporate separation as a last resort measure for developing competition, incumbents have claimed that such separation will seriously weaken their technical abilities and economic incentives to develop new services. Their argument would be that network facilities, although technically separable, are still too interdependent, or too difficult to rent out, to justify full corporate separation. Albeit less openly debated, a more threatening possibility would be that such regulatory enforced separation would enable virtual operators to take full control, not only over value-added services, but also over the customer base, thereby reducing physical network operation to a low-margin commodity business (pure transporters of non-differentiable bit streams).

As technologies and markets have kept evolving, the issue of separation has also become more complex. This relates not only to organizational separation which may vary in degree from accounting to full corporate separation, but also to technological separation which may vary in terms of effectively separable layers, from the lowest physical substrate layer to the highest final user applications layer.[4)] Due to the enormous complexity of modern telecom network and services, along with the large share of non-distributable sunk cost, defining and pricing unbundled elements and services unambiguously, has been very difficult, almost impossible. If the infrastructure were forced open by regulators, incumbents would fear that the associated price for renting or leasing network elements would no longer cover their cost, thus destroying their incentives for investing in new infrastructure and in the development of new services. No wonder that initiatives such as local loop unbundling, asymmetric roaming and virtual network operation have been strongly rejected by most incumbents.

2.4 The Competitiveness Issue

2.4.1 Competitive Advantage in general

To answer the above separation question, we first need a clearer understanding of possible sources of competitive advantage and how these may be affected by separation. First of all, to attain competitive advantage in general, companies must be able to develop and deliver products or services at lower price or higher quality than their competitors. This can be achieved by developing superior functional competence (e.g; technology, management, marketing etc.), by building stronger market positions (e.g. dominance, legal patents, exclusive licenses etc.), or by some combination of the two (i.e. lower cost due to earlier entry and deeper learning over longer time). For example, the previous monopoly operators could operate their nation-wide networks at lower accounting cost per minute than their competitors, not only due to over-depreciation during the previous monopoly period, but also due to superior competence in running those network accumulated over a longer period of time.

Then, superior competence can be used partly to reduce production costs, partly to develop more functional products at higher price. Whereas in the first case, competitive advantage and extra profit is the outcome of cost leadership, in the latter case this is the result of exceptional performance in product differentiation and innovation. In both cases, sustainable surplus is created by assets that not only are superior compared to those of the competitors, but also inimitable or otherwise protected from leaking out to competitors. In the cost leadership case, these resources are used to produce an increasing number of identical or closely related products at more rapidly declining unit costs than could be achieved by competing operations. In the innovation leadership case, common resources are used for developing faster or less costly processes than those of competitors. To the degree specific resources that contribute to the development of cost leadership or innovation leadership are difficult to trade in ordinary markets, competitive advantages will be more rapidly developed and more efficiently exploited by units of the same enterprise than by comparable units organized as independent suppliers in the market (or as part of another and differently diversified and integrated enterprise).[5)]

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4) *Neither should telecom services include only network services made separable through initiatives such as local loop unbundling, mobile network roaming and the widespread use of Internet technology. Relevant services should also contain distribution of information, education, entertainment and electronic commerce over the Internet, as well as the full range of specialized downstream customer services and support such as wholesale, retailing, customer support, system integration, outsourcing and consulting, the latter being probably more separable from network infrastructure than content distribution.*

In other words, the non-tradability of the services associated with the development and the subsequent utilization of critical resources is the major condition for corporate integration. Note that "non-tradability" is here used comparatively, meaning that development and/or utilization of these resources is considerably more costly or time-consuming to carry out by independent firms in a market than by integrated firms. This distinction corresponds of course to the more general distinction in transaction cost economics between autonomous and coordinated adaptation (Williamson, 1991) and, in particular, to the distinction between autonomous and systemic innovation in the innovation literature (Teece, 1986; Chesbrough and Teece, 1996). In the systemic case, technical improvements or innovations in single components would require simultaneous changes of the other components making up the larger system. Under autonomous innovation, however, individual components can be replaced by new ones without negative effects on the other components or on the system as a whole. In the autonomous case, efficient downstream service provision will develop without the downstream service providers having the slightest knowledge of upstream production technology and capabilities. In the systemic case, however, efficient downstream service provision would require that downstream service providers utilize the technology and capabilities of upstream network operators. To achieve such knowledge sharing corporate integration may be needed when critical knowledge is basically tacit, sticky and dispersed over a larger number of locations and team members. If less tacit, sticky and dispersed, sufficient sharing may be achieved by buying from the same supplier or adopting the same basic technology platform.

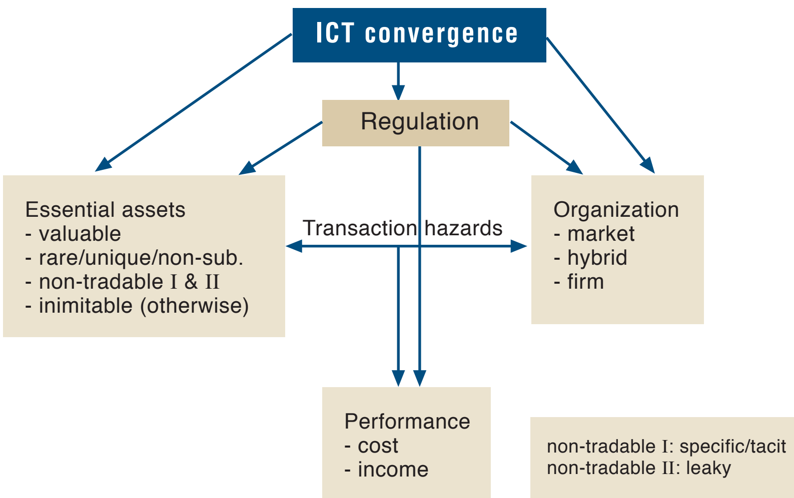
2.4.2 Competitive Advantage in Virtual Network Operations

In general, by focusing on a smaller core of resources, virtual as well as non-virtual operators may achieve extra profit to the degree these resources are valuable, rare, inimitable and well organized (Barney, 1997, chap. 5). Resources such as physical and human assets are valuable to the degree their effects on profit or value added are potentially large. They are rare in the sense of being scarce (few competing suppliers), different (rather unique compared to similar assets at the competitors' disposal), non-substitutable (no alternative kind asset or technology to perform the function) or specific (less productive value for alternative users or uses). Being rare in the absolute sense means that no useful substitute exists (e.g. telephone lines before cellular and satellite). Resources such as technology, knowledge or competence may be difficult to duplicate or copy either for "technical" reasons: to the degree they are invisible, tacit, sticky or diffused; or for economic reason: to the degree they constitute a natural monopoly or exhibit extreme degree of economies of scale or scope.

Given that the above resource conditions are fulfilled, appropriate organization and management are still needed to transform potential sources of competitive advantage into sustainable competitive advantage with above-normal return. A renting/leasing contract may suffice, but only to the degree competitively critical resources of the virtual operator can easily be separated from those of the non-virtual operator, and otherwise made tradable through some kind of leasing or rental contract. If not, corporate integration would replace contractual governance as the most efficient governance form. Consequently, integrated operators should also replace a system of virtual operators buying network service from facility-based (non-virtual) operators.

In Figure 2 the arrows linking organization, essential assets and performance summarize these relationships. Here the term "essential assets" are used because of the close relation between these assets (resource-based competitive advantage) and the "essential facility" concept in the telecom regulation literature. The latter are facilities that (i) are controlled by a monopolist, (ii) are considered a necessary input for the provision of downstream services, and (iii) cannot be duplicated in any technical or economical feasible way. According to the received

Figure 2 The competitive issue



5) *Resources such as network and competence in running the network can be traded either as objects in which case the respective physical or human assets are permanently sold, or as services in which case they are only rented out for a specified period of time. When competence is rented out, the objective may sometimes be to transfer or duplicate competence to the benefit of the client, in which case the competence both is rented out and sold.*

doctrine, appropriate candidates for regulation are only those facilities that are "essential" in the above sense because of the power abuse potential (and associated super-normal profit potential) such facilities represent.

The existence of independent VNOs, however, poses a rather crucial dilemma. By specializing in the more advanced higher-layer features, virtual operators may on the one side reduce lower-layer physical operation to a low-profit commodity business without leaving sufficient surplus to finance next-generation infrastructure investment. On the other hand, by specializing on more advanced features, virtual operators may also contribute to a higher innovation rates in the deployment of higher-level applications and development of value-added services.

To reach expected growth in advanced services and content, large-scale investment in broadband capacity will be needed both in the transport and access network. Most observers agree, however, that the chances of achieving higher margin by means of product differentiation is far better on advanced service and content than on transport services and local access. Being deeply embedded in, and practically inseparable from, the larger physical network, service development tools will for some time remain an integral part of the installed IT-systems. This, however, may gradually change as the older circuit-switching network is replaced by next generation packet-switching IP-network. The Internet technology may then cause intelligence in service development to be transferred from the IT-systems in the network to intelligent servers and computers belonging to virtual operators and final users, thus making the underlying physical network basically dumb (and correspondingly unprofitable).

Which company structure will be best positioned or endowed to achieve such differentiation advantage on the next generation IP-platform – large integrated enterprises or networks of smaller specialists – is still unsettled, although most operators and observers seem to believe in the large-scale integrated structure as the most efficient and profitable one. For example, local incumbents still prefer merging with other incumbents, so that larger synergies and cost reduction (5 – 10 %) can be attained, instead of competing on duplicated facilities and personnel in each other's home markets. The synergy from merging, however, can seldom be achieved without negative competition effects, including the attended risk of rising costs in the longer run. At least from a welfare economic point of view, mergers should not be recommended unless the positive synergy effects substantially exceed negative competition effects.

The most efficient alternative to compete on the basis of duplicated resources may, however, not be corporate integration, but rather duplicationless competition, based on leased lines, interconnection, unbundling, mobile network roaming or similar shared network usage. In particular, to the degree virtual operators develop into a rather efficient solution for new service creation and network capacity utilization, the synergy effects of mergers may easily turn negative. Virtual operators may win extra profit if cheap transport and access services are combined with advanced functionality and value-added services, produced by the VNO's own facilities and capabilities. On the other side, virtual operators will probably not be able to capture extra profit to the degree the supply of supplementary resources and services are monopolized, unless the price on those resources and services is regulated and offered at prices below historic full-cost (e.g., equal to long run incremental cost). At the same time, VNOs who rent, rather than own basic infrastructure, are compelled to specialize on a narrower field of core assets to achieve competitive advantage, the effects of which could be that additional benefits from higher specialization exceed additional transaction costs from more dispersed and specialized operations.

2.4.3 Expropriating Economies of Scale and Scope (Core Assets)

The crucial question is, however, not the size of economies of scale and scope, but whether physical operators of larger networks can prevent VNOs, as well as facility-based competitors, from "expropriating" a significant share of such economies. Expropriation of surplus will be prevented to the degree the quality is lower and/or the price higher on services that the incumbent delivers to external customers than to internal ones. For several reasons, this may often be the case.[6)] Even though the regulator officially prescribes and expects that the same quality and price should be offered external customers as internal subsidiaries, this objective may never be fully attained, due to technical difficulties and sever conflicts of interests. In turbulent times when technology standards, regulation and business practice are still evolving, both technical incompatibility and conflicts of interests will normally work against external customers.

So long as the incumbent controls the only fixed-line access network available, competing physical network operators can be prevented

[6)] *This has been the experience in USA ever since the FCC tried to implement the unbundling regime as part of the Telecommunication Law of 1996.*

from achieving economies similar to that of the incumbent, simply by providing access services of lower quality or higher price to competitors than to himself. The conditions and mechanisms making this possible are the same as for virtual operators mentioned above. In the access market, however, alternative radio, cable and cellular access may soon develop into a competitive alternative to fixed lines, and when this happens, the incumbent's first mover advantage will soon be gone. This will subsequently also help virtual operators that will be in a stronger position to buy competing high-quality access and supplementary support services at a lower price. Net brokers and retailers will also buy and sell network capacity, but contrary to VNOs, these will only compete with physical operators on service provision, not on network operation. Consequently, brokers and retailers will represent a more promising complementary growth opportunity than VNOs that most often will be regarded as competitors (Foros and Hansen, 2000).

3 Virtual Operation in ICT

To get a better understanding of the economic effects of separation and outsourcing, let us take a closer look at the development of the ICT industry, especially the computer industry and the Internet.

3.1 Lessons from the Computer Industry

3.1.1 Open Proprietary Standards, Innovation and Growth[7)]

Until the late 1970s nearly all computers were large machines used for mind-numbing calculations and bookkeeping, mostly bought by larger organizations that could afford their price and service costs. Computers such as mainframes and minicomputers were the most complicated machines ever produced. They were sold in a relatively small number, and mostly produced by large companies that were vertically integrated from basic circuitry, computer platforms and operating system software to application software and distribution. Newcomers had a hard time breaking into the business for several reasons. First, few had the resources necessary to enter at all levels simultaneously. Second, for those who entered at one or two levels, the small number of independent supplier and distributors made it immensely costly to operate. Third, due to the machines' complexity and service needs, most customers were reluctant to buy from anyone but large, established suppliers.

So far vertical integration had served two purposes. First, by internalizing the development process, computer makers controlled technology leakage so that proprietary and incompatible systems could be developed and sold to increasingly captive customers. Second, by internalizing the process, the computer makers could also develop and deploy firm-specific assets more efficiently for the production of differentiated products. Since each chain of production was vertically chained together by closed interface technology, bilateral monopolies had arisen between component suppliers and assemblers that were more efficiently managed by hierarchy than by market contracting. Competing production systems remained therefore vertically integrated until challenged by a significantly more efficient technology, the personal computer (PC) technology. With this technology installed, distributed computing and networking soon became a more flexible and efficient alternative to the mainframe system for ever-more complex and power-consuming tasks. Since the new computers could be assembled from hardware pieces and software components supplied by independent firms in the market, the new computer industry was never vertically integrated as the old computer industry. Coordinated by open interface standards, interchangeable components were outsourced to achieve economies of scale without the risk of excessive transaction costs. The need for vertical integration to control technology leakage and to manage firm-specific assets along the value chain decreased.

From its inception, the personal-computer market assumed a different pattern from the established industry, mainly because of rapid diffusion of new technology. The chip manufacturers were now able to cram a simple version of a computer's central processing unit, the circuits that did most of the actual computing, on to a single chip, a so-called microprocessor. Around this, a small cheap machine could be assembled from readily available parts used to supply the consumer-electronics industry. The most successful of all personal computers, the IBM-PC, based on Intel's microprocessor and Microsoft's operating system, became the industry standard for which a large number of application software firms wrote their programs. Fortunately for both firms, full property rights to the basic technology were retained in the initial contracts with IBM, and due to this, a large number of chips and software copies could be sold at a premium price to a booming computer industry. A parallel rapid growth in compatible application software, developed by innovative third parties, created the "network externalities" that substantially improved the value of the underlying technologies. Since Intel and Microsoft through incremental innovations succeeded in keeping their technologies both proprietary and in strong

[7)] *This subsection is previously published in Ulset (1994).*

demand, huge monopoly profits ensued. As IBM's losses kept skyrocketing, it became gradually clear to everybody that Intel and Microsoft had profited substantially more from the success of the PC than any PC-maker, including the largest of them all until then, IBM.

As additional software, equipment and network products were developed, the value of possessing an IBM-compatible computer continued to grow, and so did the sales and use of such computers. Spawned by a constant stream of technical innovations and improvements, mainframes and minicomputers lost out to PC-network and stand-alone PC for steadily more complex tasks. As distributed computing and networking continued to replace the old mainframe system, the demand for open interface standards and intersystem compatibility continued to rise, stimulated by a more open system strategy. This was most strongly demonstrated by Sun Microsystems. Soon open product standards and open network systems were demanded by most customers and supported by most computer makers. When open technology standards were supplemented with conversion programs and internetworking technology, the level of interoperability increased even more. Consequently, most personal-computer makers were never vertically integrated. Separate groups of firms supplied parts, fully assembled machines (platforms), operating-system software and application software.

By attracting a larger number of potential innovators, open standards contributed to the growth of network externalities, and thereby to the profitability of the firms that controlled these standards, such as Intel, Microsoft and Novel. Companies that did not control technology standards, including most computer makers, benefited less. When open and dominant standards are owned, patented or difficult to imitate, the owner of the standards will also tend to get rich. The assembler, however, will not tend to get rich unless some additional proprietary technology or competence is added to the system. While earning extra profit became constantly harder for computer makers, the owners of the original and incrementally improved standards got constantly richer. The emergence of open, but still proprietary standards, thus fundamentally redistributed competitive advantages and economic profits, from computer makers such as IBM (and Norsk Data) to chip producers such as Intel, and software firms such as Microsoft, Novel, Word Perfect and Lotus. Also the system-users benefited immensely. As long as they stayed within the dominant IBM-standard, customers could freely choose between a growing number of high-performing low-priced computer systems, and no longer needed to be exploited by their chosen computer maker.

However, proprietary standards will still exist, and as more companies start outsourcing a larger share of their component production, leading component technology may even develop into world standards. To the degree these are owned by one supplier, considerably higher profits can be earned after the production systems have disintegrated than before (which was and still is the case for Intel in microprocessors and Microsoft in operating-system software). Although positions as profitable as those of Intel and Microsoft are extremely rare, many firms regularly develop proprietary technology with significant profit potential. Even if future technology standards should be less proprietary than before, technological innovations within these standards can still be kept proprietary.

3.1.2 Dominance and Antitrust

Successes as impressive and positions as dominant as those of Intel and Microsoft can seldom be attained without the active use of some kind of monopoly power. Clever tricks and ploys that may pass when performed by non-dominant firms, may not pass, however, when carried out by dominant businesses. Gradually, this was also realized by Intel who wisely moderated its practice when the US Federal Trade Commission requested them to do so. Microsoft, however, did not moderate its business practice when asked to, but rather continued to punish companies that developed competing products (e.g. Netscape, Sun Microsystems) or customers that sold competing products (e.g. IBM, Gateway). The findings of the subsequent antitrust case of U.S. v. Microsoft thus unambiguously showed that Microsoft routinely used its monopoly power to crush competitors, even leading the judge to portray the company "as nothing less than a social menace" (Business Week, 1999, Nov. 22: 45).

After the court officially declared Microsoft a monopolist, regulators started to discuss remedies of which there are two major types: one behavioral type and several structural ones. The behavior remedy will require close supervision over issues such as pricing and contracts with other companies, eventually making the government the permanent overseer of Microsoft. Being very difficult to monitor, supervision of such behavior may either become overly costly and stifle innovation, or unreliable if not fully implemented. Structural remedies contain several dramatic measures such as breaking up the company into three vertically disintegrated companies (operating systems, application software, Microsoft Internet business) or three vertically integrated Mini Microsofts ("Baby Bills"), or forcing Microsoft to auction or license out proprietary technology to competing companies. The question is how to punish Microsoft and stop its abusive conduct while encouraging innovation and protecting the consumer. Although the different remedies may help to restrict monopoly pricing and power abuse they are not without costs and limits. Disintegration will not create competition in the market for operating systems, partitioning Baby Bills and auctioning Windows may fracture the Windows standard, and open-source code licensing may facilitate illegal copying. In any case, remedies can only be recommended if significant net benefit can be expected. Benefit can be gained from structural remedies both in terms of making the core technology more accessible and less costly for downstream customers, and in terms of making innovations in complementary products easier to develop and more profitable to commercialize for related businesses. Significant investment disincentives are, however, also involved since structural remedies will make investments in operating systems less profitable for the main firm. A final decision is still pending and may remain so for quite a while.

3.2 Lessons from the Internet

Under the virtual network operation model, modern technology enables coordination across firm boundaries as if the respective individual firms were parts of the same enterprise. The Internet has not only enabled the development of the World Wide Web and electronic commerce, but increasingly also a more advanced division of labor and inter-firm specialization, also internationally, without the usual increase in transaction costs. Through Web-based searching and ordering (internet/extranet/intranet), a larger portion of peripheral and semi-peripheral activities can be outsourced to external specialists, leaving a smaller and more focused portion of core activities to internal specialists, the effects of which would be quality improvement and production cost reduction, without the usual off-setting increases in transaction costs. A number of industries are now exploring these opportunities, but nowhere are these more challenging than in the multi-layered infrastructure of telecom service provision of which the Internet Protocol and WWW themselves are parts.

3.2.1 Open Non-proprietary Standards, Innovation and Growth[8)]

Internet was born about 30 years ago out of an effort to connect together a US Defense Department network called the ARPAnet and various other radio and satellite networks. The objective was to build networks that could withstand partial outage (like bomb attacks) and still work. In the ARPAnet model, communications occur by having computers talk to each other and ensure that the communication is accomplished. The network itself was assumed to be intrinsically unreliable as any part of it could disappear at any moment. To send a message, the computer simply had to put its data in an envelope, called an Internet Protocol (IP) packet, and address the packets correctly. The demand for networking then spread quickly, and Internet developers from US, UK and Scandinavia, responding to market pressure, began to put IP software on every conceivable type of computer. By then the International Standards Organization (ISO) had already spent years designing the ultimate standard for computer networking without making much headway. Users, however, adopted the IP instead. So did companies that developed workstations for local area computer networks (LANs), allowing all computers on such LANs to access ARPAnet facilities. One of those newer networks was NSFnet, commissioned by the National Science Foundation, with the objective of connecting computers of major universities. Due to bureaucratic and staffing problems, NSF decided to build its own network based on the ARPAnet's IP technology.

Demand grew rapidly until the computers controlling the network and the telephone lines connecting them were overloaded. The network needed upgrading and professional management, and the contract was awarded to Merit Network Inc., which ran Michigan's educational network, in partnership with IBM and MCI. The number of connecting networks kept growing, gradually also including non-IP-based networks connected by special gateways technologies. The participating networks financed by governments or private users, connect without a charge, only by adopting the open IP technology or some non-IP-technology with gateway to the Internet.
The modern web servers and web browsers have spawned further growth. Although the Internet was for several years mostly used for information exchange and marketing, new communication software was gradually introduced allowing the Internet to also carry interactive voice traffic. Already by mid-96 the Internet reached nearly 5 million host computers and approximately 20 million users, and its growth is still accelerating.

The ultimate authority for where the Internet is going rests with the Internet Society, or ISOC, a voluntary membership organization whose purpose is to promote global information exchange through Internet technology. ISOC appoints a council of elders, called the Internet Architecture Board, or the IAB, which meets regularly to confirm standards and allocate resources, such as addresses. It decides when a standard is needed and what it shall be. When a standard is required, it considers the problem, adopts a standard, and announces it via the network. The

[8)] *This subsection is previously published in Spiller, Ulset and Zelner (1996).*

Internet Engineering Task Force (IETF) is another volunteer organization. It operates through working groups that anyone can join. These groups makes different recommendations that either are made available to anyone or sent to IAB to be declared a standard. These standards make computers from different vendors communicate, favoring no one in particular, whether IBM, Sun or Macintosh.

3.2.2 The Bearer Service Concept of the Open Data Network

In addition to its primary information purpose, the widespread acceptance of the Internet Protocol has organizational ramifications. By implementing the Internet Protocol, a spanning layer is being built that separates lower-layered basic infrastructure (network services) from higher-layered value-added applications (customer services) thus creating the basic condition for the development of separate markets. The Internet Protocol enables applications to request network services independent of underlying physical network technologies. Moreover, new underlying network technologies may either substitute for, or co-exist with, existing network technologies without significantly affecting the broader system, enabling so-called autonomous innovations.[9)]

In other words, the "bearer service" functions as a technology-independent network layer that resides above the technology substratum and enables interoperation between diverse, high-level applications and various underlying network infrastructure. Separation of applications and services from the physical network will also imply that the creation and supply of new services can be separated, physically as well as organizationally, from network operation.[10)]

As noted by Gong and Srinagesh (1996, 1997), this bearer service market may not prove sustainable unless competing services are differentiated. If not sufficiently differentiated, Bertrand competition will lead to destructive pricing for network services with close-to-zero marginal cost. One way to avoid Bertrand competition is through bundling of bottom-layer transport with higher services, closer to final customers (vertical integration). As facility-based companies integrate with others at higher layers, variable costs rise significantly along with minimum efficient size. Policies that promote competition in the provision of unbundled bearer service will therefore eventually fall. However, since bearer services that includes Quality of Service guaranties for bandwidth, delays and losses, is not a commodity as pointed out by Kavassalis et. al. (1998), it can be differentiated by (i) choosing different substrate technologies, (ii) designing a different network typology than their competitors, and (iii) designing a different pricing policy for their service.[11)] The crucial point, however, is not whether the service can be differentiated, but whether such differentiation can be copied or imitated by competitors (Barney, 1997). Probably it can, but more easily by facility-less providers (virtual network operators) that are less restricted in choosing between competing substrata and networks, than by facility-based operators that are primarily restricted to choosing among their own substrata and networks.[12)]

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9) *This kind of architecture separating service offerings from infrastructure facilities, is by the National Research Council more generally described as Open Data Network with four levels: ...* "i) at the lowest level is an abstract bit-level service, the bearer service, which is realized out of the lines, switches, and other elements of networking technology; ii) above this level is the transport level, with functionality that transform the basic bearer service into the proper infrastructure for higher-level applications (as is done in today's Internet by the TCP protocol) and with coding format to support various kind of traffic (e.g. voice, video, fax); iii) above the transport level is the middleware, with commonly used functions (e.g. file system support, privacy assurance, billing and collection, and network directory services); and iv) at the upper level are the applications with which users interact directly. This layered approach with well-defined boundaries permits fair and open competition among providers of all sorts at each of the layers".

10) *For example, the equipment supplier Ericsson recently launches such a service creation and supply solution for mass-market Mobile Internet, called Service Network solution (Press-release, Wed, 21 Feb 2001).*

11) *Such differentiation can also be achieved by using the Service Network offered by Ericsson:* "The Service Network is designed to help operators and service providers bring services to market in the most efficient way possible. For example, a third-party application developer working closely with a mobile operator will be able to enter the operator's Developer's Zone solution, hosted within the Service Network, and log on to their own page. From there they can check existing services and create new applications, downloading them to the operator's application server to be approved. When ready, the operator can make the application available publicly and send targeted alerts to customers whose profiles match that of the application categories."

12) *In the same way as travel agencies owned by one of several competing airlines would be more restricted and less competitive than independent agencies*

13) *Since this hypothesis is more thoroughly discussed elsewhere (Ulset, 1986), only a few introductory remarks and tentative conclusions are included here. ICT means Information and Communication Technology*

3.2.3 Internet and Convergence

According to many observers, the extraordinary rapid diffusion of Internet will soon also speed up the long expected convergence of the ICT industries.[13)] That is, as the technologies for producing voice, data and video services converge, so might also the respective companies producing the associated devices and services. If so, we should already now have witnessed a large number of telephone companies expanding through mergers, acquisitions and generic growth into closely related fields. These would include not only a larger number of nearly identical operations and closely related wireless and cable networks, but also upstream equipment and content production as well as downstream data processing services and content distribution. Similarly vertical and horizontal expansions could have been expected by other ICT companies, such as equipment suppliers expanding into television distribution and telephone network operation, and cable-TV companies into network operation, telephone services and data processing.

Over the last decade, there have been many attempts at integrating these and similar activities, but until recently with only moderate success. As suggested above, interface standardization and tradability of complementary assets is one plausible explanation for the lack of commercial success. That is, by diversifying into related activities that share common resources, significant costs can be saved, superior assets developed, and extra revenue created, but only to the degree essential conditions are fulfilled concerning the attribute of underlying resources, and the corporate organization employed for using those resources. First of all, superior assets should be safeguarded by contractual, legal, and strategic means, that either (i) prevent such assets from leaking out to competitors or (ii) protect the corresponding profits from being captured by more strongly positioned suppliers or customers in the subsequent commercialization phase. Second, activities should be organized into business units and divisions, and internal governance systems (financial versus behavior control) designed and chosen for those units and divisions according to tradability of common resources so that financial control is selected over behavior control for non-related, but not for highly related activities where the opposite relation holds. As attributes of critical resources or services change, so should also their divisional structure and governance systems. I expect efficient telecom operators to be those that adjust their boundaries and restructure their divisions accordingly, and inefficient operators to be those that do not.

In a previous report (Ulset, 1998) I questioned the value of integrating primary telecom services not only with upstream equipment production, but also with upstream content production, as there are little common resources to be shared with these. As far as I could observe then, also midstream distribution of media products was little more than a pure conduit, where telecom operators basically provided a transport network of sufficient capacity for the respective media products. Downstream IT-services are probably more closely related to electronic equipment production, than to network operation, and should therefore normally be more efficiently carried out by computer companies or specialized distribution and service companies, than by network operators.

Since considerable physical and human assets may be shared, the economies from integrating voice services with data communication and video distribution should normally be significant. However, as also these assets are becoming increasingly tradable, the cost savings from integrating may gradually decline. Quite similar benefits could be obtained from expanding the number of local networks and from integrating transport networks with local access networks. However, also here tradability of critical resources is increasing, and the value of integration thus declining due to technology standardization and pro-competitive interconnection policy. If this continues, the range of activities from which most telecom operators may gain a competitive advantage may gradually shrink towards that of a pure conduit. However, until more systematic and recent data is available, the above statements should be regarded as largely untested hypotheses.

3.3 Preliminary Development in Telecom

3.3.1 Norwegian and British Initiatives

Sense Communications[14)] is a Norwegian-based firm with the objective of providing new and innovative fixed and mobile services to the European market based on contractual agreements with existing fixed and mobile network operators. The company seems to have made a good lesson from its forerunner, here named Old Sense, which went bankrupt in March 1999, even before becoming operative. The business idea of Old Sense was to offer small and medium sized enterprises (SME) tailor-made communications services on an all-inclusive basis. Old Sense classified itself as a virtual network operator (VNO) with the intention of offering services using other network operators'

14) Information sources for this company profile is Halbo et. al. (1999a, 1999b) and the company's home page (http//www.sense.com).

access and switching networks, only equipped with a minimum of network elements such as (i) Gateway Mobile Switching Centre (GMSC), (ii) Home Location Register (HLR) with Authentication Centre (AUC), and (iii) Subscriber Identity Modules (SIMs).

Old Sense wanted to use Telenor Mobil's network to provide its own customers with direct network access and additionally offer one-stop-shopping of telecom services including; Virtual Private Networks (VPN), GSM, Centrex, FMC-services and voice-mail. High demand services could be offered from their IN-platform, others via contractors. Thus, the normal modus for Old Sense' customers in Norway would be roaming in Telenor Mobil's network, while connection in Sweden would be provided through Telenor Mobil's international roaming agreements.
Old Sense planned to invest NOK 1.3 billion (£100m) by year 2000, totally dependent, however, on access and interconnection with the networks of existing operators.

After a series of difficult negotiations with Telenor for interconnection, and with owners and creditors for additional money and equipment, Old Sense went bankrupt in March 1999. Soon after the company was re-established by new owners as Sense Communications. The previous NetCom assistant marketing director, Nadir Nalbant, was elected CEO.

On August 27, 1999, after Elkjøp, a large electrical equipment chain (now Dixons) had become owner and distributor of services, Sense pioneered the launching of the first free Internet access (no subscription fee) in Norway, named Sense.Wave. The competitors Telia, Telenor and Tele1 were completely taken by surprise. The demand was enormous, and by November, Sense had delivered 50,000 Free Internet packages. In relative terms, this was equal to the success of the British company Freeserve one year ago. Soon after free Internet access were also offered by Telenor, Tele 2 Norge, Telia Norge, Dagbladet/Powertech, X-stream/Domino, TV2, NetCom GSM and CyberCity, and many others.

Later in October Lucent Technologies and Sense Communications became partners and Lucent agreed to deliver equipment and provide financial backing worth 100 million NOK.

Less than a month later, Sense, Telia Mobile in Sweden and Telenor Mobil in Norway agreed on conditions for mobile operations by Sense. Sense could now access these networks and services necessary to become a serious challenger and competitor in Norway and Sweden. In December Sense launched sense.home and sense.homeFree, the former product is a product that helps Internet users without any prior knowledge to set up their personal homepage on the web. These particular products represent a smooth, fast and simple solution for the user. The latter product, Sense.homeFree, is a product for the advanced user and is free of charge.

At about the same time, Sense concluded a private placement of 200 million NOK through Pareto Fonds. The interest for Sense is overwhelming and the company value is estimated at 600 million NOK.

Then on January 17 the following year, Sense Communications enters the Norwegian mobile market as the third but first independent competitor. Sense had prior to that signed a contract for buying traffic capacity and SIM-cards from Telenor that allowed them to sell mobile services in their own name. This time, both parties were seemingly well satisfied with the outcome. Stig M. Herbern, the CEO of Telenor/Telia Mobile for the Nordic countries, said that this deal would stimulate competition and contribute to the development of mobile communication. Like old Sense, the new firm requires access to Telenor's mobile network on their own terms. They want to manage, not only resell, mobile traffic on Telenor's mobile network, but this was turned down by the Department of Communication, and subsequently by Stortinget. In December Nadir Nalbant of Sense was elected "IT-manager of the year" by Telecom Revy for his contribution to bringing Free Internet to the people, and for stimulating innovation and competition in the Norwegian market.

Sense managed to establish itself as the first independent mobile provider in the Norwegian market, with the objective of becoming a pan-European provider of integrated telecommunications services. The Sense business idea was based on creating a network of partners, such as Elkjøp, MCI WorldCom / UUNet, Telenor Mobil, Telia Mobile, Siebel Systems and Lucent Technologies, that continuously are being developed and evaluated. With backgrounds from Scandinavia telecom and Internet business, the Sense staffs are well known for their enthusiasm and entrepreneurial approach. By choosing the "best from the best" the company aimed at becoming the leading independent Communications Service Provider in Scandinavia.

Stimulated by the Sense success, a growing number of virtual operators were subsequently established (counting 17 facility-less operators at its peak). Most of these are by mid 2001 still loosing money. Consolidation through mergers and acquisitions into a smaller number of operators is the likely outcome, if not stopped by bankruptcy and liquidation. Feeling the need for larger traffic volume and sales revenue, also Sense decided to grow bigger and therefore bought Site, another newcomer. At about the same time, the company's entrepreneurial CEO, Nadir Nalbant, resigned, but only to start assembling a new consortium with the intention of buying the bankrupt licence holder Broadband and building the third UMTS network in Norway. Sense with its 200.000 subscribers would of course be one likely member of such a consortium.

NextCall[15] is a British virtual operator, established two-three years ago by Andrew Harrington, a previous investment banker. Since 1997 BT had then been under pressure from Oftel, the UK telecoms regulator, to offer a new wholesale service to rivals called Calls and Access. Harrington's idea was to make use of Calls and Access (he describes it as "phase one local loop unbundling") to take over from BT not just specific calls such as international ones but a customer's entire traffic, and their rental charges. Harrington clearly saw this as an opportunity to develop a strong, simple marketing proposition to customers. The network owner, British Telecom, resisted the idea. They felt they had more to loose than to win by granting facility-less operators access to their network.

After a long and hard fight with BT NextCall could finally start launching its services. Infrastructure was rented from BT or Energis, and maintenance provided by BT. The Calls and Access product gave NextCall the opportunity to use BT's world-renowned technical expertise to deliver a range of products and services to residential and small business customers. The only infrastructure owned and used by the company was a billing system and a call center, leaving Nexcall free to concentrate on marketing. While NextCall enjoyed the technical support of BT, its overheads were smaller, part of the savings being passed on to customers. Although this may turn out to be a cheaper way to offer service, virtual network operators such as NextCall cannot devise its own services in the way a carrier that owns infrastructure can.

The company almost immediately ran into problems with BT. NextCall and another newcomer called Localtel became involved in a high-profile tussle over BT's slowness in letting customers switch to them. NextCall started complaining to Oftel in February 2000 and by the summer was threatening to seek a judicial review. Oftel criticized BT's stance and eventually NextCall's persistence led to changes in BT's practices and enabled the virtual operator to run its business more smoothly. By September 2000 NextCall had 50,000 residential and small-business customers (increasing at a rate of over 8k per month) to which it offers a range of services including local, long-distance and international telephone services as well as Internet access services, all on the same bill.

Its approach was to bundle these services and offer them at a price that undercuts what a customer would pay for each service individually. Initially its customers were in clusters in the southeast and the south-west/south Wales, areas it targeted using a highly localized marketing campaign. It used the model established by cable TV operators of door-to-door selling supported by local newspaper and radio advertising and sponsorship of local institutions (the Welsh Cricket Association and local boys' clubs are beneficiaries). It subsequently launched in the Midlands and Scotland, and moved later on to London. At the start of 2001 the Company employed over 400 people in a wide variety of roles and were rapidly becoming a major force in the UK communications industry.

Calls and Access was not as attractive a solution for service providers as unbundling. But a move into unbundling could pull NextCall away from being a pure VNO and towards a more facility-based operator by installing software in BT's local switches to create its own services. Although the company was not on principle opposed to this, its CEO (Mr. Harrington) thought it unlikely. "An infrastructure decision is purely financial. If we can make money from installing infrastructure I'll do it. But why should I when wholesale rate are so low?"

Despite all the hard work and all the innovative efforts, NextCall did not make it. On February 13 the UK Activity Report announced that NextCall has gone into receivership with the loss of up to 300 jobs at its headquarters in Borehamwood.

Virgin Mobile[16], was established as a 50:50 joint-venture company between Virgin Group and Deutsche Telekom's One 2 One. Launched in the UK on November 11, 1999, it was also the UK's first mobile virtual network operator. In its

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15) *This company profile of NextCall draws heavily on Financial Times Survey of June 21, 2000, written by Richard Hanford (http://www.ft.com/ftsurveys) and the company's home page (http://www.nextcall.co.uk/).*

16) *This company profile of Virgin Mobile draws heavily on Financial Times Survey of June 21, 2000, written by Niel McCartney (http://www.ft.com/ftsurveys) and the company's home page (http://www.virginmobile.com/mobile/).*

first seven months it signed up nearly 300,000 cellular telephone users, making it the fastest-ever, and probably also the earliest-ever profitable start-ups, mainly due to the fact it does not build its own network. Instead it buys bulk air-time from One-2-One. Under this arrangement, it is able to issue its own subscriber identification module (SIM) cards, the smart cards in handsets, which identify the customer and control their relationship with the network. It is this element, which differentiates the company from traditional cellular service providers. The company is thus responsible for its own tariffs, billing and customer service infrastructure, and for the full cost of acquiring customers. It carries more commercial risk than a service provider, but it also gains more benefit if it is successful.

Virgin Mobile sells its services through Virgin's Megastores and Our Price shops, but it also uses direct marketing and the Internet. A Sim-based web browser allows customers to access web sites, which use the wireless application protocol (Wap) technology, such as BBC Online and Megastore Direct, Virgin's online music retailer. This means that its customers will not need to buy special Wap handsets to access these services. But it will sell Wap telephones to those who want them. For example, VirginXtras is Virgin Mobile's unique range of mobile leisure, information and entertainment services. With VirginXtras customers can save in the range of 10 % off selected Virgin Holidays; 15 % off music, videos, DVDs and computer games; and up to 50 % off electrical goods such as TVs, stereos, fridges and microwaves compared to typical high street prices.

The company started with the considerable marketing advantage of a very strong image, courtesy of the Virgin Group. This claims to have the best-known domestic brand in the UK, with a high reputation for value and customer service. So, unlike its competitors, Virgin Mobile did not have to spend much on brand building. This allowed it to set a relatively modest advertising budget of £5m to cover its launch and the first two months of operation – far less than most of its rivals were spending at the same time. It expected to spend a total of £20m on advertising in its first year of operation.

Unlike the UK's four normal network operators, Virgin Mobile did not subsidize the cost of handsets. It sold them at cost price (plus VAT), charging £60 to £350. But it offered a cheap and simple tariff package with no subscription fees and low call charges.[17)] The company said its rates were on average at least one-third lower than anyone else's. The same prices were offered to all customers, regardless of how they pay and whether they paid in advance or were billed at the end of the month.

As well as signing new cellular users, the company is now putting more emphasis on poaching customers from its rivals. If these users have a compatible telephone, and are out of contract, they can switch to Virgin Mobile simply by buying one of the company's Sim cards for £12.50, a price that includes calls worth £10. The company estimates that about 10m UK users could switch to its service without having to buy a new phone. Virgin Mobile has also sought to differentiate itself by offering advanced services such as the facility to surf music and to send and receive three-page e-mails. It is able to deliver these services to standard handsets by exploiting the high capacity of its SIM cards. These have 32 kB (kilobytes) of memory, at least twice as much as those currently used by other UK operators. The company admits its approach generates less money than its competitors do. It says that it is getting close to £20 a month per user, significantly less than the average for the UK industry. But it argues that this is more than offset by lower costs. It also claims that the expense it incurs in acquiring each customer is 50 per cent lower than that of its nearest rival.

This combination of simple but cheap tariffs and advanced services plays a central role in Virgin Mobile's marketing message, which uses all advertising media. Unlike most of its rivals, it did not initially spell out its prices in its advertisements. Instead, potential customers were encouraged to contact the company to find out more. But the pricing message is likely to get sharper now that the service has established itself.

The Virgin Group, which holds the overseas rights to the Virgin Mobile brand name, is now seeking to replicate this success in other countries. It has set up a joint venture with Australian operator Cable & Wireless Optus. It has also signed an agreement with Singapore Telecommunications to set up a venture to offer cellular services throughout Asia, starting in 2001. More deals are in the pipeline.

Already in November 2000, as the company celebrated its 500,000th customer and first birthday, Virgin Mobile was voted "Best Network

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17) *This package involves charges of 15p a minute for the first five minutes each day and 5p a minute after that (the initial rate was 15p a minute for the first 10 minutes, 10p a minute for the next 10 minutes, and then 5p a minute).*

2000" by consumer magazine Mobile Choice for offering customers the best deal and service available in 2000.[18)] Early the following year the company announced it had exceeded its sales targets for the fourth quarter running, by attracting over a quarter of a million customers in the last three months of 2000, increasing its customer base by a market-beating 63 %. It claimed to be on course to meet its target of reaching 1 million customers by the end of March. Analysts said it may turn profitable already in 2001 and might even be floated at a value well above £1bn.

As the Virgin case suggests, also virtual operators may turn profitable if favorable conditions prevail. These may at least include cheap tariffs, advanced services and popular content, supported by a strong brand and a productive contract with at least one large facility-based operator (One-2-One). As emphasized above, crucial conditions for creating such a productive outsourcing contract include standard interfaces between technologically separable network facilities and service capabilities that connect midstream network operator with downstream services provider. After becoming sufficiently standardized, these interface facilities and capabilities are no longer tacit and sticky and therefore no longer candidates for full corporate integration. Since the basic interface codes (sometimes even the source code) are available to all, market contracting will suffice as governance form for subsequent development, transfer and utilization of the technology and the products sharing this code. No additional organizational capability would be needed. This statement applies especially well to network operators. By keeping their network open and accessible (though open interfaces) rather than closed and inaccessible to external suppliers and customer, network operators may maximize capacity utilization and minimize unit costs.

3.3.2 Responses by Regulators and Incumbents

As indicated above, the initial responses by incumbents and their owners to the various VNO-initiatives have been strongly negative. As long as VNOs are only expected to capture existent traffic, not to create extra revenue, incumbents' reactions can only be negative. Regulators, however, who would like to see more infrastructure competition, tend to be more positive. Gradually, also the negative responses have weakened, especially in Telenor who have come to realize that open access in terms of unbundling and roaming would not only be required by the regulator as a general condition for allowing Telenor to dominate the market, but increasingly also by Telenor itself as part of its international strategy. To become accepted as a VNO abroad, Telenor must also be willing to accept foreign as well as domestic VNOs at home. Besides, virtual operators may also play a more productive role. Under the appropriate conditions, virtual operators may develop into a more efficient and innovative marketing force than corresponding units of facility-based operators, generating extra profit not only for themselves, but also for their facility-based partners.

4 Summary and Tentative Conclusion

In this article I have analyzed how incumbent and new entrants may benefit from opening the value-chain; that is, by creating separate facility-less network operators that profit from service innovation while outsourcing basic network operation to facility-based operators. Being a relatively recent phenomenon in telecom, the instances of virtual business practice described and analyzed above include not only examples from telecoms, but also from the computer industry and the Internet.

Quite obviously, to profit from outsourcing, specializing and downscaling in general, and from virtual network operation in particular, the price margin of the resultant "virtual" operation must cover its costs. Since this revenue margin is likely to expand with the VNOs own freedom in service innovation, packaging and pricing, granting such freedom can be regarded as one necessary, but still not sufficient condition for profiting from this type of business practice. In addition, important conditions related to service transactions, to production resources, and to competition and governance should also be fulfilled. In particular, and according to transaction costs economics, corporate integration would be the organizational solution of choice for techno-

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18) *Orange falls to third place behind Vodafone, with One 2 One coming fourth, and BT Cellnet trumped in last place. This motivated Mobile Choice's Steve Gold to the following comment on the award: "It may be a surprise to some and a downright shock to others, but squeezing in at number one isÖVirgin Mobile. It's been an interesting year for mobiles and undoubtedly a cracking one for consumers, thanks to the arrival of the ground breaking new 15 to 10 to 5 pence tariff from Virgin - which soon slashed to a 15 to 5 pence deal this summer. Virgin deserves its number one slot after an impressive first year." - Richard Branson, chairman of Virgin Mobile responded: "We're thrilled to have received this award. It recognizes the enormous contribution all the staff at Virgin Mobile have made in making Britain's newest mobile phone company the best. It's a great compliment and a tremendous accolade to receive on our first birthday," (reported by Niel McCartney in http://www.ft.com/ftsurveys).*

logically separate operations (activities) only if the intermediate products or services produced are non-tradable or if the respective underlying production resources are non-redeployable.

As indicated above, the resultant products and services are non-tradable to the degree their quality is difficult to measure and evaluate, or to the degree basic production resources used to produce and deliver intermediate products or services, are specific, tacit or diffused and therefore also difficult to transfer or access, unless supported by additional organizational transfer or access capabilities in terms of shared values, norms, codes and routines. On the other hand, production resources that are technically separable may still be non-redeployable to the degree they are partnership-specific (tailor-made) and thereby useless for other relations or applications. Should similar partners appear, however, specialized resources would no longer be partnership-specific, although they still may be non-tradable due to being tacit or diffused.

To the degree at least some of the respective production resources and support capabilities are also valuable and unique, these may under the protection of corporate integration develop into more sustainable sources of competitive advantage. However, increasing outsourcing in general, and virtual network operation in particular, indicate the opposite trend: services are made increasingly separable due to the use of increasingly redeployable and/or tradable production resources. Whereas some of the separated activities and operating units are well positioned to protect their already unique assets or to develop new ones (e.g. differentiable content or value-added services, developed and produced by facility-less operators), others are less well positioned (e.g. non-differentiable transport services, produced by facility-based network operators). Due to significant increases in expected traffic volume generated by a growing volume of innovative services, supplied by virtual operators, also physical network operators may earn significant rents by differentiating their network operation and service provision. Increasing competition, facilitated by the recent pro-competitive regulatory reforms, is perhaps the strongest force behind this embryonic restructuring process, besides the concomitant advances in digitized technology.

Obviously, both the computer industry and the Internet world illustrate that whereas innovation and growth are enhanced by open standards, huge profits will only result from large-scale sales of products or services on the basis of some kind of upstream or downstream monopoly position. Lacking such monopoly positions, most computer makers (assembler) and Internet Service Providers (ISP) are typically characterized by small profit margins. Even among the most successful and previously high-priced online and e-commerce companies (e.g. American Online and Amazon.com) operating profits have always been tiny, even negative, due to low-priced introductory offer and large-scale marketing investment, combined with unrestricted competition in operating mostly non-proprietary production facilities.[19)] If protected by branding and copyrights, digitized content may develop into a competitive advantage. This, however, will mostly benefit content producers, not network operators unless distributed under exclusive contracts or within fully integrated companies. Nor can advances in network technology, operating support systems and service applications constitute any sustainable competitive advantage so long as these are built on open and non-proprietary technology platforms. Under such regimes, the speed by which these devices, systems and applications can be turned into a seamless system that works may be the only remaining source of competitive advantage. However, also here network operators are but one of several competing system management operators, the others being software makers and service providers.

Whether integration will have the intended effects or not, will most likely depend both on the innovation incentive of the network operator and certain key attributes of the resources used to produce the outsourced products and services. Increasing use of non-proprietary and open interfaces between network devices, operation support systems and service applications across different technology layers (facilitated by the TCP/IP protocol) have not only contributed to making all of these more separable, but also more tradable. Consequently, this has also increased the value of contracting (renting out shared devices, systems and applications or selling only the associated services) compared to full corporate integration. Furthermore, under oligopolistic network competition, service innovation will probably be more strongly promoted by facility-less operators, as above exemplified, than by facility-based operators. Then, the profitability of both virtual and non-virtual operators will depend on attributes of their core assets, especially the degree to which these assets are

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19) *On the other hand, the stock price of those companies may occasionally rise steeply and even fall steeper as it recently did due to grossly inflated demand expectation combined with enormous scale economies (high fixed, but zero marginal costs) associated with providing digitized content over future broadband networks to millions of consumers.*

uniquely valuable, inimitable or otherwise protected by patents or private contracts (co-ownership, quarantines, protective contract clauses). If inimitable, essential resources may still be made tradable under protective renting or leasing agreement, or by spinning essential resources off into a stand-alone unit capable of selling the associated services to a larger number of competing customers without too much leakage of private technology and knowledge.

Consequently, the conclusion to be drawn from the above examples and discussion should be as follows: In the telecom services industry competitively critical assets are becoming increasingly separable, tradable and less monopolized, and thereby ready for being outsourced and more widely dispersed among a larger number of specialized players, along with private knowledge needed to further develop these assets. Subsequently, this may cause virtual (facility-less) operators to develop stronger innovation incentives and competencies in service provision, and non-virtual (facility-based) operators to develop stronger capabilities in digitized network operations on the basis of increasingly more commoditized and less monopolized production assets.

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MORO – Move-On Real Options

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As part of the Move-On business case we identify and investigate several options that are implicitly contained in the business case. These options are so-called real options, and similar to financial options, they have their own intrinsic value. We will in this paper give a brief introduction to option theory and then use the theory to value the real options identified in the Move-On business case. The option theory is introduced through the financial option theory, whereas for the real options we give specific examples that relate to our special case.

Preface

Kenth Engø and Steinar Låg wrote this paper as participants in Telenor Corporate University's Master of Telecommunication Strategy Program 2000–2001.

The Master of Telecommunication Strategy Program is a cross-disciplinary education program initiated by Telenor and NTNU. The program is focused on a project case where the students by creating a "virtual company" shall write a business plan. In the 2000-2001 program, a business plan for an application provider and system integrator called Move-On was designed. The work presented in this paper was carried out as part of the analysis work for Move-On's business plan.

1 Introduction

The modern telecommunication company is evolving into a system which largest challenge is coping with the ever-increasing complexity of the telecommunication business. The reason for the increase in complexity is due to several factors; more advanced and complicated technology, more complex organisations, the multi-faceted game of co-operation and competition among actors in the market, intricate products and difficult market situations, and the complicated task of value creation [Audestad, 1998].

Hand in hand with complexity walks uncertainty. The complex system of the telecommunication business turns upside down on decision-making, because the methods used for forecasting and making projections into the future are made for a linear system. In a linear situation the response is proportional to the adjustment, and in this way no surprises will occur. The new situation that the telecommunication business is facing breeds the need for decision making under truly random (stochastic) market conditions.

The most important thing to realise in a complex world with thriving uncertainty is that randomness and stochasticity imply possibilities. Hence, uncertainty enfolds economic value – a point which it is important for managers to realize. Like financial options are used in the financial markets to tame fluctuating asset prices, real options can be used to value strategic options in a market operation. Real options is not that much about numbers as it is about strategic thinking, managing flexibility, and decision making [Amram & Kulatilaka, 1999].

Virtually any business project consists of a collection of real options. The problem is to identify the options, value them, and manage them correctly. For example, the following are real options that can be of some economic value [Trigeorgis, 1996]:

- The option to defer the start of a project;
- The option to abandon a project;
- The staged investment option;
- The option to scale up/down a project;
- The option to switch between technologies depending on prevailing market conditions;
- Growth options;
- And multiple interacting real options.

In this paper we will discuss and explore some viable real options identified for the Move-On business case. For the reader with no prior knowledge of options we include in Section 2 an introduction to financial and real options. This will by no means be an exhaustive introduction where only the key points of options valuation are introduced. Section 3 will go through the real options identified in the Move-On business case, and a valuation will be attempted. We conclude the paper in Section 4 with strategic recommendations.

2 Options in General

In this section we will introduce option valuation based on the Black-Scholes theory. For a comprehensive and detailed introduction, see e.g. [Wilmott et.al, 1995; Hull, 2000; Dixit & Pindyck, 1994].

2.1 Financial Options

The owner of a financial option has the right – but not the obligation – to buy or sell a financial asset at a fixed price – the strike price – on or before a predetermined date. The option is called *European* if the holder can only exercise the option on the date set forth in the option contract, and likewise, the option is called *American* if the holder can exercise the option at any time up till, and including the last running day of the option, agreed upon at the time of issuing the option contract.

The value of an option can be described by the Black-Scholes (BS) option pricing model. In the following we will restrict our attention to this model only.

In the BS model, the value of an option, denoted by $V(S,t)$, is a function of the current value of the underlying asset S, and time t. The value of the option is governed by the partial differential equation (PDE)

$$\frac{\partial V}{\partial t} + \frac{1}{2}\sigma^2 S^2 \frac{\partial^2 V}{\partial S^2} + rS\frac{\partial V}{\partial S} - rV = 0.$$

This is the so-called Black-Scholes equation. In the above equation σ denotes the volatility of the underlying asset and r is the risk-free interest rate (typically, it is the bank interest rate). The type of option will decide the boundary and final conditions for the PDE, and the strike price – denoted by X – enters the equation through these conditions.

A European call option is the right to buy the underlying asset S on some future date T for the amount X. The final condition is that the value of the option at the exercise time $t = T$ equals the payoff

$$V(S,T) = \max(S - X, 0).$$

This says that if the underlying asset price is less than the strike price at $t = T$ the payoff is zero, otherwise the payoff is the difference between the asset price and the strike price. The boundary conditions are applied for $S = 0$ and $S \to \infty$. In the case $S = 0$ the call option is worthless, even if there is a long time to expiry. Hence we have that

$$V(0,t) = 0.$$

As the asset price increases without bound it becomes ever more likely that the option will be exercised and the magnitude of the exercise price becomes less and less important. Thus as $S \to \infty$ the value of the option becomes that of the asset and we get

$$\lim_{S\to\infty} V(S,t) = S.$$

Having specified the boundary and final conditions it is known that the BS equation has a unique solution. Hence, this can be fed into a computer and a solution can be obtained.

In the case of European options the solution is known as a closed-form formulae both for the call and put options. The value of the European call option is

$$C(S,t) = SN(d_1) + Xe^{-r(T-t)}N(d_2),$$

where N is the cumulative normal distribution function

$$N(d) = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{d} e^{-\frac{1}{2}x^2}\,dx,$$

and d_1 and d_2 are given as the parameters

$$d_1 \frac{\log(S/X) + (r + \sigma^2/2)(T-t)}{\sigma\sqrt{T-t}}$$

$$d_2 = \frac{\log(S/X) + (r - \sigma^2/2)(T-t)}{\sigma\sqrt{T-t}}.$$

The European put option the value is

$$P(S,t) = Xe^{-r(T-t)}N(-d_2) - SN(-d_1).$$

In Figures 1 and 2 we have plotted the payoff curve and the value of a call and a put option for the Telenor stock (TEL) valued August 24, 2001, with exercise date January 17, 2002, where the underlying stock value is NOK 36.50, strike price equal to NOK 35, estimated volatility of 35 %, and risk-free interest rate of 7.3 %.

Checking the above results up against the market on the Oslo Stock Exchange, we find that the above call option – TEL2A35 – theoretically valued to NOK 3.57 is traded at NOK 4 on August 24, 2001, and the put option – TEL2M35 – theoretically valued at NOK 2.56 were offered at NOK 2.85 by the seller and bought for NOK 2 by the buyer on the same date. The differences observed between theory and observed trade is mainly due to the fact that it is American options that are traded on the Oslo Stock Exchange, and the market's different judgements of the current volatility of TEL.

Figure 1

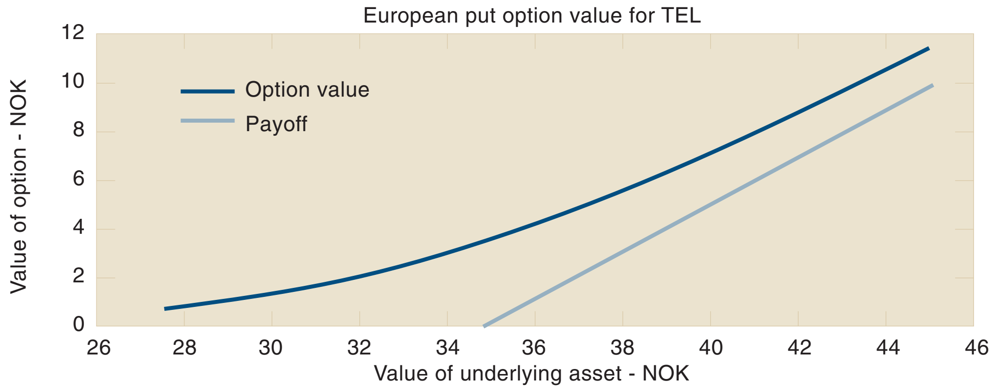
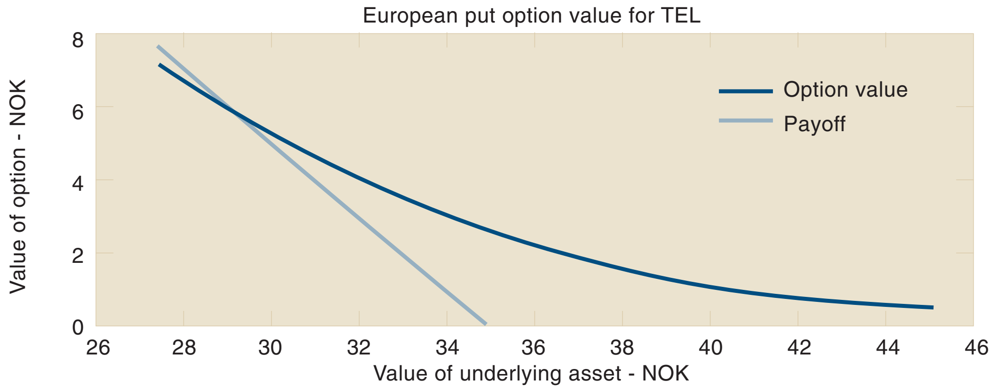


Figure 2



There are quite a few assumptions underlying the Black-Scholes option model. The model assumptions are probably the most important thing to know for users of option pricing models. The number crunching is easily fed into a computer program – and the user must be able to analyse the output in order to validate the obtained answers.

The following is the list of assumptions made in the BS option-pricing model:

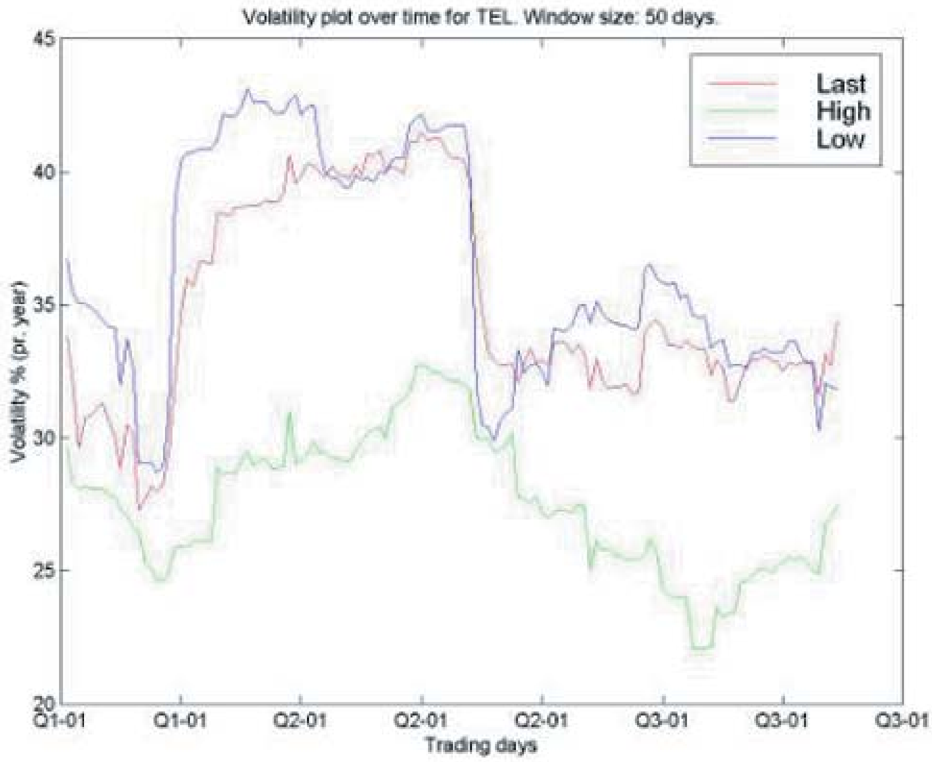
- The asset price follows a lognormal random walk.
- The risk-free interest rate r and the asset volatility σ are known functions of time over the life of the option.
- There are no transaction costs associated with hedging a portfolio.
- The underlying asset pays no dividends during the life of the option.
- There are no arbitrage possibilities.
- Trading of the underlying asset can take place continuously.
- Short selling is permitted and the assets are divisible.

How well are these assumptions fulfilled by the market? This is very important to analyse, because if the model assumptions are not observed in the market the BS model is not the correct model for the market!

The two first assumptions cause the most problem for the BS option-pricing model to correctly capture the behaviour of true financial markets. First, the assumption that the underlying asset follows a lognormal random walk is quite often a good approximation of the market performance of an asset, but it is easy to find assets that do not conform to this assumption. Second, there is no way of knowing the volatility and risk-free interest rate over the life of the option. The risk-free interest rate is not fluctuating much, and the impact of incremental changes in the interest rate does not affect the option value to a large extent. However, the volatility has a large impact on the valuation of options. Volatility also depends on the data samples. To illustrate how much volatility can change over time, and how much it can depend on the data, we have plotted the volatility of TEL calculated (data including August 24, 2001) with a 50-day data window, see Figure 3.

For the sake of comparison, we also plot corresponding graph for the OPC stock – a highly volatile stock on the Oslo Stock Exchange (Figure 4). Note that for TEL the volatility range is

Figure 3



(20 %, 45 %) annual volatility, whereas for OPC it is (40 %, 200 %).

Another point to notice about volatility is the implied volatility calculated from observing option prices in the market. If the BS model is correct and explains option prices observed in the market the implied volatility of the same underlying asset should be the same for different strike prices at the same maturity date. One should observe a horizontal line when volatility is plotted versus strike price. However, in the

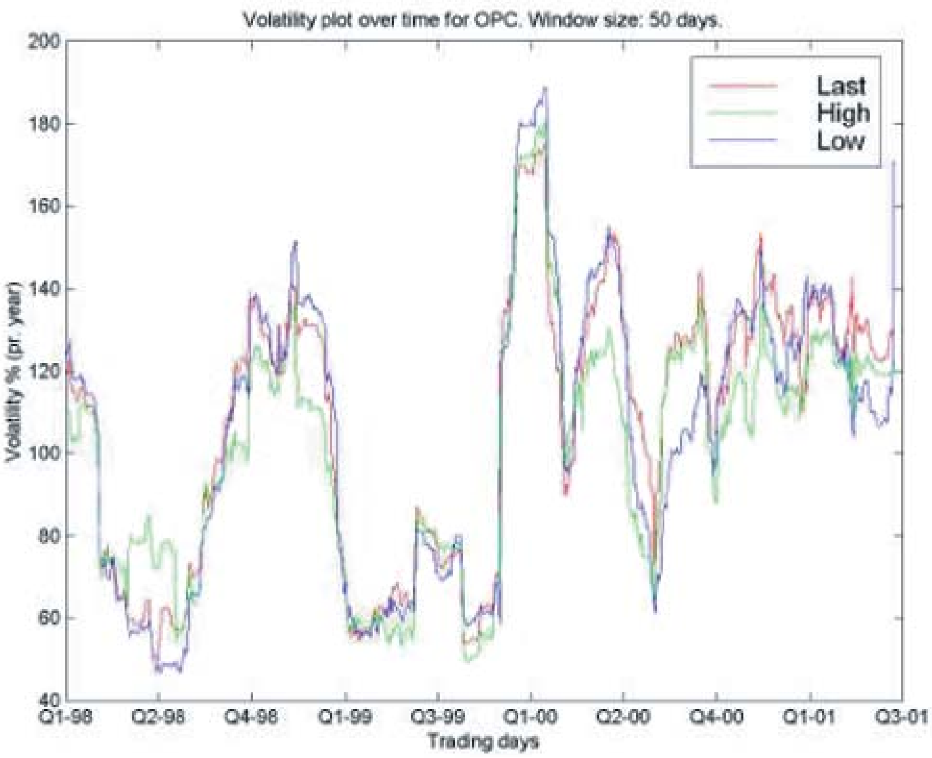


Figure 4

market one can observe a curve – the volatility smile – with increasing volatility for the larger and smaller strike prices.

Extensions of the BS model including stochastic interest rates and stochastic volatilities have been proposed, but we will not follow this any further here. We refer the interested reader to the referenced literature.

To summarize; the five central variables in the BS option pricing model are:

1 S – current value of the underlying asset;

2 X – strike or exercise price;

3 T – exercise date of the option, also called maturity;

4 r – risk-free interest rate;

5 σ – volatility of the underlying asset.

2.2 Real Options

A real option is an analogue of a financial option, but the most important difference is that the "underlying" is not a financial asset but for instance an investment project. The important exercise in the real option case is to "map" the project and its related variables onto a generic option. In this sense a real option is something more general than a financial option, but sources of uncertainty are also a lot more difficult to identify. In terms of financial valuation real options can be viewed as an supplement to the traditional discounted cash flows, where the real options approach also take advantage of the flexibility inherent in the project when valuing it.

In the following we will map a project investment onto a European call option, and use the Black-Scholes option-pricing model to value this option. One important question that the manager should ask himself is if the assumptions of the BS option pricing model are fulfilled? Does the underlying cash flow from the investment project follow a lognormal distribution? What can you say about the volatility of the investment project? The results from the calculations should undergo heavy scrutiny – with reference to the assumptions of the option-pricing model used (Figure 5).

In fact, the mapping of an investment project onto a call option is direct, once the DCF analysis is available. As seen in the above figure, the present value of a project's free cash flow corresponds to the current price of the underlying asset. Hence, referring to the assumptions of the BS valuation model, the variation of the present value of the project should follow a lognormal random walk. This assumption can hardly ever be tested. Next, an option's exercise price will correspond to the expenditures required to acquire the proposed project assets. The time of expiration for the option is the amount of time the decision to take up the project or not can be deferred. Time value of money corresponds to the risk-free interest rate. The hardest thing to estimate for a real option is the risk of the project assets, which will correspond to the underlying assets volatility. In the stock market historical data can indicate a reasonable choice of volatility, but for an investment project you will in general not have historical information available.

Strategies for choosing the project's risk can be to try out a range of possible values, or check the financial markets. One can estimate the historical volatility of companies that are traded in the financial market and have similar characteristics as to the proposed investment project. This will give an indication of how the financial market perceive and value the risk of companies operating in the same sector as the proposed project.

Figure 6 shows some examples of common real options.

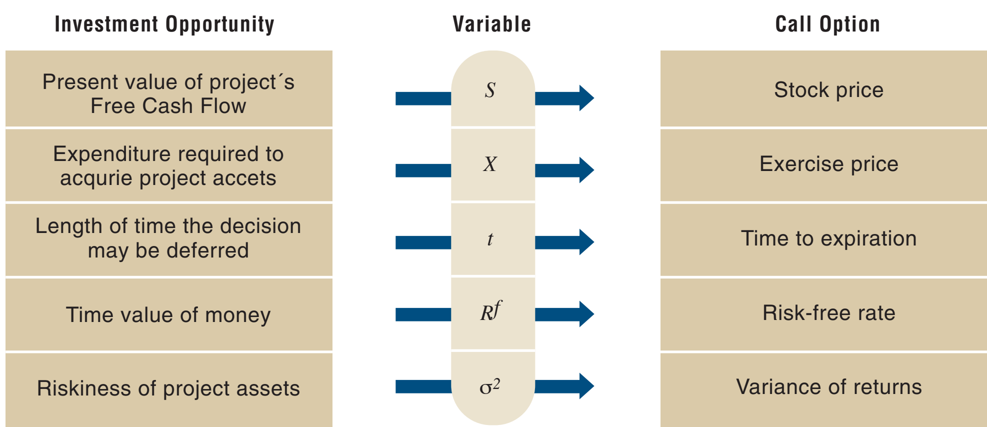


Figure 5 Real Options: The link between investments and Black-Scholes inputs

Some examples of the above real options can be the following. In the invest/grow category of real options, typical scale up options can be investments in high technology, and research and development intensive projects. The scope up option is relevant for the telecommunication business, since this option is relevant for businesses experiencing lock-in, and for de facto standard bearers. The defer option is relevant in the Move-On project, since it is desirable to wait and see how well the market accepts our products before further investment. The scale down option is also relevant here. If the product launch is not successful Move-On will want to scale down the investments or maybe even terminate the project. The last two real options illustrate that it can be difficult to identify the type of option that you are really interested in.

We will now go through an example of a real options calculation. Consider the cash flows in Tables 1–4.

Carefully looking at the present values one can see that something is happening in year 3. A large investment is planned for in year 3, and judging from the net present value (NPV), this is not that lucrative. Splitting up the above cash flow into cash flows relevant to the present operation and to the investment project in year 3 only, the situation is the following. The cash flows from the present operation are as shown in Table 2.

The cash flows relevant to the investment in the third year are as shown in Table 3.

To get the correct valuation, we discount the investment in year 3 with a risk-free interest rate of 5.5 % instead of the discount factor of 12 %. The reason for doing this is that there is no uncertainty about the investment (strike price); hence no risk is involved in this investment. This results in the updated net present value for the year 3 investments as seen in Table 4.

In order to value the option whether to invest or not, we map the above investment onto a call option. The choice is to buy the underlying project, and we can defer the decision about this till year 3. Returning to the five central variables in the BS option-pricing model, we have collected the following information:

1 Current value of the underlying asset. $S = 255.7$

2 Strike or exercise price. $X = 382$

3 Exercise date of the option, also called maturity. $T = 3$

4 Risk-free interest rate. $r = 5.5$ %

5 Volatility of the underlying asset. $s = 40$ %

We find the four first variables in the DCF spreadsheets, and as an estimate of volatility we choose 40 % per annum. This estimate can be based on historic data from similar traded assets, implied volatilities on options, or just simply a range of values.

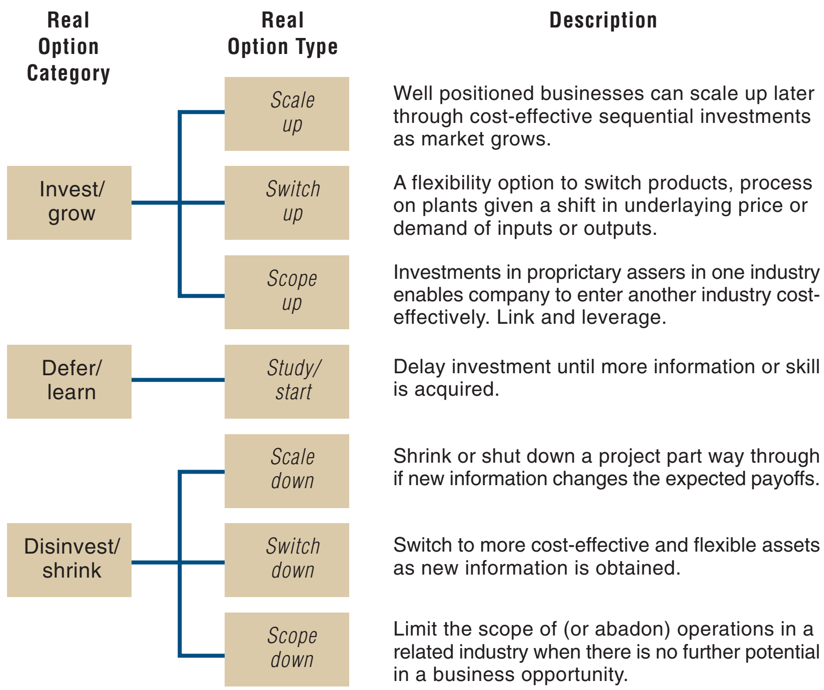


Figure 6 Common Real Options

(Source: "How much is Flexibility Worth?" Thomas E Copeland and Philip T Keenan, "The McKinsey Quarterly", 1998, No 2; "Real Options", Nalin Kulatilaka, Harvard Business School Press, 1999

Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**
Cash flows	0	9	10	11	34.7	37.5	40.7
+ terminal value	0	0	0	0	0	0	610.3
– investment	125	0	0	382	0	0	0
x discount factor 12 %	1.00	0.89	0.80	0.71	0.64	0.57	0.51
= PV (by year)	-125.0	8.0	8.0	-264.1	22.1	21.3	329.8
NPV (sum of years)	**0.1**						

Table 1

Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**
Cash flows	0	9	10	11	11.6	12.1	12.7
+ terminal value							191
– investment	125						
x discount factor 12 %	1.00	0.89	0.80	0.71	0.64	0.57	0.51
= PV (by year)	-125.0	8.0	8.0	7.8	7.4	6.9	103.2
NPV (sum of years)	**16.3**						

Table 2

Year	0	1	2	3	4	5	6
Cash flows				0	23.1	25.4	28
+ terminal value							419.3
– investment				382			
x discount factor 12 %	1.00	0.89	0.80	0.71	0.64	0.57	0.51
= PV (by year)	0.0	0.0	0.0	-271.9	14.7	14.4	226.6
NPV (sum of years)	**-16.2**				255.7		

Table 3

Year	0	1	2	3	4	5	6
Cash flows				0	23.1	25.4	28
+ terminal value							419.3
– investment				382			
x discount factor 12 %	1.00	0.89	0.80	0.71	0.64	0.57	0.51
Risk-free rate 5.5 %	1.00	0.95	0.90	0.85	0.81	0.77	0.73
= PV (by year)	0.0	0.0	0.0	-325.3	14.7	14.4	226.6
NPV (sum of years)	**-69.6**				255.7		

Table 4

Based on the above values an option calculator will value the call option to be worth 48.7, or about 19 % of the underlying asset value. Hence, the total value of the investment project is 16.3 + 48.7 = 65, which is a long way from the initial NPV of 0.1. The project is in fact a very attractive one.

In the next section we turn to the real options in the Move-On business case.

3 Applications to Move-On

3.1 Introduction

The Move-On project is based on the business idea to develop and deliver community functionality to mobile terminals. See [Move-On Business Plan, 2001] for further details. The NPV analysis in the business plan indicates a positive business opportunity.

As we see in Table 5, there are negative cash flows for the first four years, before experiencing positive cash flows from year 5 and onwards. An important question is whether the Move-On Project contains any real options, which would enhance the business case, or at least reveal possible opportunities that could arise from Move-On's initial business. The purpose of this section is to identify and explore three such intrinsic real options, and consider their value and possible implications to the Move-On Project.

In the following we have chosen to explore the subsequent three options; the *building IP zones option*, the *integrating IP zones option* and the *shutdown option*. In Section 3.3 we consider the option to build a network of IP-zones (using Wireless LAN equipment). For Move-On, this would mean expanding the product offering in a market where the initial business has already been established. Conventional NPV analysis does help in evaluating the attractiveness of making such an investment, but offers no help when it comes to considering whether there is greater value in postponing this investment decision. In Section 3.4 we consider another option related to deployment of IP-zones, i.e. the option to integrate IP-zones, which have already been built by others. This is a "lighter" version, in that capital investments and network rollout times are considerably shorter. Again, the questions are how much does it cost to buy and prepare for this option, how much uncertainty will be resolved while waiting and what is the value of

Year	0	1	2	3	4	5
CFO	-5909	-16937	-16198	-4642	31226	97947
Terminal value						216000
Invest	7066	1590	9826	21190	37337	45595
x discount (rf)	1	0.97	0.94	0.92	0.89	0.86
x discount (rd)	1	0.87	0.76	0.66	0.57	0.50
DFCF	**-12975**	**-16110**	**-19678**	**-16985**	**-3494**	**128994**
ADFCF	**-12975**	**-29085**	**-48762**	**-65747**	**-69241**	**59753**
NPV	**59753**					

Table 5 Free Cash flows for the Move-On Project (in kNOK)

postponing the decision. Whereas the two first options are expansion (or growth) options, Section 3.5 introduces the shutdown option, which is almost the opposite. The shutdown option represents the opportunity to stop the project, if technology, market developments or any internal or external condition turns out to significantly reduce the value of the project. Unlike the expansion options, the value of the shutdown options lies in reducing downside. However, the shutdown option does also require some preparatory actions and costs, which is further discussed in Section 3.5 below. Finally, in Section 3.6 we mention other real options relevant to the Move-On project.

Before exploring the identified real options, and attempting to evaluate them, we first need to derive and estimate various parameters, which is done in the next section.

3.2 Parameter Estimation

3.2.1 The Risk Free Interest Rate (rF)

From [Bøhren & Michaelsen 2001] we see that based on the Norwegian government bonds in the period 1992–2000, the average value is approximately 2 % after deflating with CPI growth (i.e. real r_F). The real r_F for the last two years (1998–2000) has been approximately 3 %. Judging the macro-economic conditions in Norway as of August 2001, there are no signs of any near-term immediate reductions from this level, so in the following we will use $r_F = 3$ %.

3.2.2 Discount Rate (r)

A well-established method to evaluate projects or companies is to find the net present value (NPV).

$$NPV = E(X_0) + \frac{E(X_1)}{(1+r)} + \frac{E(X_2)}{(1+r)^2} + \ldots + \frac{E(X_T)}{(1+r)^T} = \sum_{t=0}^{T} \frac{E(X_t)}{(1+r)^t}$$

It is based on summing up discounted versions of estimates for future cash flows. NPV is the most common tool to guide investment decisions, and the decision logic is very simple: *"If the NPV is greater than zero; invest, otherwise do not"*.

The discount rate (r) should be set according to the owners' growth requirements, which in turn depends on the risk the company or project is exposed to. There are various ways to deduce discount rates from financial data, see for example [Bøhren & Michaelsen, 2001]. However for the purposes of this topic, we shall just assume $r = 3$ % for the Move-On project itself, as well as the associated options. This number, which is not an unusual one for relatively risky Telecom/IT projects, will be used in the remainder of this paper.

3.2.3 Volatility (σ)

Volatility is perhaps the most important parameter to consider when dealing with options. However, it is not straightforward to estimate, and we need to estimate equity volatilities of all three phases (σ_{O1}, σ_{O2} and σ_{O3}). As shown in Section 2.1, we can estimate the volatility by using available historic trading data. We make the assumption that that volatility of the Move-On project and the three identified real options will be similar to the volatilities of some key Norwegian IT/telecom stocks. Calculating by applying a 10 (trading) days sliding window over 1 year of trading data until May 2001 we obtain:

$\sigma_{NER} = 64$ %, $\sigma_{TEL} = 25$ %, $\sigma_{ENI} = 86$ %, and $\sigma_{SOI} = 47$ %.

One may assume that a start-up company like Move-On will face more uncertainties and be exposed to more risk than the average telecom/IT stock. We also have to take into account that the Enitel stock has been subject to extreme variations over the last year. Based on this we end up estimating an equity volatility of 70 % for the Move-On project, which is slightly higher than Nera. Hence, as a rough estimate we use this value for all the three identified options: $\sigma_{O1} = \sigma_{O2} = \sigma_{O3} = 70$ %.

3.3 Building IP Zones

3.3.1 Description

In Move-On's final business plan, IP zones (Wireless LAN deployment) is considered from the perspectives of a possible additional communication network available to Move-On's terminals and applications, recognising the fact that several telecom players have started various IP zones network initiatives. However, early on in the project, the possibility that Move-On itself could *build and operate* a network consisting of interconnected IP zones was considered. This idea was rejected due to anticipated large investments and time delays associated with network rollout, and the need to focus on the business idea of community applications. In this section, we consider these two versions of deploying IP zones as possible options, i.e. opportunities Move-On may or may not take up some time after launch of its initial business (community services). In the remainder of this section we will call this option *Building IP-zones option* (or simply *BI*), as opposed to the *Integrating IP-zones option* (or *II*), which is dealt with in the next section.

Uncertainty

The uncertainty related to the potential success of deploying IP zones have several sources:

- Market risks (or systematic risks)
  - Will macro-economic market conditions develop favourably?

  - Will the demand for IT/Telecom continue to grow at the current pace?

  - What will be the outcome of other IP zones initiatives; e.g. Telenor Mobile Communications, Netcom and WAN? Will they together grow a new market? Will one actor end up taking the whole market?

  - What will become the positioning of IP zones business compared to GSM/GPRS and UMTS?

- Private risks (or non-systematic risks)
  - Will Move-On succeed with the initial product portfolio, and thereby being capable of (and willing to) expand with new products?

  - Will Move-On be capable of retaining the needed in-house competence and necessary relations to partners?

  - Will Move-On's owners appreciate and support the progress of the initial business and Move-On's suggested ideas for expansion?

Although not being an exhaustive list, the above-mentioned risk factors indicate that there is a significant level of uncertainty related to the IP zones option for Move-On. It is also likely that some of this uncertainty will be resolved with time. Hence, it does make sense, at least intuitively, to postpone the decision about the deployment of IP zones until some of the above questions can be answered. In the following analysis we want to find out whether it pays off to delay this decision.

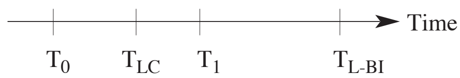
Associated activities and costs

In [Move-On Business Plan, 2001] a server system called MPCS (Multi Purpose Community Server) is proposed as the required network solution to support the initial community services. The expected costs associated with the MPCS are 4 MNOK, split equally between hardware and software.

The functionality required to support the integration of IP-zones is envisaged to be related to access control, authentication, and roaming. These are all functions that could be implemented centrally, and we assume that the required functionality could be implemented entirely by software on the MPCS platform, at an additional cost of 500 kNOK to cover the extra software development. We assume that there is no additional development time, because development time of integrated and complex HW/SW systems is typically dominated by fixed elements such as testing, configuration and installation. For the same reason if the IP-zones option is not identified at the initial investment decision, a new SW development contract must be placed with the manufacturer, resulting in significant cost and development impacts later.

The above applies to both IP zones options. For the BI-option, additional aspects include the cost and time involved in rolling out an IP zone infrastructure. Assuming a network of 100 IP-zones with an average establishment cost of about 200 kNOK, we end up with an additional network investment of 20 MNOK. Network rollout time is in this case considered to be approximately 12 months.

The costs involved with core network infrastructure required to interconnect the IP zones are ignored.



Timeline:

In the following we shall assume the following sequence of events:

T_0: time for initial investment decision (Move-On project incl. options)

T_{LC}: time for launch of community services (i.e. initial service offering);

T_1: time for decision whether to launch IP zones (integrating or building option);

$T_{L\text{-}BI}$: time for launch of the building IP-zones option (only relevant if exercised).

Then we will make the following assumptions about the spacing between the events:

$T_{LC} = T_0$ + 6 months: typical development time for a complex HW/SW system

$T_1 = T_{LC}$ + 6 months = T0 + 12 months: assuming 6 months of operations

The earliest possible $T_{L\text{-}BI}$ would be 12 months after T_1 to cater for IP zones network rollout time.

3.3.2 Calculations

We assume that if the option is exercised at maturity the total investment (of 20.5 MNOK) will have to be committed, in addition to annual costs of 5 MNOK to cover marketing, sales, R&D, and other operational activities, which are specific to the IP zones option. If the option is not exercised, these costs will not be committed. We assume a modest customer take-up, increasing with 5000 customers each year after launch. Further, we assume a terminal value of zero for the IP zones option for simplification purposes. Finally, we assume revenues corresponding to a fixed subscription fee of 80 NOK per month per user.

The parameters relevant to this option are:

- S = the present value of the cash-flows generated by the BI-investment;
- X = 20.5 MNOK. The required investment for the BI-option;
- T = postponement time. We consider $T = 0$ and $T = 1$;
- $r_F = 3\ \%$;
- $r = 15\ \%$;
- $\sigma = 70\%$.

First, we consider the NPV of building IP zones now, i.e. corresponding to a straight forward NPV analysis ignoring the option to postpone. We get NPV = 1550 kNOK, which according to the conventional NPV logic, would result in the decision to invest in building IP zones now.

Second, we develop the cash-flow analysis for delaying the building of IP zones with 1 year. Note that the investment is discounted with the risk free rate. We also note that NPV is -729 kNOK, indicating a negative business case.

Then we go on to find the value of the option to wait 1 year. When we apply an option calculator to $T = 1$ year, S = 19174 kNOK (sum of all BI-related cash flows), together with the other parameters stated above, we obtain the option value of *4993 kNOK*. This means that there is greater value in waiting one year, than building now.

Recalculating for $T = 2$, we get an NPV of -2650 kNOK, and the option value is this time 5577

Year	**0**	**1**	**2**	**3**	**4**	**5**
Inv	20500	0	0	0	0	0
OPEX	5000	5000	5000	5000	5000	5000
Revenues	0	4800	9600	14400	19200	24000
FCF	-25500	-200	4600	9400	14200	19000
x discount (rf)	1	0.97	0.94	0.92	0.89	0.86
x discount (rd)	1	0.87	0.76	0.66	0.57	0.50
DFCF	**-25500**	**-174**	**3478**	**6181**	**8119**	**9446**
ADFCF	**-25500**	**-25674**	**-22196**	**-16015**	**-7896**	**1550**
SUM of NPVs	**1550**					

Table 6

Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**
Inv	0	20500	0	0	0	0	0
OPEX	0	5000	5000	5000	5000	5000	5000
Revenues	0	0	4800	9600	14400	19200	24000
FCF	0	-25500	-200	4600	9400	14200	19000
x discount (rf)	1	0.97	0.94	0.92	0.89	0.86	0.84
x discount (rd)	1	0.87	0.76	0.66	0.57	0.50	0.43
DFCF	**0**	**-24251**	**-151**	**3025**	**5374**	**7060**	**8214**
ADFCF	**0**	**-24251**	**-24402**	**-21377**	**-16003**	**-8943**	**-729**
SUM of NPVs	**-729**						

Table 7

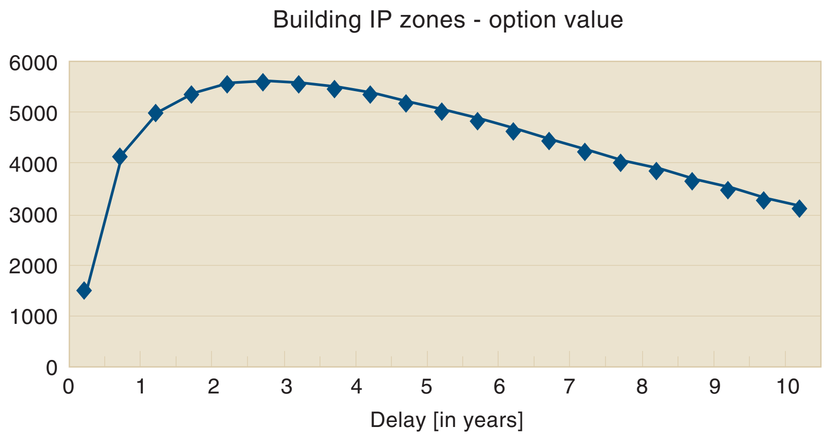


Figure 7

kNOK. In the graph in Figure 7 we plotted option value versus postponement time.

The reason for this curve shape is related to the input parameters to the Black-Scholes equation. Partly there is a benefit from delaying heavy investments, but the relatively high volatility also plays a beneficial role and is an important driver for the value of postponing.

The option value (for 1 year) of 4993 kNOK also indicates how much we should be prepared to commit in preparatory costs *prior* to possibly exercising the option. In this particular case, we assume no preparatory costs, i.e. the option comes for free. This is because we regard the necessary investments (i.e. MPCS software and IP zones network infrastructure) to form the exercise price, to be paid at the time of execution, rather than being preparatory costs to be paid in advance. However, in a realistic setting, there would potentially be time or cost advantages associated with carrying out some of these activities prior to the decision. For example, carrying the 500 kNOK MPCS SW upgrade forward to the Year 0 would be one such possibility. This could be justified easily, because the cost of making that preparation (500 kNOK) is well below the option value of waiting one year (4993 kNOK).

Conclusion
Whereas the conventional NPV approach gives the somewhat faulty advice to invest now, the advice from the real option approach is very clear: *Do not invest now, because there is greater value in waiting. Reconsider the situation later when some of the uncertainty has been resolved.*

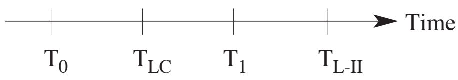
3.4 Integrating IP Zones

3.4.1 Description

The previous section discusses the option to build and operate an IP zones infrastructure. A "lighter" IP zones business alternative is to *integrate* IP-zones which already has been rolled out, for example by providing functions such as access control, roaming, etc. on a central server. Other IP zone networks could then "hook up" to Move-On's server, and thereby participate in an aggregated network of interconnected IP zones. This would require lower investments, but this business case has big challenges associated with it. For example, a consequence of not owning the complete network infrastructure is that Move-On will need to consider revenue sharing arrangements with the IP zone owners. In the following analysis we explore if it pays off to delay this decision.

Uncertainty
The uncertainty related to the business opportunity to integrate IP zones is similar to building IP zones, see Section 3.3.1.

Associated Activities and Costs
The additional software change to cater for authentication, authorisation, accounting and roaming functionality in the MPCS, with an estimated cost of 500 kNOK, is also required for this option. However, the heavy capital investment for network infrastructure required in the BI-option, is not applicable here. As for the BI option, costs associated with interconnecting the IP zones are ignored.



Timeline
In the following we shall assume the following sequence of events:

T_0: time for initial investment decision (Move-On project incl. options);

T_{LC}: time for launch of community services (i.e. initial service offering);

T_1: time for decision to launch IP zones or not (integrating or building option);

$T_{L\text{-}II}$: time for launch of the integrating IP-zones option (relevant only if exercised).

The following assumptions have been made about the timeline events:

$T_{LC} = T_0 + 6$ months: typical development time for a complex hard-/software system

$T_1 = T_{LC} + 6$ months $= T_0 + 12$ months: assuming 6 months of operations

Table 8

Year	0	1	2	3	4	5
Inv	500	0	0	0	0	0
OPEX	5000	5000	5000	5000	5000	5000
Revenues	0	2400	4800	7200	9600	12000
FCF	-5500	-2600	-200	2200	4600	7000
x discount (rf)	1	0.97	0.94	0.92	0.89	0.86
x discount (rd)	1	0.87	0.76	0.66	0.57	0.50
DFCF	**-5500**	**-2261**	**-151**	**1447**	**2630**	**3480**
ADFCF	**-5500**	**-7761**	**-7912**	**-6466**	**-3835**	**-355**
NPV	**-355**					

Table 9

Year	0	1	2	3	4	5	6
Inv	0	500	0	0	0	0	0
OPEX	0	5000	5000	5000	5000	5000	5000
Revenues	0	0	2400	4800	7200	9600	12000
FCF	0	-5500	-2600	-200	2200	4600	7000
x discount (rf)	1	0.97	0.94	0.92	0.89	0.86	0.84
x discount (rd)	1	0.87	0.76	0.66	0.57	0.50	0.43
DFCF	**0**	**-4833**	**-1966**	**-132**	**1258**	**2287**	**3026**
ADFCF	**0**	**-4833**	**-6799**	**-6931**	**-5673**	**-3386**	**-360**
NPV	**-360**						

$T_{L\text{-}II}$ will happen no earlier than T_1 (or shortly after), assuming the required functionality is implemented and can be switched on at the maturity of the option.

3.4.2 Calculation

We assume that at maturity the total investment (of 500 kNOK) will have to be committed, in addition to an annual cost of 5 MNOK to cover marketing, sales, Research&Development, and other operational activities, which are specific to the IP zones option. If the option is not exercised, these costs will not be committed. As for the BI option, we assume a modest customer acquisition, increasing with 5000 customers each year after launch. Finally, we assume zero terminal value and revenues corresponding to a fixed subscription fee of 40 NOK per month per user. The latter is 50 % of the fee used in the BI option, based on the rationale that Move-On will have to enter a revenue sharing scheme with the IP zone owners.

The parameters relevant to this option are:

- S = the present value of the cash-flows generated by the II-investment;
- X = 500 kNOK. The required investment for the II-option;
- T = postponement time. We consider $T = 0$ and $T = 1$;
- $r_F = 3$ %;
- $r = 15$ %;
- $\sigma = 70\%$.

First, we consider the NPV of integrating IP zones now, corresponding to a straight forward NPV analysis, ignoring the option to postpone. We get NPV = -355 kNOK, which according to the conventional NPV logic, would result in the decision not to invest in integrating IP zones now.

Second, we develop the cash-flows analysis of delaying the integration of IP zones with 1 year. In this case the NPV is -360 kNOK, still indicating a negative business case opportunity. Next we find the value of the option to wait 1 year. Crunching the numbers: T = 1 year, S = 126 kNOK (sum of all II-related cash flows), together with the other parameters stated above,

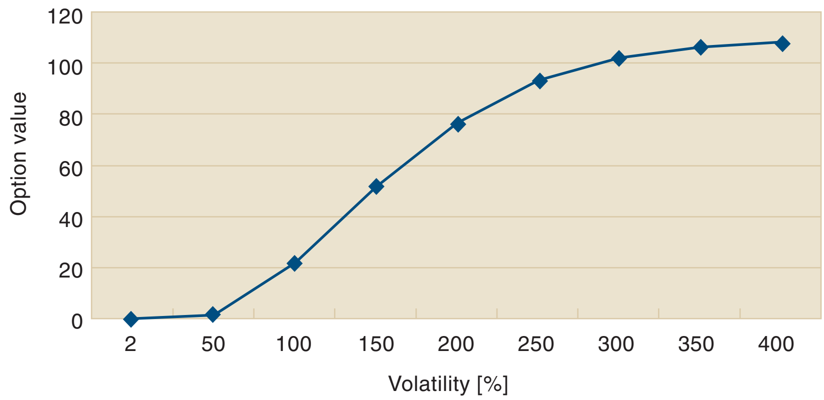


Figure 8

the option value turns out as *1.7 kNOK*. This means that there is a certain value, although very small, in waiting one year, compared to start integrating now. Repeating the exercise for T = 2, we get an NPV of -362 kNOK and an option value of 6.4 kNOK.

We may wonder why the values of BI-options and II-options are so different? The only difference is in S, the value of the investment project today, and X, the exercise price of acquiring the investment project. The BI option has a much higher value of X (20.5 vs. 0.5 MNOK) so the there is a more positive effect for BI by postponing this investment. The BI option also has a much larger S-value (19174 vs. 126 kNOK), so the underlying investment project also has a much higher value.

However, it is important to note that if the II-option had some other characteristics that were significantly different, then the option values would be affected accordingly. For instance, an increase in volatility or expected revenues would give a higher option value.

For illustration, the graph in Figure 8 shows how the II option value (here for T = 2) depends on volatility.

Conclusion

The conventional NPV approach gives the correct advice in this case, which is not to invest, and the real options approach strengthens this conclusion by indicating that there is not much value in postponing the decision.

3.5 Shutdown Option

Is there value in having the possibility to shut down an operation? Absolutely! The decision to shut down is in many circumstances a very drastic decision, and one should also consider the possibility of just scaling down or contracting the operation. The option to shut down or contract is valued as a European put option on the relevant part of the project, with exercise price equal to the potential cost savings. Hence, the real value of shutting down a running project lies in the money that potentially is saved on future investments. However, one also has to take into account the lost revenues and different deals that has to be negotiated with different parties like employees and customers. In fact this last point is very important, and very hard to value. How do you compensate customers that no longer get the telecommunication service that the company has promised them, and how to compensate the employees?

The value of the shutdown option does not put a total value on the project as a whole, but merely the option value reflect how much investments the management can undertake on securing the option to abandon the whole project. Hence, if the real cost of obtaining (buying) the option is exceeding the put option value, it is not economically viable to buy this option. Hence, it is possibly too expensive to shut down the project, and you are better of continuing the operation.

3.5.1 Description of Move-On Shut Down Option

We will in the following investigate the option of terminating the project in two years time. The course of the project is that there are heavy initial investments followed by two years of just minor investments. From the third year substantial investments will be performed each year, hence it is of interest for the Move-On project to estimate the value of acquiring the option to terminate the project after two years. In the two-year period much of the uncertainty will disclose, and future market conditions for our products should be judged as either good or bad. In the case of good market conditions Move-On should continue the project with its investments and update the cash flow prognoses. In the other case, one should be able to shut down the Move-On operation limiting the losses. An attempt to value the shut down option will indicate how much we are willing to spend on securing the deals with employees and customers to be able to stop the business in two years time. In the next section we calculate the value of this put option.

3.5.2 Calculation

We have to separate between the following: First, the option in itself has value, and we have to be prepared to pay for negotiating the deals with the employees and customers in order for them to accept that the service is possibly shut down in two years. Second, at maturity we will have to pay the exercise price, which is the agreed compensation to involved parties. In other words we should be willing to pay for being able to possibly pay compensation! This might seem awkward, but limiting the downside in a risky investment does have its price. This

Year	0	1	2	3	4	5
CFO	-5909	-16937	-16198	-4642	31226	97947
Invest	7066	1590	9826	21190	37337	54495
x discount (rf)	1	0.97	0.94	0.92	0.89	0.86
x discount (rd)	1	0.87	0.76	0.66	0.57	0.50
DFCF	**-12975**	**-16110**	**-19678**	**-16985**	**-3494**	**21603**
ADFCF	**-12975**	**-29085**	**-48762**	**-65747**	**-69241**	**-47638**
NPV	**-47638**					

Table 10

way we are only "buying" the upside potential in the investment project.

Estimating the amount of compensation – the strike price – is practically impossible. Here we have to make an educated guess based on the number of employees and the number of customers. In the following (Table 10) we choose 10 MNOK as the options strike price.

To find the value of the option today, recall the proposed free cash flows for the Move-On project (see the above table). The accumulated cost savings relating to the shut down will be the difference in the accumulated discounted cash flows between year 5 and year 3. Subtracting this we end up with the current value of our project assets as 1124 kNOK.

The Black-Scholes parameters with relevant values to the present option are:

- S = 1124 kNOK
- X = 10000 kNOK
- T = 2
- r_F = 3 % (see 3.2)
- r = 15 % (see 3.2)
- σ = 70 % (see 3.2)

Feeding the numbers into an option calculator we end up with a value of the option of 8310 kNOK. Hence, we are in principle willing to buy the flexibility of possibly shutting down the Move-On operation in 2 years for 8.3 million NOK.

In the above calculation we have not included an estimate of the terminal value. This will of course have an impact on the valuation of the shutdown option. The larger the terminal value, the less the option value, this is because the more value that is coming in the future the less interested we are in shutting down the business.

Conclusion

We see that the conventional NPV approach does not really know how to value the option of shutting down an operation. There is very much value hidden in this real option, and hence our strategic recommendation is to acquire this option. This is because it will add substantial value to the Move-On operation by limiting the downside risk of the investments.

3.6 Other Move-On Real Options

In the Sections 3.3 and 3.4 above, we have considered two versions of IP zones deployment, which both are typical growth or expansion options. Unlike the IP zones options, which consider expanding with new products, one could also consider the opportunity to expand the business into new geographical markets. In the case of the Move-On project, the other Scandinavian countries and Germany have been considered as possible future target markets, where Move-On could reuse and benefit from the products and experience developed in Norway. Instead of making the decision to enter the German or the Swedish market initially, which would increase the overall risk associated with the Move-On Project, such an option would allow Move-On to maintain the possibility to enter one of these markets at a later stage, at the cost of carrying out the necessary preparations.

One could possibly treat Move-On as a staged investment project within the same geographical market. An initial launch of the IP zones will be restricted to e.g. a few cities in Norway. Further expansion in Norway, to other cities and towns, can then be staged by selecting for instance 5 new areas to be populated with IP zones in the next stage. Depending on the popularity of the previous investments, demographic profiles, etc., further investments can be halted in the case of unfavourable market conditions.

The size of the community server system is crucial in the IP zone business case. Investing in a larger server than actually needed is an inefficient investment. However, the opposite case of not having a large enough server to supply for an unexpected and surprisingly huge customer base is probably worse, because expanding an existing system typically is more expensive than allocating for the same capacity initially. Thus, incorporating a scalable server solution from the start can turn out to be a very valuable real option.

Having identified several different real options, a few words have to be said about the collective value of all the real options acting together in the same business case. Multiple interacting real options follow a non-additivity law. This means that the value of the individual real options can not just be added together to get the collective value of all the options that are active at the same time. The options interact in a non-linear way.

4 Conclusions

In the Move-On business case we have identified three real options; two growth options and the option to terminate the whole project. The growth options are related to potentially expanding the product portfolio with IP-zones, and the option to abandon is the strategic choice of shutting down after a period of operations.

The first two growth options are the IP-zone "wild cards". IP-zones is emerging as a possible competitor to the UMTS networks, and the importance of recognising this as an important strategic option is attempted in valuing the option to expand the product portfolio with IP-zones after some time of initial operation in the relevant market. In Move-On's case this is Norway initially, but the arguments also apply to any other market. Two variants of this option are considered, the first being the option for Move-On to build and operate an IP zones network itself, the second is to act as an integrator for other players building IP zones. To prepare for these options, it may be necessary to commit some additional investment costs to the multi-purpose community server platform (MPCS) initially. Once the uncertainty about Move-On's initial products and ongoing IP zones initiatives (carried out by other players) have been revealed – which could be evaluated some time after the initial service launch – the decision whether to deploy IP-zones can be made. The value of these options then reflects how much Move-On should be willing to spend on preparing for IP zones deployment.

Analysis of the *building IP-zones option*, revealed a greater value in postponing the decision with one year (option value 4993 kNOK) than building IP-zones immediately (NPV: 1550 kNOK). Whereas the conventional net present value (NPV) approach gave the somewhat flawed advice to invest straight away, the advice resulting from using the real option approach was very clear: *"Do not invest now, because there is greater value in waiting. Reconsider the situation in one year"*.

For the *integrating IP zones option* we found that the value of postponing the decision was marginal. The conventional net present value for integrating IP zones was found to be -355 kNOK, and the option value associated with delaying the investment decision was negligible; 1.7 kNOK for one year and 6.4 kNOK for two years. So, in this case we conclude that the conventional net present value approach gives a sensible advice; *"Do not invest"*. The real options approach actually strengthens this argument by indicating that there is not much additional value in postponing the decision.

We have also investigated the *shutdown option*, i.e. the option to terminate the whole project after two years. During that period of time Move-On will have launched its first line of products and we will have a much better understanding of how the market judges the product ideas. Depending on how successful the product launch is, the project can be terminated at the end of the two-year period. The value of this option reflects the amount that Move-On should be willing to invest in obtaining the possibility of terminating business in two years time.

To conclude, the strategic recommendations from the real options analysis are:

- Even though building IP-zones appears as an attractive investment opportunity, do not make the investment decision now. There is greater value in waiting for some time, for example one year, and then reconsider the situation.

- With the assumptions made, integrating IP-zones does not appear like an attractive business opportunity. Neither is there any significant option value by postponing the decision, so there needs to be fundamental changes to the assumptions made (e.g. improved cash flow estimates) before it is worth reconsidering this option.

- There is very much value hidden in the option of shutting down the operation after two years, and hence our strategic recommendation is to acquire the option. This is because it will add substantial value to the Move-On operation by limiting the downside risk of the investments.

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The Open Service Access and Opportunities for MVNOs

DO VAN THANH AND GUNVALD MARTIN GRØDEM

Aiming at opening up the value chain and allowing third parties development and deployment of value-added services, the 3rd Generation Partnership Project (3GPP) promotes the Open Service Access (OSA). This article will give a comprehensive introduction to OSA and discuss how OSA can benefit third parties, especially Mobile Virtual Network Operators (MVNOs). The focus is especially on the flexibility and the ability to adapt to customers needs like e.g. personification of services. Another important issue is the integration of services and customer databases.

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1 Introduction

Nowadays, telecom services run in the telecom operator's domains. The networks belong to the operators and are totally closed for other parties. The service providers wishing to offer service to customers through the networks must have their services running in the network operator's domain. In that case, the service providers have little or no control of the applications and it is difficult to integrate the service with their databases and services. The development of services intended for theses networks is quite complex since it must be carried out in close collaboration with the operator and their suppliers.

With the advent of the Internet, which offers a large and diverse range of applications, the demand of more services in telecommunication is increasing. Further, the introduction of 3rd generation mobile systems like e.g. UMTS creates needs for new services. To be able to differentiate with competitors, a telecom operator needs to be able to offer more value-added services. The development of such services costs quite a lot in terms of resources but also in time. In order to cope with the situation the operators are forced to open their networks and let 3rd parties participate in the development, deployment and offering of services (see Figure 1-1). The service providers benefit from the opening of telecom networks in that they can develop their own applications running at their own application servers. They can run the same applications that earlier had to run in the telecom operator's domain, but now it is much easier for the service providers to integrate the services with each other and to use their own databases and infrastructure. Such an opening brings also opportunity to Mobile Virtual Network Operators (MVNOs) with expertises in specific sector to enter into the mobile business.

This article starts with a brief explanation of the development and deployment of value-added services. A summary of the 3GPP architecture is given next. The article will then clarify how the Open Service Access can be beneficial for MVNOs.

2 Development and Deployment of Value-added Services

In current mobile systems such as GSM there are a number of network capabilities that are useful for value-added services/applications, such as:

- Setting up a connection between to devices;
- Monitoring the status of a terminal (switched off, switched on, busy etc.);
- Locating a user's terminal;
- Sending messages to a user's terminal.

An example of a value-added service that uses some of the capabilities mentioned above is a Taxi dispatch. A customer calls, via his mobile phone, a phone number associated with the Taxi dispatch to order a taxi. The Taxi Dispatch application queries the location of the customer from the mobile system and then also requests

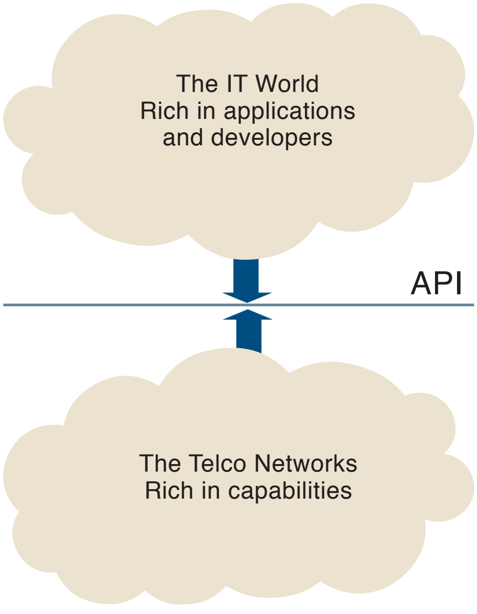


Figure 1-1 Opening of telco networks

the location of all taxis in order to choose the closest one. The locations of all taxies inside a certain boundary could e.g. be shown on a map of the area where the customer is located. Next, the Taxi dispatch calls the taxi in question and informs the taxi driver about the order. Alternatively, the Taxi dispatch could also send a message informing the taxi about the order.

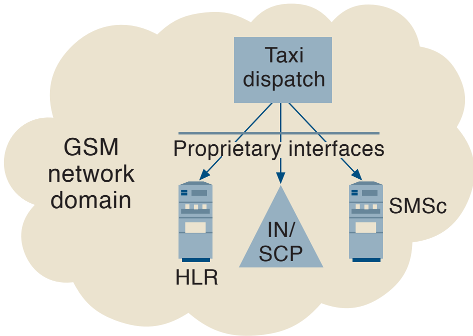


Figure 2-1 Application running inside a GSM network operator's domain

Another example of value-added service is a personal forwarding service. A user can define which devices the calls should be forwarded to for example in case of no answer from the mobile phone. For example, the user could specify that calls should be forwarded to the fixed phone at work between 0900 and 1700 and to the fixed phone at home otherwise. If there is no answer at any phone, the call should be forwarded to the voice-mail. When someone calls to the user's mobile phone, the service checks first with the mobile system for the status of the mobile terminal. If the mobile phone is switched off the call is routed according to the rules described above. If the mobile phone is switched on, the call is first routed to the mobile phone. If there is no answer then the call is routed according to the rules described above.

As shown in the examples, the network capabilities like call control, terminal status and user location are very valuable for value-added service but are unfortunately not available outside the GSM network domain (see Figure 2-1).

To build an application, which makes use of the mentioned capabilities is quite difficult. The different network elements that provides different capabilities, e.g. the IN system providing capabilities for connecting devices, the HLR providing location information and terminal status, the location server providing location information, the SMSc providing capabilities to send messages to users, etc. have different interfaces and protocols. The developers of the value-added services need to have considerable knowledge about different network elements, interfaces and protocols. Hence, many developers may be needed since each developer may be expert on only one single network element, protocol or interface. An application developed for one vendor's equipment is not necessarily portable to another vendor's equipment.

If a taxi company wants to provide a taxi dispatch application to the customers, it needs to collaborate with the network operator in order to develop the service. The taxi company needs to specify the requirements of the application to the network operator, who then has to examine whether it is possible to develop. Only after that the network operator and the service provider have agreed, the expert developers working at the network operator can develop, deploy and run the service. As we can see the developing process is complex and time and resource consuming.

As stated earlier, the telecom operators need to develop and deploy many new value-added services in order to cope future needs and the Internet's ability to supply services. In order to

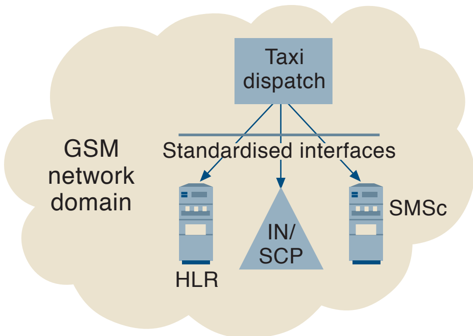


Figure 2-2 Application using standardised interfaces inside a network operator's domain

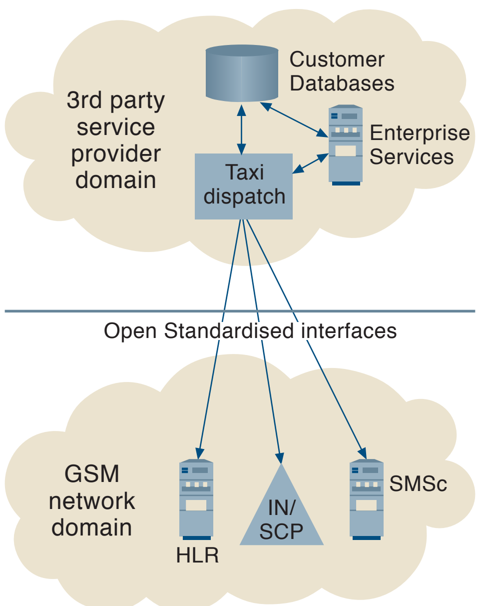
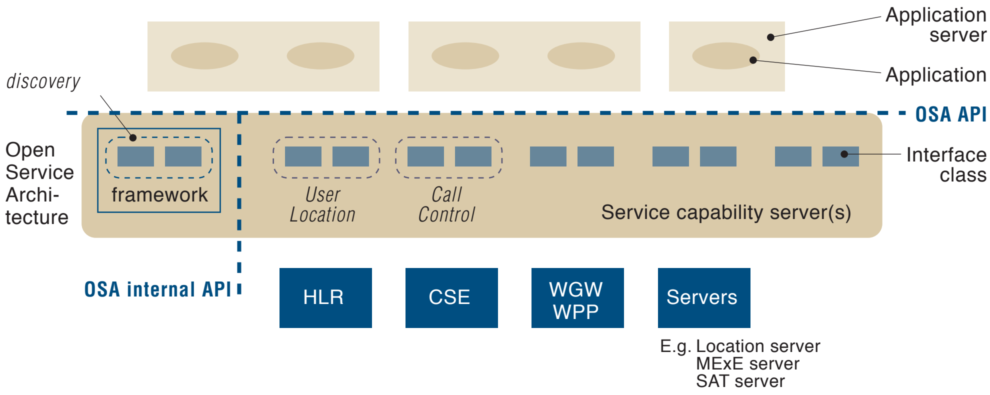


Figure 2-3 3rd party application using network capabilities through standardised interfaces

Figure 3-1 Overview of Open Service Architecture [1]



accomplish this there is a need to improve the development process for value-added services. One approach is to standardise the interfaces to different network capabilities. By standardising the interfaces the developers do not need to have knowledge of the proprietary interfaces specific from each equipment vendors. The development and deployment of new services are going to be much easier, and consume less time and resources.

But standardising the interfaces to network capabilities does not only benefit the developers working for a network operator. It will be easier to let 3rd parties get access to network capabilities through open standardised interfaces. By using open standardised interfaces the applications may be developed, deployed and run by 3rd party service providers. The network operator should supply mechanisms that ensure that only authorised 3rd parties get access to these interfaces. This solution makes it much easier for the 3rd party service providers to integrate the value-added service with other enterprise solutions and customer databases, since the application is now running in the value-added service provider's (VASP's) domain (see Figure 2-3).

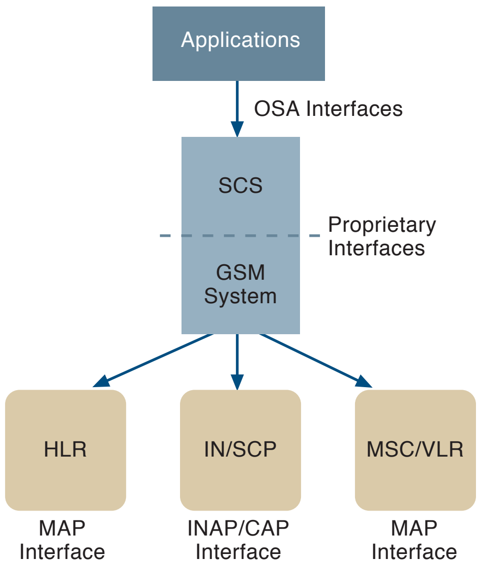


Figure 3-2 SCS as gateway between OSA interfaces and proprietary interfaces

3 3GPP's Open Service Architecture

The 3GPP (Third Generation Partnership Project), which purpose is to prepare, approve and maintain globally applicable technical specification and technical report for a 3rd generation Mobile System (UMTS), based on an evolution of GSM/GPRS, has specified the Open Service Architecture (OSA) [1], which enables network operators and 3rd party service providers access to network capabilities such as Call Control, Messaging, Location Information, etc. in a simple and secure way. OSA is 3GPP's suggestion to solution to the problems in the development and deployment of value-added services mentioned earlier. The 3GPP has also proposed OSA as one approach to allow 3rd party service provision for UMTS.

Architecture

In OSA, 3GPP has standardised a set of open interfaces to the network capabilities in the wireless (GSM/UMTS) network [2]. The interfaces are specified in OMG IDL [3], which is a defacto standard interface definition language. The interfaces are grouped into *Service Capability Features* (SCF). The SCFs are abstractions of the underlying network functionality. For example, the Call Control SCF includes all the interfaces that deal with controlling calls i.e. call forwarding and call events. The SCFs run on a *Service Capability Server*(s) (SCS(s)), which serve as a gateway between the OSA interfaces and the proprietary interfaces specific to each network capability, e.g. MAP, INAP, ISUP, CAP, etc. Hence, the standardised interfaces are mapped into the specific proprietary interfaces to the corresponding network capabilities (see Figure 3-2). For example, the interfaces in the Call Control SCF have to be mapped into the interfaces to the CAMEL (Customised Application for mobile network enhanced logic) system used in the current GSM/UMTS network. The protocols and interfaces may vary from different implementation i.e. Ericsson and Alcatel.

Applications

Typically applications that can use OSA are personal forwarding services, personal communication services, Taxi dispatch, pizza ordering, location based applications (find the nearest cinema, gas station, hotel, map navigation, etc.), Bank service, etc. The Service providers are free to use the SCF in the way that they want as long as they follow the agreement with the OSA provider. The Telco world, when opening their networks with OSA, will benefit with many new and fancy "killer applications".

Applications that wish to use SCFs through OSA can either run on application servers located inside the network operators domain or on application servers running in a 3rd VASP's Domain (see Figure 3-3). Hence, the OSA may benefit the network operator as well as the 3rd party VASP in the way that the developers only need to know the OSA interfaces, no matter whether they develop applications for the network operator (OSA provider) or for the 3rd party VASP. This will hopefully lead to faster and simpler development both for network operators (OSA providers) and 3rd party VASPs.

Service Capability Features (SCFs)

The network service capabilities are available to applications through the SCFs. Currently, the following SCFs are specified in OSA Release 1999 [1]:

- *Call Control:* Allows applications to control network-initiated calls e.g. call barring, call forwarding, pre-paid calls, etc.;

- *User Location:* Enables applications to get hold of users' current geographical position, delivered by the network;

- *User Status:* Provides applications with mechanisms to obtain the current status of a user's terminal;

- *User Interaction:* Allows applications to interact with end users by sending messages/announcements to users and to collect information from them. The applications may also control a message sent by a user;

- *Data Session:* Enables applications to control data sessions initiated by a terminal, e.g. pre-paid data sessions;

- *Terminal Capabilities:* Provides the applications with mechanisms to obtain the current capabilities of a user's terminal.

3GPP are currently working on SCFs for eCommerce, Instant Messaging, Multimedia control etc., which will be included in future releases of the OSA specification when they are ready.

Framework

In order to ensure secure and simple access to the OSA SCFs, 3GPP has specified an OSA Framework. The Framework is responsible for protection against misuse of the network resources in the telco networks and to ensure integrity of the system.

Before a third party can use any mechanisms provided by the OSA framework, the OSA

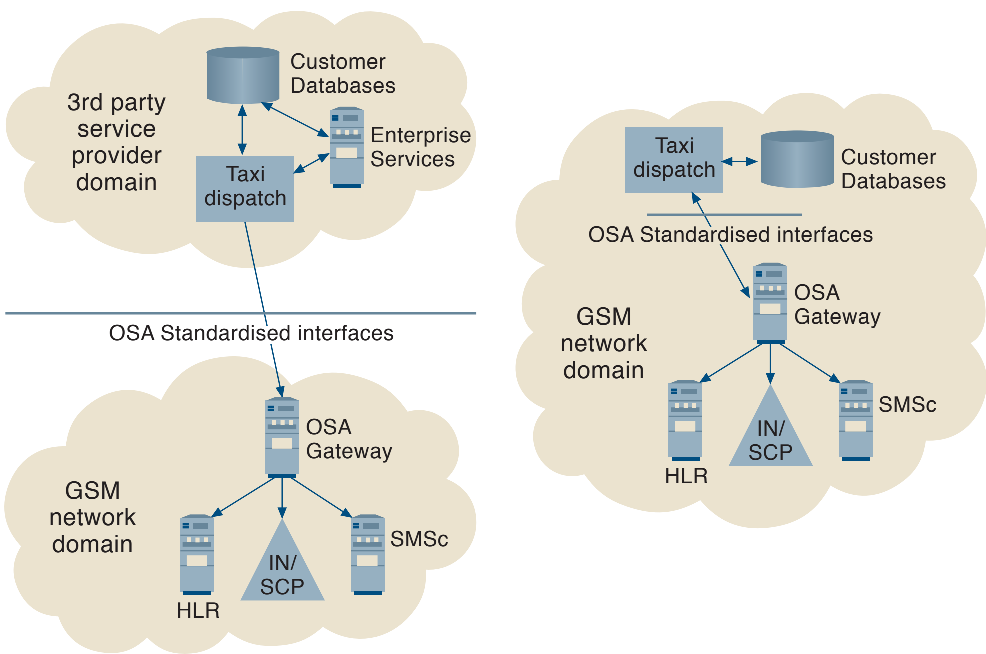


Figure 3-3 OSA applications residing inside or outside the telco domain

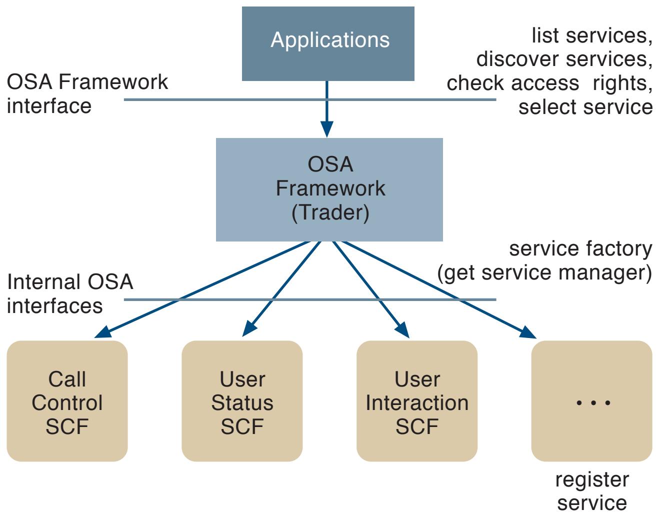


Figure 3-4 The OSA Framework

provider and the third party needs to establish a Service Level Agreement (SLA) between them. The SLA is an off-line business-level transaction, were the two parities agrees on terms of use of OSA Services.

Applications that wish to use network capabilities through OSA need to get authenticated with the framework and visa versa. The OSA framework is able to differentiate between applications, e.g. the applications running inside the network operator's domain could be marked "trusted", which do not need to authenticate itself and applications running outside the network operator's domain as "distrusted", which always have to authenticate itself. The security policy and mechanisms of the OSA framework are quite flexible and it is up to the OSA provider to decide which security mechanisms to provide (e.g. CORBA Security, SSL etc.) and which policies are going to be used.

The OSA framework has much in common with the ODP Trading Functions described in [4]. Hence, the OSA framework works like a "Trader" for the telco network domain. It provides applications with mechanisms to list and discover which services the OSA framework currently supports. Hence, the different SCF types supported in the network domain, register themselves with the OSA framework using an internal interface to the OSA framework. The applications also have the possibility to check the access right to each service at run- time (access to services are agreed in the SLA). Through the Framework's interface an application can select the service that it wish to use, e.g. Call Control or User status, the framework then uses the Service Factory to make an instance of the selected service and returns a reference to the service to the application (see Figure 3-4). The application can then use the reference to access the SCF.

Communication between Applications and OSA

In order to be able to use the framework and network SCF offered by OSA, the applications need to be able to communicate with OSA. This could be a difficult task due to different computers, operating systems, implementation language, both at the Application server and the OSA servers. The applications have to set up a connection to OSA framework and to send messages to OSA, in a format that is understandable for OSA. This could be a complex task and will make it very difficult for applications to use OSA.

CORBA [3] is an object-oriented technique for client-server communications. It enables a client object to invoke methods on Remote object (Server object)'s interface, specified in OMG IDL. Hence, CORBA is a Remote Method Invocation (RMI) middleware. A "remote object" means that the object is running in a different process than the client object, either on the same computer or in any computer connected in a computer network. CORBA hides the complexity of the communication between the client and the server objects, hence the client does not need to worry about how the communication to the server takes place e.g. it does not need to set up connections and to send messages to the server. In addition both the server and the client object may be implemented in any object-oriented programming language like Java, C++, SmallTalk etc. and they can run at any Operating System. CORBA hides all the differences between the client and the server. By using a CORBA IDL compiler on the interfaces specified in OMG IDL, is it possible to generate all the CORBA specific code and the corresponding APIs, which enables the communication between the client and the server. There is a specific compiler for each programming language, e.g. if the client/server are going to be implemented in Java, an IDL-to-Java compiler needs to be used. In order to communicate with the server, the client only needs to include the generated CORBA code (client stubs) in the client code and use an Object Request Broker (ORB). The developers can then program (call methods) against the server's API, generated by the IDL compiler, as if the server object is a local object (running in the same process as the client). The server object also needs to use an ORB and some generated CORBA code (server skeletons) in order to be able to deliver the messages from the client to the right server object.

By using CORBA as described above, the applications can communicate and access the OSA interfaces in a simple way. The OSA interfaces specified in IDL can easy be compiled to OSA APIs, in the programming language that the developers want to use in the OSA application (see Figure 3-5).

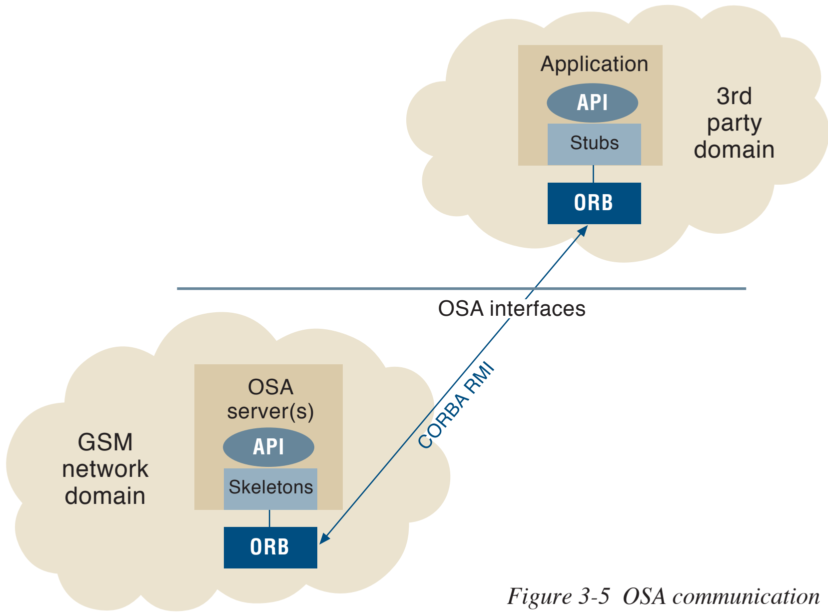


Figure 3-5 OSA communication

OSA Application Scenario

In this section we will describe a scenario where an application uses OSA Call Control (CC) SCF to control the processing of a call. Note, that the scenario will be quite similar when other SCFs than CC are used by the application. The purpose of this section is to give an example of how an application proceeds, in order to use an OSA SCF.

At first, a Service level Agreement has to be established between the VASP and the OSA Provider. In the agreement process the two parties agree on term of use of the CC SCF. The application then needs to get a reference to the "initial point of access" to OSA, using a Naming Service, Trading Service, etc. The application is now able to start interacting with the OSA framework (see Figure 3-6).

At first the application calls 'initialeAuthentication' (1), in order to start the authentication process. The application then calls 'selectAuthMethod' (2) specifying which authentication method that should be used in the authentication process. The framework always needs to authenticate itself to the application. In order to authenticate the framework, the application calls 'authenticate' (3) on the framework's 'Authentication interface'. The application only needs to authenticate itself to the framework if the application is of "distrusted" type to the framework. In order to authenticate the application, the framework calls 'authenticate' (4) on the application's 'Authentication interface'.

The application is now in an authenticated session with the OSA framework and it may access the SCFs that the framework supports. Note, that the authentication process (1-4) only needs to take place at initial contact with the framework or after an application have called 'endAccess', which ends the authenticated session. In order to be able to access the SCFs, the application needs a reference to the 'OSA Access interface', which it obtains when it calls 'accessInterface(OSA_Access)'(5).

The application is now able to discover and select the CC SCF, and calls first 'obtainInterface(Discovery)'(6), which returns a reference to the 'Discovery interface'. The application then calls 'listServiceTypes'(7), in order to get a list of the SCFs supported by the framework. Next, the application gets a full description of the CC SCF, including all the properties it supports when calling 'describeServiceType' (8). The properties typically deal with non-functional and non-computational aspects of the SCFs The application specifies the desired properties for the CC and calls 'discoverService' (9). In response, the application gets a unique 'Service ID' for the CC SCF and a list of the associated property values. The result from (9) is used as parameters for the application's call for 'selectService' (10). The application's call for 'selectService' makes the framework to ask the application to digitally sign the service agreement text, 'signServiceAgreement' (11), which in turn makes the application to ask the framework to digitally sign the service agreement text, 'signServiceAgreement' (12). If the framework agrees to sign the agreement text, the framework contacts the CC Service Factory and asks it to make a new Call Manager (CM) object, 'getServiceManager' (12-2). The Service Factory makes a new CM object (12-3), and the reference to the object are then returned to the application via the framework. The application has now obtained a reference to a Call Manager Object and is able to perform call related issues. The application has access to the object until the

Figure 3-6 OSA application scenario

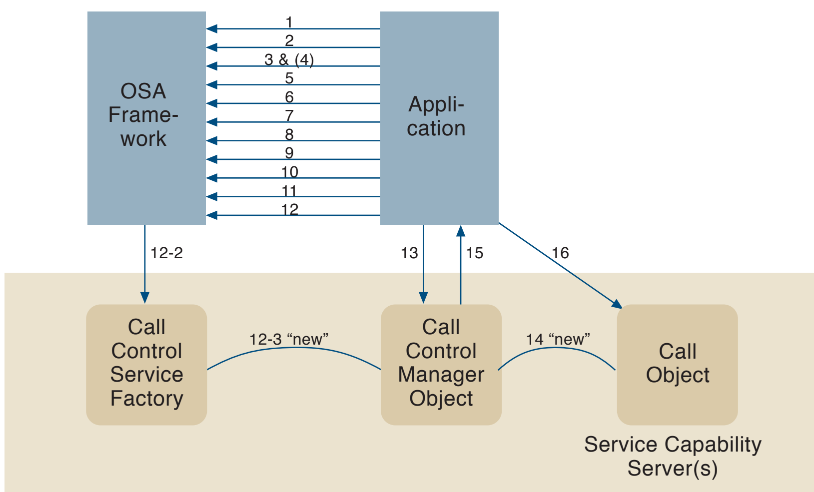
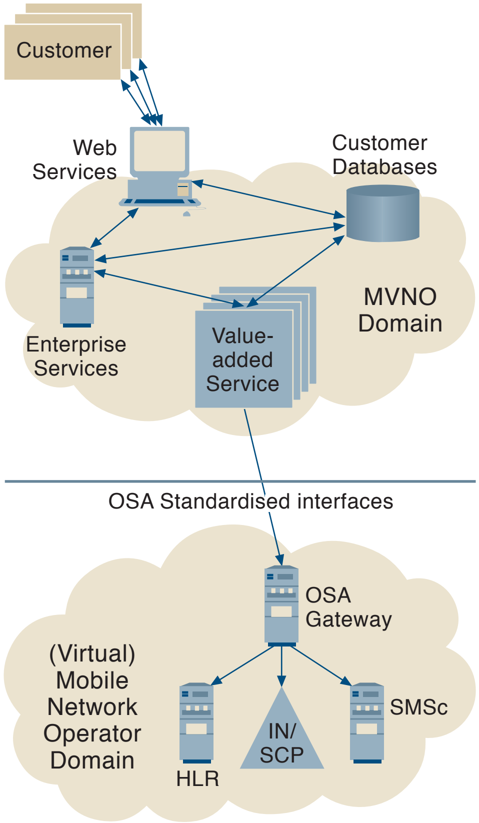


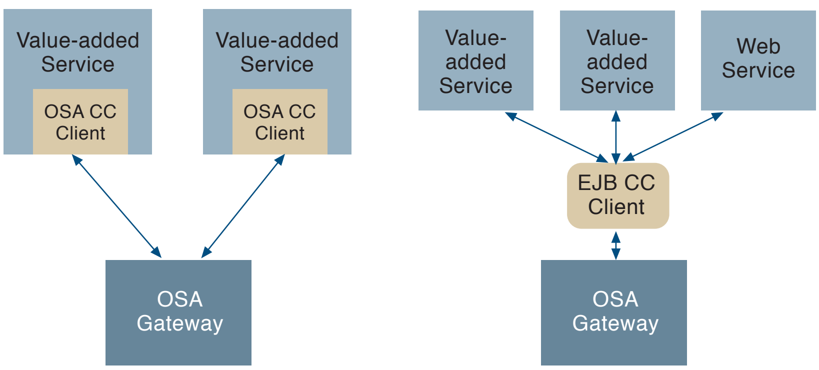
Figure 4-1 A MVNO that uses OSA to develop value-added services



'terminateServiceAgreement' method is called, which destroys the CM object or the 'endAccess' method is called, which ends the current authenticated session with the framework.

The application wish to get notified when call arrives for a certain number 'x', thus the application calls 'callEventNotify(x)' (13) on the CM object's interface. When a call arrives for x, the call processing in the network is paused; the CM spawns a new Call Object (14) and returns the reference to the Call object to the application, in the call for 'eventNotification(x)' (15). The application decides to route the call to 'y' and calls the 'routeReq(y)' (16) method on the Call object's interface. The call processing in the network resumes and the call is routed to 'y'.

Figure 4-2 Implementation of OSA applications



4 How can OSA Benefit Mobile Virtual Network Operators?

Mobile Virtual Network Operators (MVNOs) do not own a radio infrastructure but rely on the Mobile Network Operator (MNO)'s one. In order to be able to compete and survive it is crucial for them to offer attractive value-added services. To develop services and application in close collaboration with an MNO is a complex and slow process. It is also difficult for the MVNOs to adapt applications and services according to the customers' demands.

With OSA, the development and deployment of value-added services is much easier for the MVNOs. The applications can run on application servers inside the MVNOs domains using SCFs through OSA (see Figure 4-1). The MVNOs can use their own software developers to develop and deploy the value-added services in an appropriate speed, without being dependent of work done by the developers working for the network operators. It will also be easier to integrate the value-added services with other services and applications, e.g. databases, directory services, Web Services, Enterprise Services, running in the MVNOs' domains.

It will be much easier for the MVNOs to provide value-added services according to the customers' demands. For example, by combining Web services with the customer databases, the value-added can be personified, e.g. personal forwarding service, personal 'buddy lists', etc. The customers could for example specify how they want a service to operate through a web page, e.g. where to forward the call, who to put on the 'buddy list', etc. The customers profile could be saved in some databases/directory services and easily be used by the value-added services.

Implementation of Value-added Services using OSA

There are many alternatives of implementing value-added services using OSA. We suggest an approach that enables fast implementation of value-added services using OSA and easy integration with other services (see Figure 4-2).

Each value-added service could itself be a client to the OSA API, using call control, user status, etc, but in that case each application has to know the specific CORBA code (client stubs) to the OSA API and an OSA client has to be implemented in each value added service. To improve this, the MVNOs could use Java's component model, Java Enterprise Beans (EJB) [5]. It is then possible to construct, "implement once run everywhere", software components that work as clients for the OSA APIs, e.g. a Call Control EJB. Hence the Call Control EJB may be used by any value-added developed by a MVNO and also easily integrated with other services running in the MVNO's domain. An alternative to use EJB is to implement the OSA client as a CORBA object that also acts as a server to other services in the MVNO's domain. For example, value-added services that wish to use Call Control just act as a client to the Call control server object. Some advantages of using component models like EJB or CORBA are that the OSA clients only need to be implemented once (reusable code), and the developers are able to customise the interface against the services running in the MVNO's domain. This will probably lead to faster creation of new value-added service and easier service integration.

5 Conclusion

Nowadays, development and deployment of value-added services in telecommunication is a complex and time-consuming task. Third party service providers and MVNOs have to collaborate with a network operator in order to provide customers with value-added services and the services have to run inside the network operator's domain. By using 3GPP's OSA, network operators, 3rd party service providers and MVNOs is able to access network capabilities in a simple way through standardised APIs. The applications can run on application servers inside the 3rd party/MVNO's domain, which will lead to better service integration using object oriented techniques like CORBA and EJB and more control of the applications. Using OSA will make it possible for network operators and third parties to provide value-added services according to the constantly changing demands of the customers, like e.g. personified services.

3GPP has only specified OSA to enable applications to get access to network capabilities in wireless networks (GSM/UMTS). However, network operators may also operate a PSTN network and an IP-based network and may want to provide OSA APIs also for those networks. Value-added services may hence be accessible from heterogeneous networks. 3rd party/MVNOs will therefore be able to provide services for a wider range of customers. It is necessary to investigate how it is feasible to provide OSA on heterogeneous networks such as PSTN and IP. For example, should it be only one CC SCF for the whole system or should it be a separate CC SCF for each underlying network. Another issue is whether each network domain should have its own OSA implementation and the third parties have to deal with many different OSAs or there should be a unique OSA providing applications with SCF across network domain boundaries. How the different approaches will impact the applications and how each approach is implemented on each heterogeneous network should be studied.

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Option Pricing of Mobile Virtual Network Operators

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1 Definition of the Problem

1.1 Mobile Networks

In this paper, we present a model by which the price a mobile virtual network operator (MVNO) has to pay for services from a mobile network operator (MNO) can be determined. The model is based on how investment risk should be divided between the two types of operators in order to avoid arbitrage. The model is based on the theory of financial and real option pricing ([1], [2], [3], [4]).

A mobile network is as shown in Figure 1. The network has the same basic structure for GSM, UMTS, and wireless LANs so that the discussion that follows is independent of the particular type of network considered. See [5] and [6] for details concerning the structure of different mobile networks.

A mobile network cooperates with other fixed or mobile networks in order to offer the following services to the users:

- *Transport of bits* between the communicating parties;
- *Routing* of calls between communicating parties;
- *Terminal mobility* enabling the mobile terminal to move between different base stations and updating its location;
- *Continuity* allowing continuity of conversations when the mobile terminal moves between base stations (handover);
- Maintaining and managing the *user profile*, that is, the set of services and capabilities contained in the subscription;
- *Roaming* enabling mobile users to access networks owned by different operators.

It is not important how these capabilities are designed in particular networks. What is important is to understand that these functions are supported by all mobile networks. They represent the core functionality of mobile communications.

As in all networks, the applications and services the users are receiving exist outside of the networks supporting mobility and transport of bits. This observation is important since services beyond those listed above are not part of the networks, fixed or mobile. However, the services and applications determine the characteristics of the traffic the network has to support. This separation between network functionality and services is particularly easy to see in the Internet. In the Internet, the functions listed above are all supported by the IP protocol (and other protocols at the network layer). All applications and services exist on top of TCP or UDP. TCP and UDP are end-to-end protocols the header and content of which are not visible to the network.

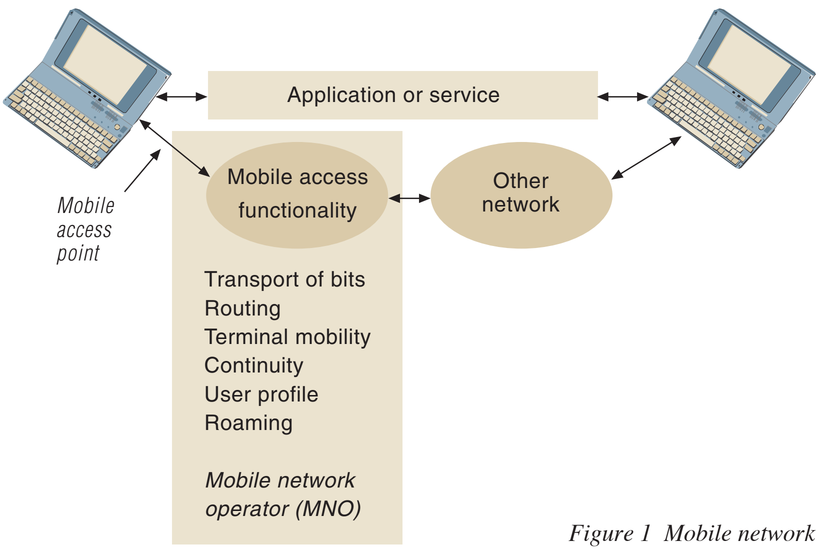


Figure 1 Mobile network operator (MNO)

1.2 Traffic, Cost and Revenue in Telecommunications

The traffic can be defined in terms of a few parameters such as temporal variation of call intensity, mobility of users and call duration. We know from experience the value of the traffic characteristics of speech and we can predict the performance of networks supporting only speech with good accuracy. We also know that the traffic characteristics of the short message service (SMS) are completely different: shorter call duration and higher call intensity. The performance of pure SMS networks can also be computed with sufficient accuracy. However, in systems with mixed traffic such as speech and SMS having different values of the traffic characteristics, it is much more difficult to assess the network performance. WAP access to the Internet makes this task even worse.

The next important observation is that the major cost of telecommunications networks is associated with investments and operation, both of which are approximately proportional to the peak traffic the network can carry. Traditionally, the performance of networks is defined in terms of the peak traffic they can support. This is called the *grade of service* of the network. More precisely, the grade of service specifies the amount of traffic, e.g. 2 %, that will be rejected because the network cannot carry more traffic. Therefore as a first approximation, we may state that the cost of the network is proportional to the grade of service offered to the customers. If the grade of service cannot be met because the traffic has increased or changed its characteristics, the network has to be increased, requiring more investments.

The revenues of telecommunications are essentially proportional to the average number of customers and the average traffic they generate. We are thus facing a situation where costs are proportional to the peakedness of the traffic while the revenues are proportional to the average traffic generated by the customers. The peakedness corresponding to the stated grade of service can be determined, with reasonable accuracy, from the variance of the statistical distribution of the traffic. In certain cases also higher order moments are important such as skewness and kurtosis. However, this is not important for this discussion. Observe the important fact that there is no relationship between the average and variance of a statistical distribution (except in the simple case of a one-parameter distribution such as a Poisson distribution).

Therefore, we conclude that there is no mathematical relationship between cost and revenue in telecommunications since each is derived from independent statistical parameters. This means that if the statistical distribution of the traffic changes, the ratio between revenue and cost also changes. Let us illustrate this behaviour by two examples. The average traffic may increase while the variance is constant (or increases less rapidly). In this case, the revenue increases while the cost is constant (or is increasing at a slower rate). Telephony is an example of such behaviour where cost is increasing slower than the income allowing the operator to reduce prices over time. On the other hand, when we mix traffic with different characteristics such as telephony, SMS and Internet, the average traffic may be unchanged while the variance may increase requiring more investment in networks. In this case, the price must sometimes be increased in order to retain the profit.

This behaviour is often different from production of goods where the revenue per good is proportional to the cost of producing it. This is the situation when a major part of the cost of producing the good is associated with each item produced (raw material, workforce, handling) and only a small part of the cost is common for the whole production (administration, sales).

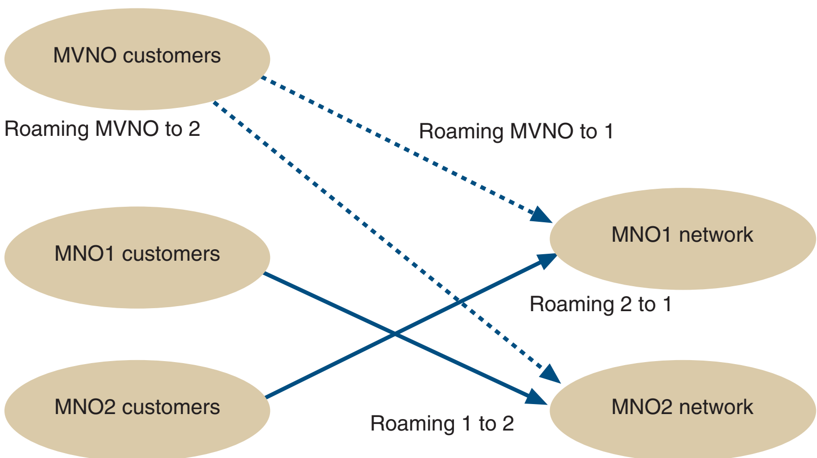


Figure 2 Roaming

1.3 Virtual Mobile Network Operator

The MVNO does not own its own mobile network but offers roaming and maintenance of the user profile. All other functions are bought from ordinary mobile network operators (MNOs) but the customers of the MVNO will view the total offer as coming from the MVNO.

The customers of the MVNO can implement their own services and applications on top of the capabilities offered by the MVNO.

The motives of the MVNO are several: to avoid binding investments capital, to offer ordinary mobile communications in competition with MNOs, and to offer something entirely different such as worldwide mobile business communications. The motives may not be publicised so that the MNOs (and other MVNOs) do not comprehend the underlying business plan of the MVNO. We will come back to this when looking at the types of market games the MVNO is playing.

1.4 Roaming

One of the major problems associated with MVNOs is associated with roaming. Note that we are using the term roaming in the precise meaning that it allows customers of one mobile operator (MNO or MVNO) to access the network of other operators (MNOs). Note that it is only meaningful to access the network of an MNO since roaming is associated with the act of connecting the terminal to the physical resources of the network. Roaming is shown in Figure 2.

Figure 2 shows how roaming takes place between MNOs and MVNOs. For simplicity, only two MNOs and one MVNO are shown. Roaming between MNOs is simple because it is symmetric in the sense that some customers of MNO1 roams to the network of MNO2, and some customers of MNO2 roams to the network of MNO1. If the two streams are equal, no change takes place with regard to the number of customers accessing each network. If the streams are not equal, e.g., because of tourism, the number of customers may increase in one network and decrease in the other network. The situation is nevertheless well understood and it is simple to settle business disputes by international roaming agreements. What is even more important is that MNO1 and MNO2 cover different geographical regions so that the networks do not compete for the same customers.

The situation is different for the MVNO. Since the MVNO does not own its own network, no customers can roam to that operator. However, all the customers of the MVNO have roamed to the networks of the MNOs. This makes the situation asymmetric, and, what is worse, it is not covered by the international agreements guaranteeing MVNO customers the right to access other networks. The MVNO and MNO are also competing for the same customers.

Below we shall look at the consequences of this asymmetry and suggest a method to handle it on a fair basis for all parties involved.

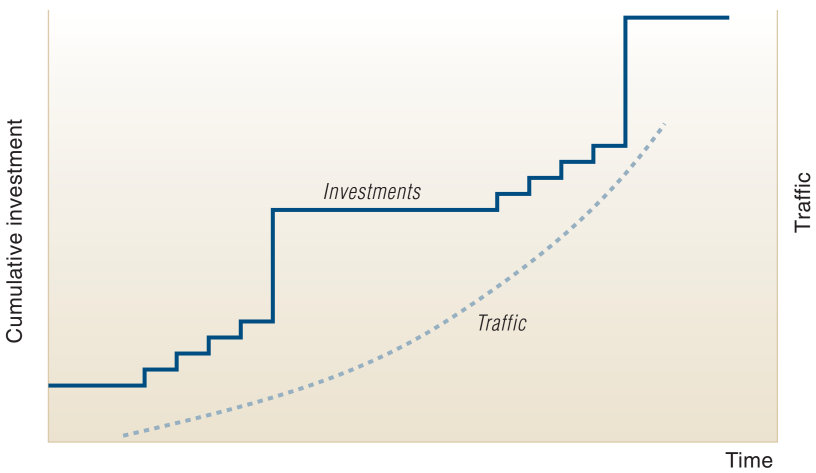
2 Roaming and Investment Risk

Figure 3 shows how investments are done in a mobile network. Sometimes the investments are small. This is so if the traffic increase can be satisfied by adding more channels to the base stations. Sometimes the investments are large. This is so if the cell configuration of the system must be altered.

The rational behind this evolution is the following. The frequency spectrum allocated to a mobile system is limited and capable of supporting a certain amount of traffic. This resource is shared between all operators covering the same geographic area. The amount of base station equipment required is proportional to the traffic supported by the base station. A reasonable strategy is then to invest in base station equipment just enough to meet the traffic demand. The investment of adding more equipment to the base station is small.

At some stage, the whole frequency spectrum available to the operator in a given area has been used up. The operator can then increase the capacity by building a new pattern of radio cells in the area by making each cell smaller. In Figure 4, the number of cells covering a given are has been increased from 4 to 20, that is by a factor of five. This means that the new cell arrangement can serve approximately five times as much traffic as the original cell pattern. However, this increase in traffic requires five times as many base stations, thus requiring much investment.

Figure 3 Investment as function of time



Such development of the cell pattern can be done in two ways as shown in Figure 5 (note that the ordinate is logarithmic). The base station antenna may be located such that there is free sight between that antenna and the antenna of the mobile terminal. The received power then drops off first at a rate of approximately d^{-2}, where d is the distance between the base station and the mobile terminal, and then at a rate of d^{-4} because of interference with the wave projected along the surface of the earth. The base station may also be hidden behind buildings and other obstacles such that there is no free sight between the base station antenna and the antenna of the mobile terminal. Because of diffraction, some of the radio power is propagated into the shadow of the obstacle. The received power then drops at the rate d^{-4}. In general this makes it possible to construct larger cells in rural areas than in cities.

Small cells can then be designed by hiding the antenna behind buildings and other obstacles which, in practice, means that the antenna is placed close to street level. This is an efficient method of reducing the cell size in cities. Another method is simply to reduce the power radiated by the base station. This does not alter the shape of the propagation curve as shown in the figure.

The problem the mobile network operator faces is that the capacity of the network must be increased from time to time if the service demand is increasing or the variance of the traffic distribution becomes larger. This gives rise to a stochastic time series of investments as shown in Figure 3. The size of the investment depends upon whether the demand can be satisfied by a small investment or by a large one as explained above.

The investment must be done by the operator owning the network (the MNO). The requirement for investment is determined by all operators creating traffic in the network. This may be the operator owning the network, operators owning their own network but creating roaming traffic, and operators not owning a network but buying traffic capacity for serving their own customers (MVNOs). In the first case, the investment risk is carried by the operator owning the network. In the second case, roaming is mutual and it is fair to assume that roaming between networks is approximately equal in the two directions so that the risk carried by each operator is the same. Even if the roaming traffic is not symmetric, this type of risk sharing is reasonable and can be settled by international roaming agreements. In the third case, one operator carries all the investment risk while the MVNO carries no risk. This situation may be balanced by including the investment risk in the price of using the network.

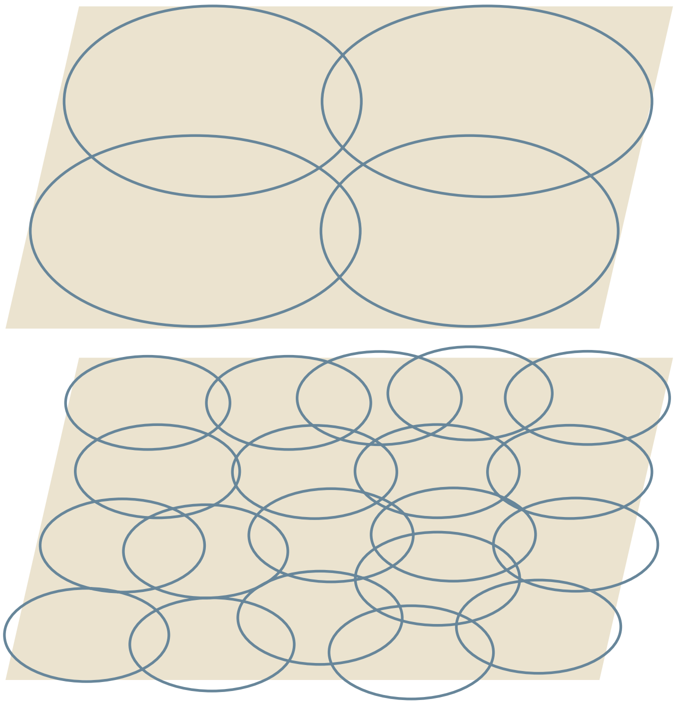


Figure 4 Cell patterns covering the same area

Note that the investment required to support the MVNO is nondecreasing over time, that is, the investment may be zero but it is never decreasing (we assume that the overall telecommunications market is not decreasing).

3 Option Pricing

The idea is to determine the price the MVNO has to pay for using the network such that the economic risk is distributed on both the MVNOs and the MNOs in a fair manner. The MVNO will then pay a premium for increasing the risk that the MNO has to invest in more infrastructure. The premium must then ideally be such that the risk is divided equally between the MNO and the MVNO. This is similar to option pricing in the financial market.

The price the MVNO has to pay consists of two components: the price, p, for using the network assuming that the average traffic and the variance is constant, and a premium Δp determined from the expected probability of investing in more infrastructure. The total price is then $p + \Delta p$. Note that $p + \Delta p$ can be the price per access, a fixed price for a certain period of time (a month or a year), or a combination of these. How the price p is determined is subject to negotiations and has no impact on the determination of Δp. What is important is that p and Δp are determined independently of each other.

Δp is a function of the expected traffic increase caused by the MVNO, the expected change in variance, the ratio between traffic caused by the MVNO and the MNO, and the geographic distribution of the traffic (i.e. where investments are

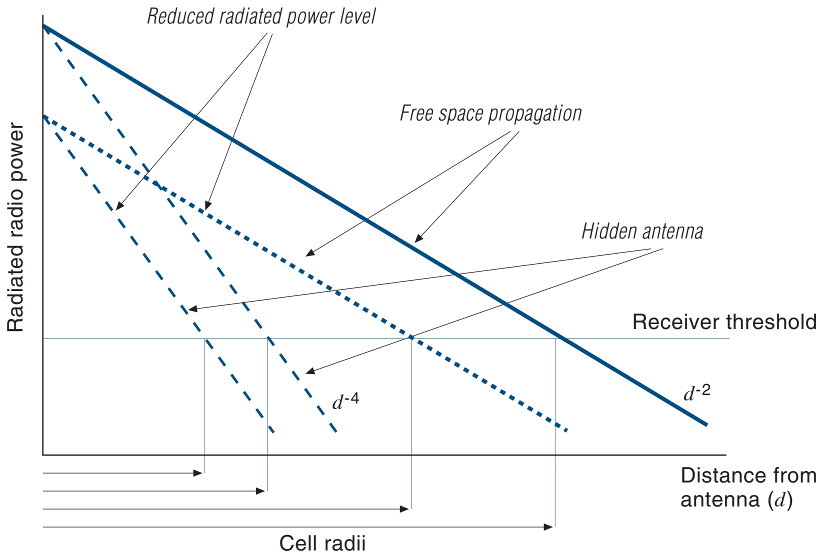


Figure 5 Cell radii and propagation

required). The third variable reflects the point that the MVNO shall not pay for the investment risk caused by the MNO alone.

The MVNO may have similar agreements with several MNOs depending upon how the MVNO is designed to operate.

The determination of Δp is not trivial. The method can be based on the same ideas as determining the premium of financial options. The dynamics of the market may also be captured as follows. The price increment Δp is settled for a certain period, say one year. Thereafter the value of Δp is renegotiated.

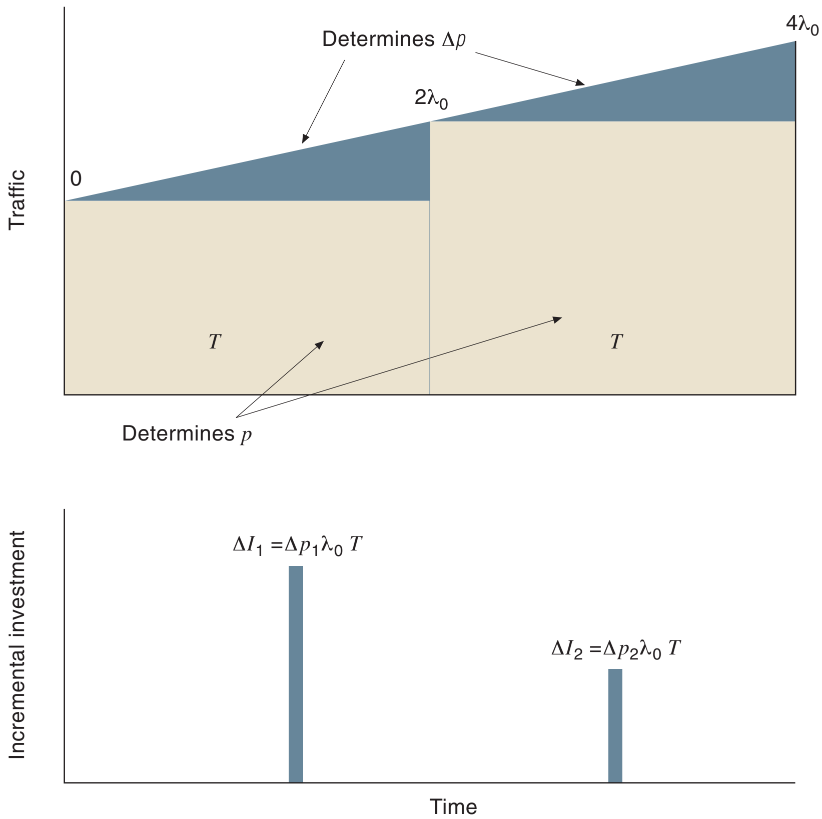


Figure 6 Two periods with average incremental traffic λ_0

Let us consider two examples:

Example 1. Assume that the traffic intensity generated by the MNO is constant while that generated by the MVNO is on average λ_0 during the negotiation period T (see Figure 6). The additional traffic generated during the period is then $\lambda_0 T$. The revenue generated by the MVNO during he time T is $(p + \Delta p)\lambda_0 T$, where the last term should compensate for the new investment ΔI. This gives:

$$\Delta p = \Delta I / \lambda_0 T.$$

Note that $\Delta p = 0$ if $\Delta I = 0$ as it should be: no investment, no premium. Figure 6 shows how Δp is calculated over several periods.

Example 2. In this example, the traffic of both the MNO and the MVNO increases. Assume that the increase of the traffic alone of the MNO requires new investment at time T_1 while the additional traffic generated by the MVNO requires that the investment is made at an earlier time T_2. Then we require that the discounted difference of the value of the investment between these instances is paid by the MVNO. With discount rate r this gives (note that $T_1 > T_2$):

$$\Delta p = \Delta I(e^{-rT2} - e^{-rT1}) / \lambda_0 T$$

where λ_0 is the average traffic rate generated by the MVNO in the contract period T.

In real cases, we should determine ΔI and Δp such that the economic risks are approximately the same for the MNO and the MVNO. The MNO should than save as much on average because the traffic does not increase so much that investments are necessary that the MVNO saves because the traffic increases so much that more investments than anticipated are required. This is the difficult task.

Another approach to quantitative modelling of competition and cooperations between network operators in the presence of uncertainty is considered in [7]. This approach is based on stochastic programming enhanced with selected ideas from games theory.

4 Some Problems Related to Games

The examples above assume that we can predict future investments accurately. This is, of course, not the case. We are instead faced with a number of problems. ΔI must be estimated based on historical data, simulations, or guesses concerning the future development of the market. The intentions and business plan of the MVNO are also important. ΔI is also a stochastic variable so not only the average probability but also the variance and perhaps higher moments must be estimated.

Questions that are likely to arise are. Are the MNO and the MVNO competing for the same traffic, or in other words, is this a zero-sum game? If so, all traffic gained by the MVNO is lost by the MNO. Is the business plan of the MVNO such that most of the traffic is new traffic only generated by the presence of the MVNO? If so, are the operators facing a cooperative non-zero-sum game? Is the game something in between? If the game is cooperative, that is, inducing traffic that otherwise will not be present, should then more of the risk be allocated to the MNO?

How can we trust the traffic estimates provided by the MVNO? Has the MVNO deliberately underestimated the traffic in order to reduce the premium? Should there be a penalty premium if such cheating can be proved? And how should this premium be determined, and who should act as arbiter in such conflicts? Has the MVNO overestimated its traffic increase allowing the MNO to request a higher price Δp than required?

The uncertainty is similar from the viewpoint of the MVNO. How is the investment risk calculated? Is the MNO cheating claiming higher investment probability than actually necessary? Is the MNO deliberately underestimating its own traffic increase? Is the MNO overestimating its traffic increase so that the risk of the MVNO is reduced?

How often should the contract be renegotiated, once a year or more often? What are the criteria that one of the parties can request renegotiating the contract before it expires?

None of the above questions is simple. And they are likely to have different answers for different MNOs and MVNOs.

5 Similar Cases

This paper only studies the case of the relationship between MNOs and MVNOs. However, there are several similar cases of cooperation leading to similar solutions. It is likely that the same principles applies to all virtual network operators (VNOs) and not only mobile virtual network operators. It is harder to define the business of VNOs in general. A special problem is related to the fact that IP and TCP puts a definite distinction between services involving the network and only the hosts (terminals). Therefore, a service offered on top of TCP must be treated in a different way than a service offering IP. Examples of the former are transaction services, web services, e-mail services and payment services. Examples of the latter are dark fibre and mobile access.

The models for cooperation between network operators and operators only offering services above IP and services involving IP are different. Operators of the latter type are similar to the MVNOs discussed above and the problems that the VNOs and the operators owning the network (NOs) are facing are the same as those described above.

The problems facing operators offering services above TCP (let us call them TOs for simplicity) and NOs (mobile or fixed) are different. In this case, there are at least to components that must be studied in order to understand the relationship between them. These are the costs the operation of the TOs are causing in the NOs. Example of such costs are provision of access and transport of bits. On the other hand, the traffic the TO generates may not be generated by any other means. In such cases it is fair that the NO pays the TO for providing this traffic since it is a joint effort to create value in the network.

Note that the problems we have been addressing above are new. The MVNO concept has existed for not more than five years we have had services such as those generated by TOs for less than ten years. Therefore, the aspects of cooperation between virtual operators and operators owning the network infrastructure is by no means sufficiently understood.

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Introduction

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Per Hjalmar Lehne (43) obtained his MSc from the Norwegian University of Science and Technology in 1988. He has since been with Telenor R&D working with different aspects of terrestrial mobile communications. 1988 – 1991 he was involved in standardisation of the ERMES paging system in ETSI as well as in studies and measurements on EMC. His work since 1993 has been in the area of radio propagation and access technology, especially on smart antennas for GSM and UMTS. He has participated in the RACE 2 Mobile Broadband Project (MBS), COST 231, and COST 259 and is from 2000 vice chairman of COST 273. His current interests are in 4th generation mobile systems and the use of MIMO technology in terrestrial mobile networks, where he participates in the IST project FLOWS.

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As the Internet Protocol (IP) suite has become the single technology with probably the highest momentum in today's telecom world, it is time to look into how the Internet technology is standardised. Up till a few years ago, the telecom and computer worlds were separate. The Internet was used basically to connect computers in networks. Now, IP is evolving to serve also typical telecommunications needs, like voice and video, providing reliability and security. There is still some way to go before IP can provide the necessary level of quality of the previously mentioned aspects, but much effort is put into it.

In this issue of *Telektronikk*'s Status section, we focus on the standardisation work of the *Internet Engineering Task Force (IETF)* by two contributions from highly skilled participants in the process.

The first paper is given by Zaw-Sing Su and gives an overview of how the work is carried through in IETF and how the standardisation process works. One thing worth noting is that IETF is almost purely driven by personal members and the organisational context is less important. The paper also gives some advice on how European telecom operators should position themselves towards IETF and which strategies they should use to influence the Internet standardisation process.

The second paper is given by Paal Engelstad and gives an overview of the background for IPv6, based on the fact that different 'dialects' and ad-hoc solutions made the current IPv4 less efficient and transparent. It concludes with three solutions for the migration towards IPv6: a short-term or ad-hoc solution, and two different long-term models.

IETF and Internet Standards

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Internet Engineering Task Force, an outgrowth of a U.S. Government sponsored project, is a standards body somewhat different from others. In this article, we go beyond the surface to allow some appreciation of its inner workings and briefly recommend a way forward for its engagement.

1 Historical Perspective

Opening the Internet for commercial use in the beginning of '90s together with the introduction of World-Wide Web catapulted Internet technology into focus for worldwide communications. Internet technology is based on packet switching, which was developed to meet robustness and stringent bandwidth requirements of military communications. Information communicated over the network is segmented into and transmitted in packets. Packets are propagated along available paths toward their destinations, circumventing network failures to achieve robustness and filling available slots to make efficient use of communication bandwidth.

The basis of Internet technology is the Internet Protocol (IP), developed for interconnecting networks of different transmission media. It thus achieves media independence and unifies communications across different media. Various applications and services can thus be developed based on IP, independent of underlying transmission media.

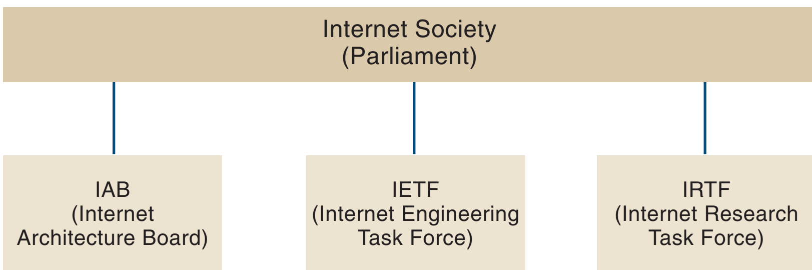
Prior to commercialization, Internet was a project developed in the '70s and '80s under the auspices of Defense Advanced Research Projects Agency of the U.S. Department of Defense, and later U.S. National Science Foundation. During that period, there were a number of research and development projects around the world pursuing packet based network communication. Not the least was the effort by major vendors and telecommunication operators under the International Organization for Standardization. Well-known results of that effort include the seven-layer Reference Model for Open System Interconnection and the X series, including X.25, protocols.

During sponsorship of the U.S. Government, the Internet was operated under its authority. The Government contracted the execution of its operations to Information Science Institute of University of Southern California, a non-profit organization, and Bolt, Baranek and Newman, a Cambridge-based technical consulting firm. It purchased hardware from computer vendors, leased point-to-point communication bandwidth from telecommunication carriers, and contracted research and development organizations for networking and software design and development.

Established in 1985, Internet Engineering Task Force (IETF) was the organization for coordinating technical development among participating contractors as well as user organizations, such as the military, other government agencies, academic institutions, as well as research and development organizations. When Internet technology started to mature, vendors specialized in building Internet equipment, such as Cisco, Proteon, 3com and Sun Microsystems, started to appear. IETF, in the mean time, became dominated by equipment vendors while operations of the Internet remained under government authority. The use of Internet was limited to and free of charge within government sponsorship.

2 Organization

Upon worldwide adoption of the Internet, the need for standardization of its technology became obvious. In the mean time, the U.S. Government terminated its sponsorship. This combination of events enabled the commercialization of Internet operations and transferred the management of continuing development and evolution of Internet technology to a non-profit



public entity, the Internet Society. However, organizations and the organizational structure formed under the government remained. These organizations include the Internet Architecture Board, under which The Internet Engineering Task Force, the Internet Research Task Force, and other related entities.

2.1 Internet Society (ISOC)

The Internet Society is a non-profit international membership organization of Internet experts that comments on its policies and practices. Internet Society may be considered the "parliament" of Internet community. It oversees a number of boards and task forces dealing with network policy issues and enjoys the support of more than 150 organization and 6,000 individual members in over 170 nations worldwide. Work of the Internet Society focuses on standards, public policies, as well as education and training information technology leaders around the world.

2.2 Internet Architecture Board (IAB)

The IAB is responsible for defining the overall architecture of the Internet and providing guidance and broad direction to the IETF. It also serves as the technology advisory group to the Board of Trustees and Officers of Internet Society. It acts as a source of advice and guidance to the Board of Trustees and Officers of the Internet Society concerning technical, architectural, procedural, and (where appropriate) policy matters pertaining to the Internet and its enabling technologies.

The IAB oversees a number of critical activities in support of the Internet. It appoints the IETF chair and all other IESG (Internet Engineering Steering Group – see below) candidates from a list provided by a nominating committee. It provides oversight of the process used to create Internet Standards and also serves as an appeal board for complaints of improper execution of the standards process.

IAB members are also nominated by the nominating committee, and reviewed and appointed by the Internet Society Board of Trustees. They serve two-year terms. Thus, each spring about half of its members need be reviewed.

The nominating committee for filling IAB and IESG vacant positions consists of ten voting members: a non-voting chair, and at least three non-voting liaison members – one liaison from each of sitting IAB and IESG, and chair of the previous year assumes the other. The voting members are randomly selected among volunteers from the Internet community. The non-voting chair is appointed by the Internet Society President. [1]

2.3 Internet Engineering Task Force and its Steering Group

The IETF was originally designated the protocol engineering and development arm of the Internet organization. When the need for standardizing its technology became apparent, the responsibility of Internet standards fell onto it. As a standards body for Internet, a communication technology, it has not, at least not yet, come under the jurisdiction of International Telecommunications Union (ITU). But, a memorandum of understanding (MoU) was signed between ITU and IETF during the Oslo IETF meeting in 1999.

To carry out its mission, IETF subdivides its efforts into Work Areas (Areas) and Working Groups. Each Area may consist of a number of Working Groups under the management of one or two Area Directors. The Area Directors sitting as a body, along with the IETF Chair, comprise the Internet Engineering Steering Group (IESG). The IETF Executive Director is an ex-officio participant of the IESG, as are the IAB Chair and a designated IAB liaison.

The IETF meets at least once a year around March. In practice, IETF meets traditionally three times each year, twice in the U.S. and another time elsewhere. More discussion on the Working Groups and Internet standards process follow in the next section.

The IESG is responsible for technical management of IETF activities and the Internet standards process. It administers the standards process according to the rules and procedures ratified by the ISOC Trustees. The IESG is directly responsible for the actions associated with entry into and movement along the Internet "standards track". Although most of the Internet standardization processes are carried out within IETF, the IESG is responsible for the approval of specifications as Internet Standards.

2.4 Internet Research Task Force and its Steering Group

The Internet Research Task Force (IRTF) is composed of a number of small Research Groups. Research Groups are usually focused and long term, though short-lived "task forces" are possible. They work on topics related to Internet protocols, applications, architecture and technology. Research Groups are expected to have stable long-term membership (with respect to the lifetime of the Research Group) needed to promote the development of research collaboration and teamwork in exploring research issues. Participation is by individual contributors, rather than organizational representatives.

The IRTF is managed by the IRTF Chair, in consultation with the Internet Research Steering

Group (IRSG). The IRSG membership includes the IRTF Chair, the chairs of the various Research Groups and possibly other individuals ("members at large") from the research community. The IRTF Chair is appointed by the Internet Architecture Board (IAB). The Research Group chairs are appointed in the formation process of the Research Groups, and the IRSG members at large are chosen by the IRTF Chair in consultation with the rest of the IRSG and on approval of the IAB. In addition to managing the Research Groups, the IRSG may from time to time hold topical workshops focusing on research areas of importance to the evolution of the Internet, or more general workshops to, for example, discuss research priorities.

The guidelines and procedures for the operations of IRTF Research Groups are described more fully in [2].

3 IETF Working Group and the Standards Process [3, 4, 5]

As mentioned, IETF activities are organized into Working Groups. Each Working Group belongs to an IETF Work Area. Currently, there are 8 Areas in IETF: applications, Internet, operations and management, routing, security, sub-IP, transport services, and user services. While they may come and go as needed, Work Areas are relatively stable. The number of Working Groups in an Area varies. In a "busy" Area, there can be as many as 20. In recent years, there are close to 100 active Working Groups each time IETF meets.

3.1 Working Group Operations

In Working Groups, protocols, mechanisms and other networking issues are specified, discussed and matured. One or two chairpersons may chair a Working Group. Goals and milestones are defined for a focused effort to address a specific problem or to produce specific deliveries. Wherever necessary or appropriate, an Internet protocol or technology would be standardized. The standards process, as a part of Internet technology development, also takes place in the Working Group.

A Working Group is expected to be short-lived, at least short-lived in nature. Work is carried out through mailing list discussion and face-to-face meetings.

There is no formal membership in IETF. Participation is open to all interested parties, by individuals rather than by formal representatives of organizations. Participation has swelled hundred fold from initially around 20 participants to in excess of 2,000 in recent meetings.

3.2 Internet Documents

Internet documents include Internet Drafts (IDs) and Request for Comments (RFCs). Internet drafts document work in progress, and enjoy no status of any kind. They are not archived and are deleted after six months from the time of submission or last revision. Internet drafts are announced and disseminated by IETF. Those promoted to become Working Group documents are prefixed with "draft-ietf-(working group acronym)".

Request for Comments are of an archival document series of IETF. Not all RFCs are standards track. Besides standards track RFCs, an RFC may be of "Best Current Practice", "Informational", "Experimental" or "Historic". They are edited, announced and disseminated by the RFC Editor. For a standards track RFC, it can be a "Proposed Standard", a "Draft Standard", or a "Standard".

3.3 Working Group Formation

Working Groups are typically created to address a specific problem or to produce one or more specific deliverables, such as a guideline or a specification for a standard. A Working Group may be established at the initiative of an Area Director or initiated by an individual or group of individuals.

Often it is not clear whether an issue merits the formation of a Working Group. A Birds of a Feather (BOF) session at an IETF meeting together with an email list for preliminary discussion would allow an assessment of interests and pinpoint the technical issues. A Working Group may result if there is enough interest and focus in the subject, and with the approval of the Area Director for the Area in which the Working Group would fall.

A Working Group may have one or two chairpersons. It must have a clear and focused charter, established goals and milestones. The charter of a Working Group is like a contract between the IETF and the Working Group, which is committing to meet explicit milestones and deliver specific deliverables. The charter may be renegotiated periodically to reflect the current status, organization, or goals of the Working Group.

Upon completion of its goals and achievement of its objectives, the Working Group is to be terminated. When appropriate, a Working Group may be extended with a modified charter. Such an extension must be with the concurrence of its chair, its participants, the responsible Area Director and thus indirectly the IESG.

3.4 Standards Process

Initiation of a standard is submitted as an Internet Draft to a Working Group. In line of achieving its objective, the Working Group may accept and promote an Internet Draft to become a "Working Group document" to be actively worked upon. The Working Group, or an individual, may recommend to the Area Director a "standards action" to promote an Internet draft along the standards track. The Area Director relays the recommendation to the Internet Engineering Steering Group for review. IESG then approves a standards action. If necessary, it may commission an independent technical review of the recommendation. Upon approval if with modification, the document is sent back to the Working Group for "Last Call", a final review by the Internet community. The Last Call must last at least two weeks. To advance along the standards track, an Internet Draft becomes a Request for Comment (RFC), a historical name for the archived Internet document series. It should be noted that not all RFCs are standards track, but they all share the same process to advance from Internet Drafts.

A standards-track RFC must remain a Proposed Standard for at least six months, and a Draft Standard for 4 months. The Internet standards process calls for no formal voting, but an approval process with rough consensus. Disputes are resolved by discussion and system demonstration. Listed goals of the Internet standards process include technical excellence; prior implementations and testing; clear, concise, and easy understood documentation; openness, fairness, and timeliness.

4 Operator Strategy

The exponential traffic growth in early '90s catapulted Internet technology into focus for worldwide communications, and called for its standardization. Exploration also began in earnest to employ Internet technology to offer a unified infrastructure for both "best effort" as well as real-time communications. It imposes a challenge to traditional telecommunication operators with changing business models, uncertain market place, and to keep up with the continuing evolution of Internet technology.

In recent years, there is increasing participation of European operators in Internet community. The high threshold for participation calls for careful evaluation and strategic engagement. Such a strategy may call for:

- *Focused effort:* Given the growing complexity of Internet technology, efforts of engagement can ill afford to spread too thin. They should be necessarily focused to closely follow business strategies. A business offering can be thought as, for example, of infrastructure, service platform, or applications and services. Where infrastructure offerings are for bearer bandwidth with possible improvements such as quality of service or virtual private network with security considerations. Service platform offerings are to third party providers who may base on such offerings to build services and applications; while the operator itself may directly offer user services and applications.

- *Leveraged engagement:* On selected subject areas with defined objectives, alliance and collaboration to leverage efforts may be pursued. With an appropriate vendor one may, for example, tackle service platform technologies. Pre-competition collaboration with other operators may explore multi-domain issues on end-to-end communication.

- *Community participation:* Participation in IETF emphasizes on personal rather than organizational involvement. Professional involvement by individuals not only may play a key role in IETF participation, but may also offer the best possibility of penetration into Internet community. Consistent and focused participation in IETF by selected technical staff is recommended.

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Towards a new Internet Architecture? – Or how IPv6 Addresses the Future

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Introduction

A number of prominent researchers in the Internet Engineering Task Force (IETF) have lately warned that the Internet architecture is about to change. This creates new complications and problems, which means that the Internet may not be able to accommodate new types of communications in the future Internet – an internet where computer- and tele-communication have converged and where security, mobility and quality of service can be taken for granted. This document uses the time glass model to describe the changes in the Internet architecture, and shows how the new problems are being addressed in IETF.

IP Described by the Time Glass Model

To fully understand how the Internet architecture is about to change, it is necessary to take a closer look at how IP was originally designed. This article uses the time glass model for this purpose (Figure 1). The model illustrates that all higher layer protocols are running over the same Internet Protocol (IP), while the IP protocol may run over a number of underlying technologies. It was an important choice of design to only allow one Internet protocol. This choice facilitates maximal interoperability between networks and a minimal the number of service interfaces, which makes implementations easier.

The width of the time glass illustrates the number of protocols as well as the amount of functionality that is present at each layer. The 'narrow' IP protocol incorporates limited functionality at the IP layer, while there are much more functionality at higher and lower layers. IP was designed as simple as possible, and the functionality is pushed out to the hosts on the edge of the Internet. This is called the end-to-end principle, which means that all higher layer protocols are implemented in the hosts. A 'narrow' Internet protocol includes a maximal number of networks by posing a minimal number of requirements to underlying technologies. The result of pushing most of the networking logic to the hosts is a simple, functional, efficient, generic, manageable and scalable Internet.

This was the IP architecture, as we knew it five years back in time. However, this architecture is about to change.

The Time Glass Model is no longer Valid

IP technology has experienced an enormous growth over the past decade in terms of number of users and in terms of expectations to what IP technology should accommodate. It seems that the original IP protocol was designed into such a 'narrow' protocol that the time glass finally broke. Figure 2 illustrates the situation as of today.

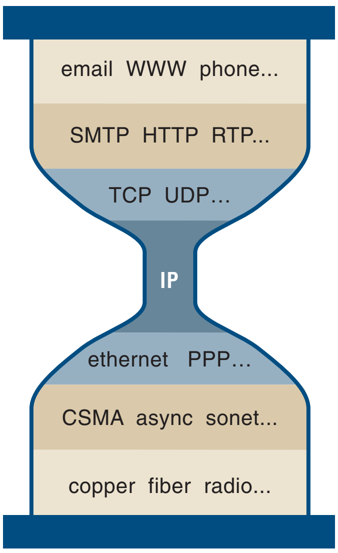

Figure 1 The time glass model

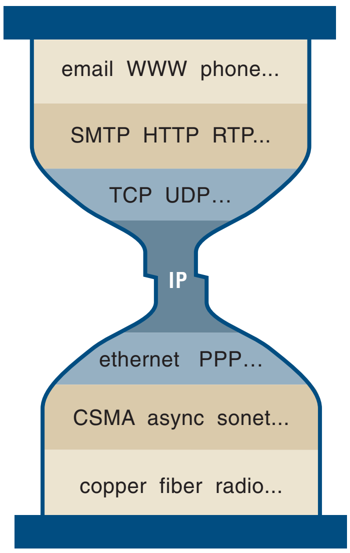

Figure 2 Something went wrong ...

(Figures from presentation by Steve Deering at 51st IETF)

What we are currently trying to do is to "glue together the fragmentation of the time glass" by means of different ad hoc solutions, which unfortunately are not perfect. Therefore, some applications and higher layer protocols that are designed based on the time glass model will cease to function properly. Furthermore, they have no opportunity to determine which ad hoc solutions are currently effective at the IP layer, and the network behavior seems random and non-deterministic.

There is a number of ad hoc solutions that have gained popularity due to missing functionality of IP. Firewalls, for example, compensate for the lack of security features in IP. Some applications and higher layer protocols such as basic Mobile IP still cease to work, because firewalls are not part of the original time glass model.

More important are Network Address Translators (NAT). NATs are increasingly gaining popularity due to the lack of globally routable IPv4 addresses. A NAT replaces a private IP address with a global address in a packet that is leaving an intranet and entering the Internet. It also makes sure that a reply packet destined for the global address is forwarded to the original private IP address. When the communication session is terminated, the global address can be reused by new sessions and new hosts on the intranet. This ad hoc solution saves globally routable address space, because most of the communication happens within the intranet where the private IP addresses are valid. It is only the fraction of traffic entering the Internet that passes through the NAT.

Functionality we are About to Lose

The lack of functionality of IPv4 (e.g. lack of address space) has lead to an enormous success for different ad hoc solutions in the marketplace. This fact has a major impact on the networking architecture of the Internet, and the simplicity of the time glass model is about to vanish. As a result, the following functionality of the Internet architecture is about to be lost:

- *Network transparency for protocols and applications*
  Before, all applications could transparently use IP. This is now getting dependent on the network configuration, e.g. it there is a NAT or a firewall present. The application requires that the ad hoc solution is adapted to the applications to be run, e.g. that there is an Application Layer Gateway (ALG) implemented in the NAT. The network is no longer transparent for applications and higher layer protocols.

- *Dynamic and robust routing*
  Some ad hoc solutions (such as NATs) require that state information about a session is stored in a particular router in the network. If the session relies on this information, all traffic of a session must passes through the router. (A TCP session, for example, will be dependent of state information in a NAT for the session not to break.) Thus, routing is not as dynamical and robust as in the original Internet architecture.

- *Connectionless services*
  Some ad-hoc solutions (such as NATs) require that state information about a session is stored in a particular router in the network, and the underlying communication model that is not longer connectionless. The result is that it will be more difficult to implement connectionless services at higher layers, too.

- *Stable and unique IP addresses – 'always on' services*
  A private IP address is, unlike a global one, not a globally unique id of a network access point. Due to the extensive use of private addresses, the IP address can no longer be used in generality for global identification. It also is common to allocate temporary IP addresses to hosts in order to save address space (i.e. not bind addresses that are not in use). The temporary allocation may be implicit (e.g. NAT) or explicit (e.g. DHCP). The use of private and temporary addresses makes it more difficult to provide 'always on' services.

- *The peer-to-peer communication model*
  NAT is an ad hoc solution that transforms the original peer-to-peer communication model into a client-server model. The NAT requires that all communication is initiated from within the intranet. This works well as long as hosts access web servers, ftp servers or mail server on the global Internet. However, new applications that require peer-to-peer communication (such as Napster-resembling services or certain configurations of SIP) will cease to work. Two hosts that are located behind different NATs cannot communicate with each other directly, because each host is required to initiate the communication.

Solutions to the New Problems

The change in the Internet architecture as described above seems like a serious degeneration of the original time glass model. IETF have invested years and years into development of the protocols (e.g. Mobile IP, IPSec, SIP, Rsvp, 6to4 etc.) that were intended to form the basis for the future Internet – an internet where computer – and tele-communication have converged and

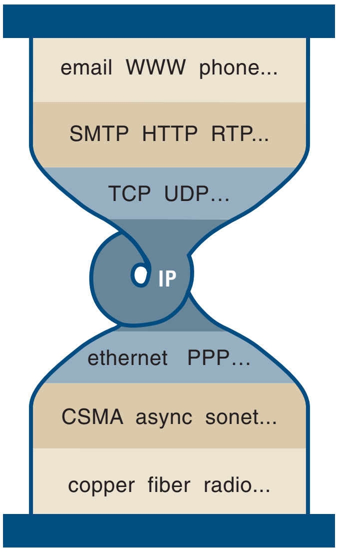

Figure 3 IP-in-IP tunnelling

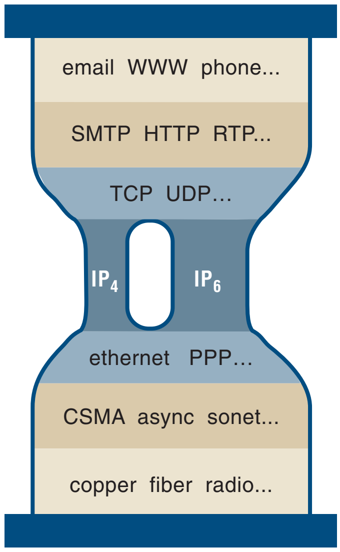

Figure 4 'Mid-life crisis'

(Figures from presentation by Steve Deering at 51st IETF)

where security, mobility and quality of service can be taken for granted. Instead, the protocols, which are developed under the assumption that the time glass model and end-to-end principle are valid, cease to work as intended.

IETF and the Internet society are currently working hard to assure that the Internet architecture does not get to a state that excludes further development. There are three different approaches to handle the new situation:

1. New temporary ad hoc solution (short-term)
In a short-term perspective one can fix shortcomings of ad hoc solutions by making new ad hoc solutions. For example:

- Firewall traversal: 'Reverse Tunneling' is an example of a solution that makes basic mobile IP work despite the existence of a firewall. Lately we have seen a number of new proposals on how to adapt existing protocols to the presence of a firewall.

- NAT traversal: An FTP-ALG implemented in a NAT can make FTP work across the NAT. There are a number of ALGs for other protocols and applications. Many NATs on the market is not possible to configure or are expensive to configure and maintain. IETF therefore works intensively with other solutions that do not require changes to the NAT.

- IP-in-IP tunneling has become a popular basis for solutions. Such solutions are often in line with the original Internet architecture and the resulting time glass model is maintained as shown in Figure 3. It is unfortunately limited how many problems can be solved by means of IP-in-IP tunneling.

The drawback of the efforts described above is that each protocol calls for a separate solution.

2. MIDCOM communication (long term)
Another approach is to develop protocols that let nodes (e.g. hosts, clients, servers or agents/proxies) communicate with a 'MIDBOX' (i.e. a logical unit in the network such as a NAT or a firewall). One accepts the existence of MIDBOXes as part of a new communication model. This may for example mean a farewell to the end-to-end principle in its current form and to the assumption of network transparency. MIDBOXes, such as firewalls, are expected to be around even after the introduction of IPv6.

3. IPv6 (long term)
IPv6 was developed from scratch as a new Internet Protocol that restores the simplicity and functionality of IP and the validity of the time glass model, as shown in Figure 4. It will probably take some years before IPv6 is fully adopted because the user base of IPv4 is so big. Meanwhile the time glass model must go through a 'mid-life crisis' with two Internet protocols in use (Figure 5). During this transition period there will be problems with interoperability between the two Internet protocols. The doubling of service interfaces will lead to complexity, and changes in higher and lower layers will also be required.

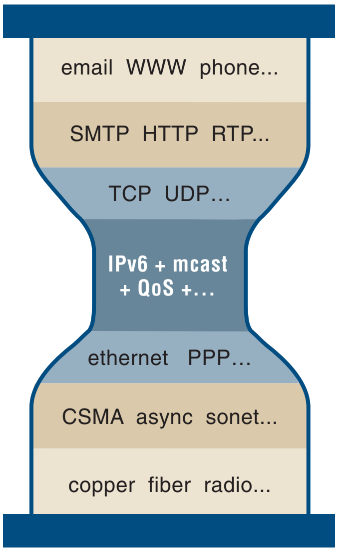

Figure 5 Putting on weight ...

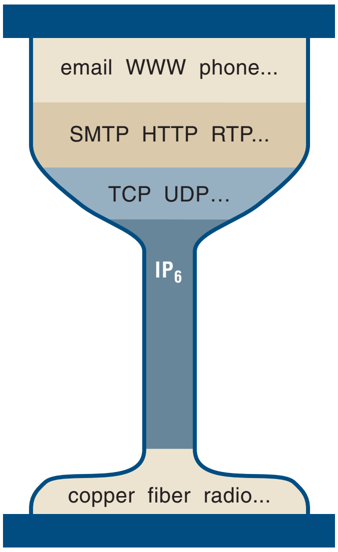

Figure 6 The wine glass model

(Figures from presentation by Steve Deering at 51st IETF)

From 'Time Glass Model' to 'Wine Glass Model'?

Figure 5 illustrates that IPv6 is less 'narrow' than IPv4. This reflects that IPv6 has a significantly larger address space. Furthermore, IPv6 is designed for extensibility by means of 'header extensions' in the IP header. This will make it possible to integrate mobility, security, re-numbering etc. into the IPv6 protocol.

As IPv6 is a 'wider' protocol the IP layer will be able to solve problems that are solved by underlying technologies today. Many people in the Internet society and in IETF dislike doubling of functionality, and would rather see that redundant functionality at lower layers be removed. If this wish comes true we might one day replace the time glass model with the 'Wine glass model', as shown in Figure 6.

Conclusion

The Internet architecture is about to change. The well-known functionality that it is about to lose, due to this change includes network transparency, dynamic and robust routing, connectionless services, stability and uniqueness of IP addresses, always on services and the peer-to-peer communication model. In a short-term perspective the changes creates new ad hoc solution. In a long-term perspective IPv6 and midcom communication will restore the original model and solve the problems. In the future, we may see that unnecessary functionality of underlying technologies are stripped off, and the time glass model may be replaced by 'wine glass model'.