EDGE: Enhanced Data Rates for GSM Evolution

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Abstract:-

This paper gives an overview of the EDGE concept. It gives a global overview of second generation systems migration to International Mobile Telecommunications in the year 2000 (IMT-2000). It also gives the rationale behind the development of the EDGE concept, including standardization background and efforts, aspects of introducing EDGE in GSM, and capacity and coverage performance.

Introduction:-

In line with the efforts of International Telecommunication Union (ITU) to provide global recommendations for IMT-2000, spectrum identification has been made, identifying parts of the 2 GHz band for IMT-2000 usage. Deploying IMT-2000 capable systems is however not limited to this spectrum band. The EDGE concept, a new TDMA-based radio access technology for both TDMA/136 and Global System for Mobile Communications (GSM) systems, provides third-generation capabilities in the existing 800, 900, 1800, and 1900 MHz) frequency bands.

Enhanced Data rates for Global Evolution (EDGE) are a radio based high-speed mobile data standards. A technology that gives Global System for Mobile Communications (GSM) the capacity to handle services for the third generation of mobile network. EDGE was initially developed for mobile network operators who fail to win Universal Mobile Telephone System (UMTS) spectrum. EDGE gives incumbent GSM operators the opportunity to offer data services at speeds that are near to those available on UMTS networks. EDGE enables services like multimedia emailing, Web infotainment and video conferencing to be easily accessible from wireless terminals.

High Speed Wireless Terms:-

- ## *1G or first generation:*

  The first generation of cellular networks used analog transmission. This is available in all cellular markets today.

- ## *2G or second generation:*

  The second generation of wireless networks uses digital transmission for voice signals. The development of digital transmission allowed carriers to fit more calls on the same frequency and eliminate more noise and static on each call. Digital technology also improved the battery life for wireless phones and added many vertical features like Caller ID, text messaging and intelligent roaming. In this network, data is usually transported over voice channels at speeds ranging from 9.6 kbps to 14.4 kbps.

- ## *2.5G or 2.5 generation:*

  2.5G doesn't change how voice is transported, but introduced packet data services, allowing for speeds of 20 to 40 kbps about the same speed as a dial-up service.

- ## *3G or third generation:*

  The third generation of wireless networks increases the speed of packet data transport through the network to speeds above 100 kbps.

Current Market Technologies:-

- ## *GSM (Global System for Mobile Communication):*

  The largest digital mobile standard in use today, used in over 170 countries worldwide. More than 70 percent of the world's digital phones operate on GSM technology. Implemented in 400MHz, 800MHz, 900MHz, 1800MHz and 1900MHz frequency bands.

- ***GPRS (General Packet Radio Service):***

  An enhancement for GSM core networks that introduces packet data transmission, GPRS uses radio spectrum very efficiently and provides users with "always on"? connectivity and greater bandwidth. GPRS users will eventually enjoy worldwide roaming while 1xRTT users today cannot. GPRS is the internationally accepted standard for roaming based on GSM technology, which is employed by over 170 countries around the world.

- ***EDGE (Enhanced Data rates for Global Evolution):***

  EDGE is a technology that gives GSM Networks the capacity to handle services for 3G. EDGE was developed to enable the transmission of large amounts of data at peak rates of up to 472kbps. Users should experience average speeds of 80 kbps to 130 kbps. EDGE deployment will begin in 2003 with full deployment finishing in 2004. EDGE devices are backwards compatible with GPRS and will be able to operate on GPRS networks where EDGE has not yet been deployed.
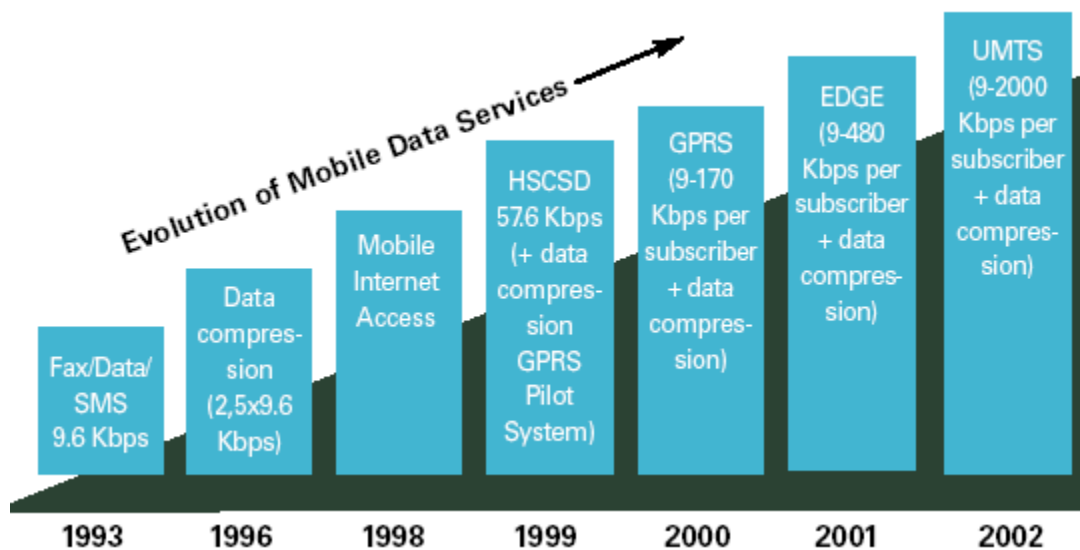
Figure. 1

The Second Generation Evolution to EDGE:-

GSM and TDMA/136 are two second-generation cellular standards with worldwide success. Today GSM is used by more than 135 million subscribers in over 100 countries, and the TDMA/136 system family (including EIA-553 and IS-54) serves over 95 million subscribers in over 100 countries worldwide. Although speech is still the main service in these systems, support for data communication over the radio interface is being rapidly improved. The current GSM standard provides data services with user bit rates up to 14.4 kb/s for circuit switched data and up to 22.8 kb/s for packet data. Higher bit rates can be achieved with multislot operation, but since both high-speed circuit-switched data (HSCSD) and General Packet Radio Service (GPRS) are based on the original Gaussian minimum shift keying (GMSK) modulation, the increase of bit rates is slight.
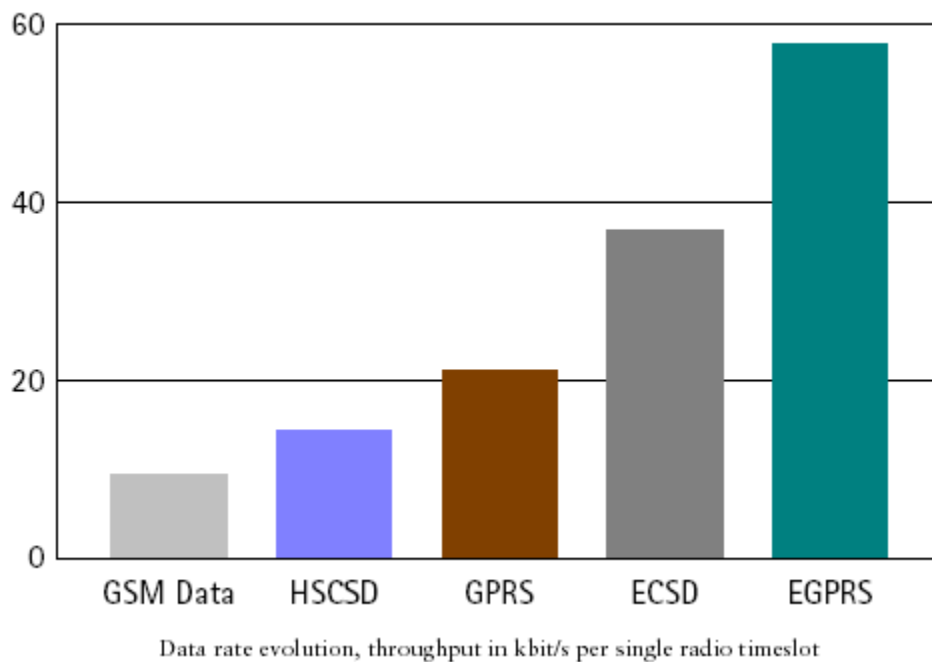

Data rate evolution, throughput in kbit/s per single radio timeslot

Figure. 2

EDGE uses high-level modulation in 200 kHz TDMA and is based on plug-in transceiver equipment. Universal Mobile Telecommunications Service (UMTS) is a new radio access network based on 5 MHz wideband code division multiple access (WCDMA). UMTS can be used in both new and existing spectra.

By adding third-generation capabilities to the GSM network implies the addition of packet switching, Internet access, and IP connectivity capabilities. With this approach, the existing mobile networks will reuse the elements of mobility support, user authentication/service handling, and circuit switching. Packet switching/IP capabilities are added to provide a mobile multimedia core network by evolving existing mobile telephony networks.

Development of EDGE:-

EDGE was first proposed to European Telecommunications Standards Institute (ETSI) in Europe, as an evolution of GSM at the beginning of 1997. Although EDGE reuses the GSM carrier bandwidth and time slot structure, it is by no means restricted to use within GSM cellular systems. Instead, it can be seen as a generic air interface for efficiently providing high bit rates, facilitating an evolution of existing cellular systems toward third-generation capabilities. After evaluating a number of different proposals, EDGE was adopted by UWCC in January 1998 as the outdoor component of 136HS to provide 384 kb/s data services. This was in support of the technology evolution for GSM and TDMA/ 136 systems.

Since then, EDGE development has been concurrently carried out in ETSI and UWCC to guarantee a high degree of synergy with both GSM and TDMA/136. The standardization roadmap for EDGE foresees two phases. In the first phase the emphasis has been placed on Enhanced GPRS (EGPRS) and Enhanced Circuit-Switched Data (ECSD).

EDGE uses the same TDMA (Time Division Multiple Access) frame structure, logic channel and 200 kHz carrier bandwidth as today's GSM networks, which allows existing cell plans to remain intact. Its high data transmission speed offers more diverse and media rich content and applications to GSM subscribers.
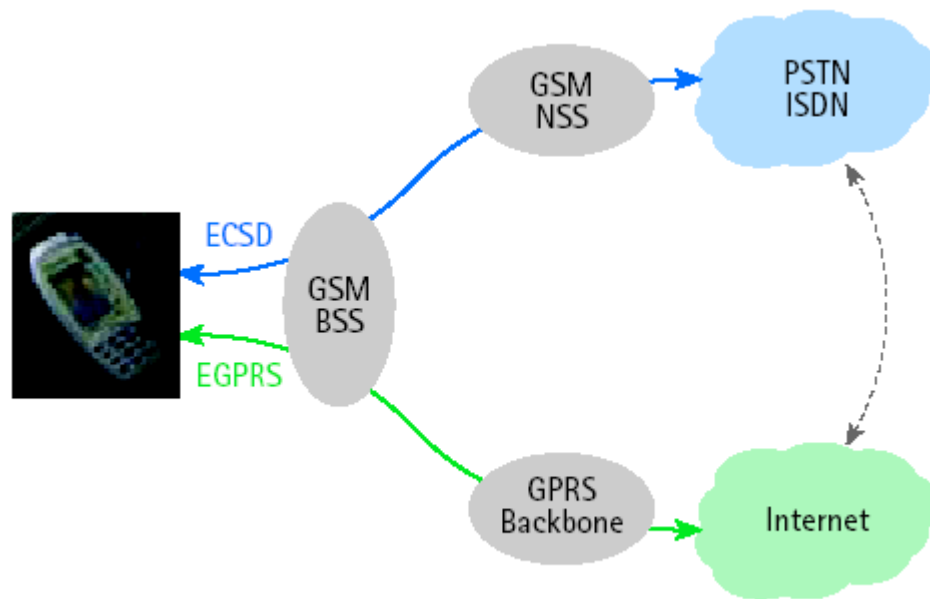
EGPRS and ECSD, enhanced packet and circuit switched services in GSM network

Figure. 3

Implementing EDGE:

Implementation of EDGE by network operators has been designed to be simple. Only one EDGE transceiver unit will need to be added to each cell. With most vendors, it is envisaged that software upgrades to the Base Station Controller (BSCs) and Base Stations can be carried out remotely. The new EDGE capable transceiver can also handle standard GSM traffic and will automatically switch to EDGE mode when needed. Some EDGE capable terminals are expected to support high data rates in the downlink receiver only (i.e. high dates rates can be received but not sent), whilst others will access EDGE in both uplink and downlinks (i.e. high data rates can be received and sent).

The later device types will therefore need greater terminal modifications to both the receiver and the transmitter parts. EDGE is designed for migration into existing GSM and TDMA networks, enabling operators to offer multimedia and other IP-based services at speeds of up to 384 kbits/s (possibly 473 kbits/s in the future) in wide area networks.

An important attraction of EDGE is the smooth evolution and upgrade of existing network hardware and software, which can be introduced into an operator's current GSM or TDMA network in existing frequency bands.

In addition, the TDMA industry association, the Universal Wireless Communications Corporation, has introduced what it calls **EDGE Compact.**

The Technology behind EDGE:-

The first stepping stone in migration path to third generation wireless mobile services (3G) is the General Packet Radio Services, GPRS, a packet-switched technology that delivers speeds of up to 115kbps. If GPRS is already in place, Enhanced Data rates for Global Evolution (EDGE) technology is most effective as the second stepping stone that gives a low impact migration. Only software upgrades and EDGE plug-in transceiver units are needed. The approach protects operators' investments by allowing them to reuse their existing network equipment and radio systems.

EDGE provides an evolutionary migration path from GPRS to UMTS by implementing the changes in modulation for implementing UMTS later. The idea behind EDGE is to eke out even higher data rates on the current 200 kHz GSM radio carrier by changing the type of modulation used, whilst still working with current circuit (and packet) switches.
 EDGE is primarily a radio interface improvement, but in a more general context it can also be viewed as a system concept that allows the GSM and TDMA/136 networks to offer a set of new services.

- *Improvement in Existing Radio Interface Network:*

  One fundamental characteristic of a cellular system is that different users tend to have different channel qualities in terms of signal-to-interference ratio (SIR), due to differences in distance to the base station, fading, and interference. Despite attempts to affect channel quality through power control, there will typically be a distribution of channel quality in a system, for example, according to the left side of **Figure 4.** A traditional service such as speech requires a certain target SIR to give good quality, below the target the quality is unacceptable, while above the target the quality is good and practically independent of channel quality.

   Thus, the radio network planning must make sure that only a small fraction of users are below the SIR target. Unfortunately, a large part of the user population will then experience unnecessarily high SIR (i.e., excellent channel quality from which they cannot benefit). This is the case for today's GSM and TDMA/136 systems, for speech and data services, thereby leaving room for enhancements in spectral efficiency. EDGE is designed to improve the situation by employing what is referred to here as *link quality control.*
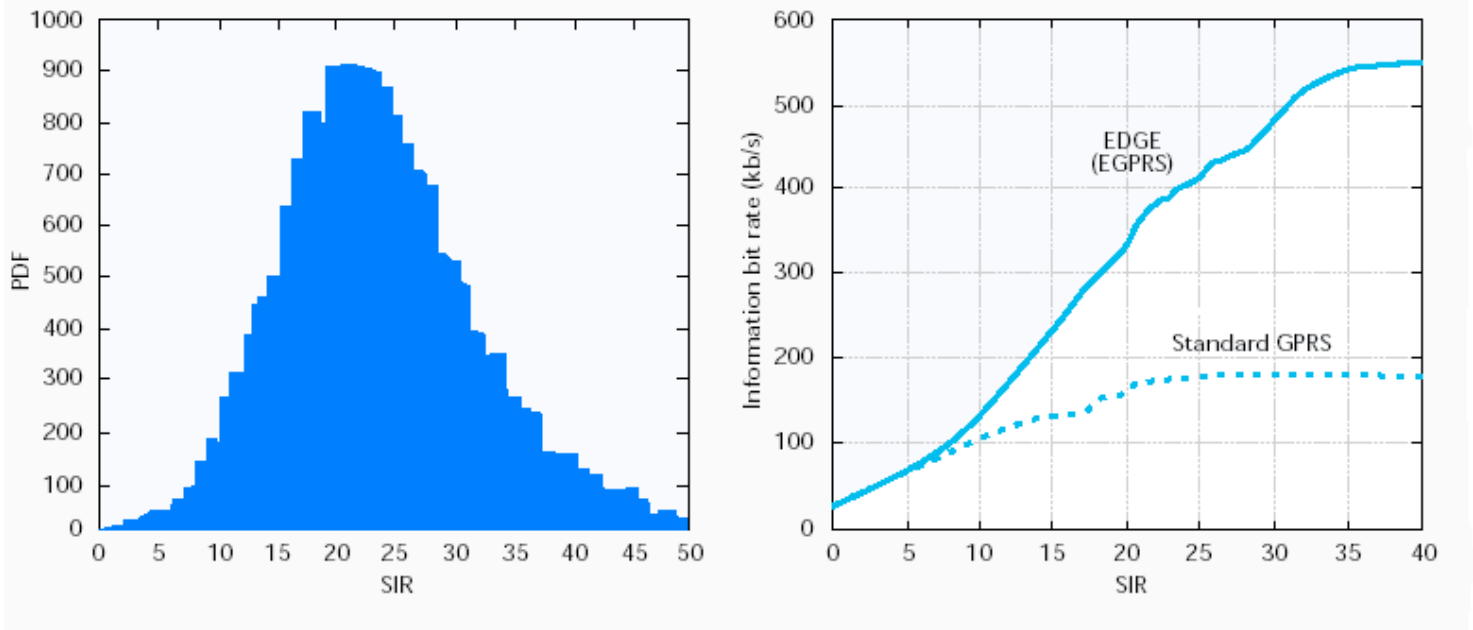
A typical channel quality distribution (left), and the perceived user quality in terms of bit rate for EDGE and standard GPRS assuming an eight-slot terminal (right).
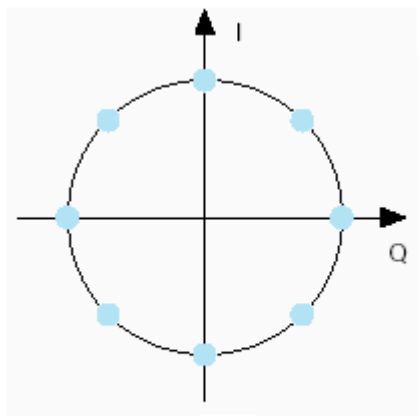
Figure. 4

Link quality control adapts the protection of the data to the channel quality so that for all channel qualities an optimal bit rate is obtained. The principle is illustrated on the right of **Figure 4**, showing user quality in terms of information bit rate with EDGE (EGPRS) and standard GPRS as a function of channel quality. Standard GPRS saturates at rather low SIR, whereas EDGE user quality increases with increased channel quality. Naturally, to obtain the characteristics in **Figure 4**, EDGE must include transmission modes with significantly higher information bit rates than those of standard GSM and TDMA/136. This is the reason for the introduction of the new modulation, 8-PSK, which is the core of the EDGE concept.

- ***Basics of Radio Interface:***

The EDGE air interface is intended to facilitate higher rates than those currently achievable in existing cellular systems. In order to increase the gross bit rate, 8-PSK, a linear high-level modulation, is introduced. 8-PSK, as shown in **Figure 5**, is selected since it provides high data rates, high spectral efficiency, and moderate implementation complexity. GMSK modulation for GSM is also part of the EDGE system concept.

The symbol rate is 271 kb/s for both modulations, leading to gross bit rates per time slot of 22.8 kb/s and 69.2 kb/s for GMSK and 8-PSK, respectively (including two stealing

bits per burst). The 8-PSK pulse shape is linearized GMSK, allowing 8PSK to fit into the GSM spectrum mask.

8-PSK modulation: sig-
nal constellation in the phase plane.

Figure. 5

Many EDGE physical layer parameters are identical those of GSM. The carrier spacing is 200 kHz, and GSM's TDMA frame structure is unchanged. Also, the 8-PSK burst format is similar: a burst includes a training sequence of 26 symbols in the middle, three tail symbols at either end, and 8.25 guard symbols at one end. Each burst carries 2 x 58 data symbols, each comprising 3 bits (**Figure. 6**). Channel coding and interleaving are intimately related to the layer 2 protocols.
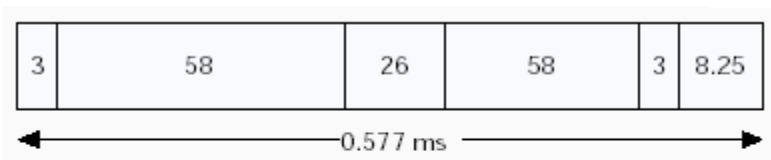
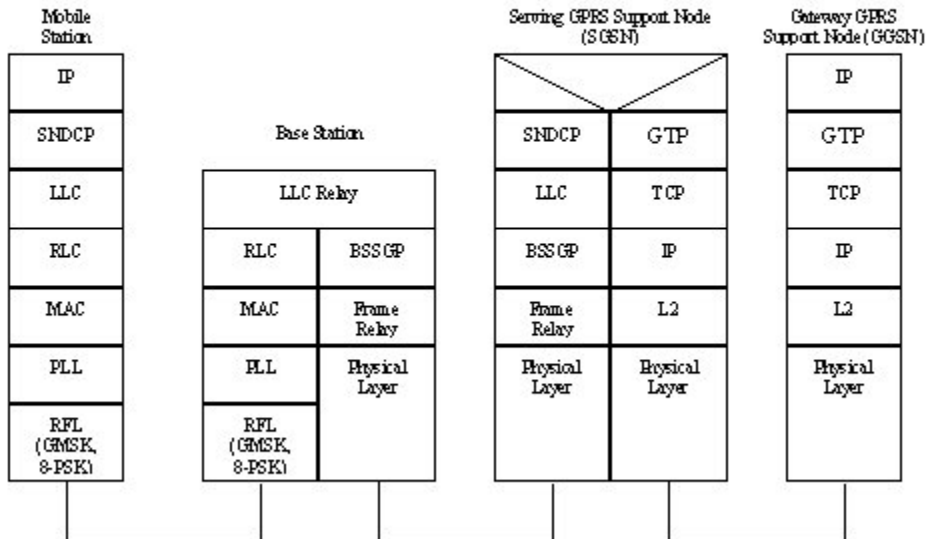*The burst format for EDGE is very similar to that of*
GSM, including a training sequence of 26 symbols in the middle,
three tail symbols at either end, and 8.25 guard symbols at one end.
Each burst carries 2 x 58 data symbols.

Figure. 6

- *Protocol design:*

EDGE Protocol Stack

The radio protocol strategy for EDGE is to reuse the protocols of GSM/GPRS whenever possible, thus minimizing the need for new protocol implementation. However, due to the higher bit rates and new insights Obtained in the radio protocol field, some protocols are changed to optimize performance. The EDGE concept includes one packet-switched mode and one circuit-switched mode, EGPRS and ECSD, respectively.

- *Packet-Switched Transmission: EGPRS:-*

  Due to the higher bit rate and the need to adapt the data protection to the channel quality, the EDGE radio link control (RLC) protocol is somewhat different from the corresponding GPRS protocol. The main changes are related to improvements in the link quality control scheme. As mentioned earlier, link quality control is a common term for techniques to adapt the robustness of the radio link to varying channel quality. Examples of link quality control techniques are *link adaptation* and *incremental redundancy*.

  A link adaptation scheme regularly estimates the link quality and subsequently selects the most appropriate modulation and coding scheme for coming transmissions in order to maximize the user bit rate. Another way to cope with link quality variations is incremental redundancy. In an incremental redundancy scheme, information is first sent with very little coding, yielding a high bit rate if decoding is immediately

successful. If decoding fails, additional coded bits (redundancy) are sent until decoding succeeds. The more coding that has to be sent, the lower the resulting bit rate and the higher the delay.

EGPRS supports a combined link adaptation and incremental redundancy scheme. In this scheme, the initial code rate for the incremental redundancy scheme is based on measurements of the link quality. Benefits of this approach are the robustness and high throughput of the incremental redundancy operation in combination with the lower delays and lower memory requirements enabled by the adaptive initial code rate.

As in GPRS, the different initial code rates are obtained by puncturing a different number of bits from a common convolution code (rate 1/3). The resulting coding schemes are listed in **Table 1**. Incremental redundancy operation is enabled by puncturing a different set of bits each time a block is retransmitted, whereby the code rate is gradually decreased toward 1/3 for every new transmission of the block. The selection of the initial modulation and code rate to use is based on regular measurements of link quality.

Channel name	Code rate	Modulation	Radio interface rate per time slot
CS-1	0.49	GMSK	11.2 kb/s
CS-2	0.64	GMSK	14.5 kb/s
CS-3	0.73	GMSK	16.7 kb/s
CS-4	1	GMSK	22.8 kb/s
PCS-1	0.33	8PSK	22.8 kb/s
PCS-2	0.50	8PSK	34.3 kb/s
PCS-3	0.6	8PSK	41.25 kb/s
PCS-4	0.75	8PSK	51.6 kb/s
PCS-5	0.83	8PSK	57.35 kb/s
PCS-6	1	8PSK	69.2 kb/s

■ **Table 1.** *Channel coding schemes for EDGE packet-switched transmission (EGPRS). The first four are those of standard GPRS, while the last six use 8-PSK modulation.*

- *Circuit-Switched Transmission: Enhanced CSD:-*

    For the ECSD mode of EDGE, the aim is to keep the existing GSM circuit-switched data protocols as intact as possible. A data frame is interleaved over 22 TDMA frames as in GSM, and three new 8-PSK channel coding schemes are defined along with the four already existing for GSM. As shown in Table 2, the radio interface rate varies between 3.6 and 38.8 kb/s per time slot. For nontransparent transmission, the current assumption is that the radio link protocol of GSM is to be used.

Channel name	Code rate	Modulation	Radio interface rate per time slot
TCH/F2.4	0.16	GMSK	3.6 kb/s
TCH/F4.8	0.26	GMSK	6 kb/s
TCH/F9.6	0.53	GMSK	12 kb/s
TCH/F14.4	0.64	GMSK	14.5 kb/s
ECSD TCS-1 (NT+T)	0.42	8PSK	29 kb/s
ECSD TCS-2 (T)	0.46	8PSK	32 kb/s
ECSD TCS-3 (NT)	0.56	8PSK	38.8 kb/s

■ **Table 2.** *Channel coding schemes for EDGE circuit-switched transmission (ECSD). The first four are those of standard GSM, while the last three use 8-PSK modulation.*

Types of EDGE:-

- *EDGE Classic:*

    The EDGE Classic air-interface is based on the EDGE standard developed by the European Telecommunications Standards Institute (ETSI). EDGE Classic is ETSI-EDGE with minor modifications, primarily information related to ANSI-136, that enables it to be overlaid as a packet data carrier on top of the existing ANSI-136 30 kHz air-interface. Examples of such information are pointers to the ANSI-136 Digital Control Channels (DCCH) covered by the EDGE cell and some of the broadcast information available on the ANSI-136 DCCH.

    A class B ANSI-136 terminal (a terminal with ANSI-136 voice and EDGE packet data) needs this information when camping on the EDGE packet data channel in order to originate and terminate circuit-switched services, e.g., incoming and outgoing voice calls. Operators who can set aside 2.4 MHz of initial spectrum for data applications can overlay

EDGE Classic on top of their existing ANSI-136 air-interface.

- ***EDGE Compact:***

  EDGE Compact uses the same modulation scheme as EDGE Classic. However, there are certain key differences that enable it to be deployed in less than 1 MHz of spectrum. The key characteristics that differentiate EDGE Compact from EDGE Classic are:

  - *Inter base station time synchronization:*

    A key characteristic of EDGE Compact is that the base stations are time synchronized with each other. This makes it possible to allocate common control channels in such a way as to prevent simultaneous transmission and reception. This creates a higher effective reuse, necessary for control signaling, e.g., 3/9 or 4/12. The base station synchronization is carried out such that the timeslot structure is aligned between sectors and the hyper-frame structures are aligned between all sectors.

  - *Time Groups and Discontinuous transmission:*

    Each base station site is typically allocated at least three frequencies, one per sector, using a 1/3 frequency re-use pattern. Inter base station time synchronization makes it possible to create time-groups within every frequency. Each sector is assigned one time-group. EDGE Compact is capable of supporting up to four time-groups per carrier. The typical re-use configurations with three carriers are:

    - 3/9 re-use using three out of the four time-groups
    - 4/12 re-uses using all four time-groups.

    When a sector belonging to one of the time-groups transmits or receives common control signaling, the sectors belonging to other time-groups are idle, i.e., are silent in both uplink and downlink. It is worth noting that the data traffic is carried over these same frequencies without using the time group concept. This results in a 1/3 re-use pattern for data traffic.

    - New logical control channel combination based on a standard 52 multi-frame
    - Time Group rotation of Control Channel.

Offered EDGE Bearer Services:-

The result of the EDGE radio interface and protocol enhancements is a set of bearers that are offered from the network to carry data over the wireless link. The definition of these bearers specifies what the user can expect from EDGE.

- ### *Packet-Switched Bearers:*

  The GPRS architecture provides IP connectivity from the mobile station to an external fixed IP network. For each bearer that serves a connection, a quality of service (QoS) profile is defined. The parameters included are priority, reliability, delay, and maximum and mean bit rate. A specified combination of these parameters defines a bearer, and different such bearers can be selected to suit the needs of different applications.

  EDGE introduction calls for an updated parameter space for QoS parameters. For example, the maximum bit rate possible for an EGPRS bearer will be at least 384 kb/s for terminal speeds up to 100 km/h and 144 kb/s for terminal speeds up to 250 km/hr [13]. Also, mean bit rate and delay classes may be affected by the introduction of EDGE.

- ### *Circuit-Switched Bearers:*

  The current GSM standard supports both transparent and non transparent bearers. Eight transparent bearers are defined, offering constant bit rates in the range of 9.6–64 kb/s. A nontransparent bearer employs a radio link protocol (RLP) to ensure virtually error-free data delivery. For this case, there are eight bearers offering maximum user bit rates ranging from 4.8 to 57.6 kb/s. The actual user bit rate may vary according to the channel quality and the resulting rate of retransmission.

  The introduction of EDGE implies no change of bearer definitions. The bit rates are the same, but what is new is the way the bearers are realized in terms of the channel coding schemes defined in Table 2. For example, a 57.6 kb/s nontransparent bearer can be realized with coding scheme ECSD TCS-1 and two time slots, while the same bearer requires four time slots with standard GSM (using coding scheme TCH/F14.4). Thus, EDGE circuit-switched transmission makes the high bit rate bearers available with fewer time slots, which is advantageous from a terminal implementation perspective. Additionally, since each user needs fewer time slots, more users can be accepted, which increases the capacity of the system.

- ***Asymmetric Services Due to Terminal Implementation:***

  For mobile stations, there is a trade-off between the new possibilities of EDGE and the requirements for low cost, small size, and long battery life. The 8-PSK transmitter is more of a challenge to incorporate into a low-complexity mobile station with today's commercial technology than is the receiver. The approach taken by ETSI is to standardize two mobile classes, one that requires only GMSK transmission in the uplink and 8-PSK in the downlink, and one that requires 8- PSK in both links.

  For the former class, the uplink bit rate will be limited to that of GSM/GPRS, while the EDGE bit rate is still provided in the downlink. Since most services are expected to require higher bit rates in the downlink than in the uplink, this is a way of providing attractive services with a low complexity mobile station. Similarly, the number of time slots available in up- and downlinks need not be the same. Transparent services will, however, be symmetrical. This is not a new evolution path for GSM mobiles: the GSM standard already includes a large number of mobile station classes, ranging from single-slot mobile stations with low complexity to eight-slot mobiles providing high bit rates. EDGE will introduce a number of new classes, with different combinations of modulation and multislot capabilities.

EDGE in GSM Systems:-

- ***Effects on the GSM System Architecture:***

  The increased bit rates of EDGE put requirements on the GSM/GPRS network architecture. **Figure. 7** illustrates the GSM/GPRS architecture, the shaded parts of which are discussed in this section. Other nodes and interfaces are not affected at all by EDGE introduction.
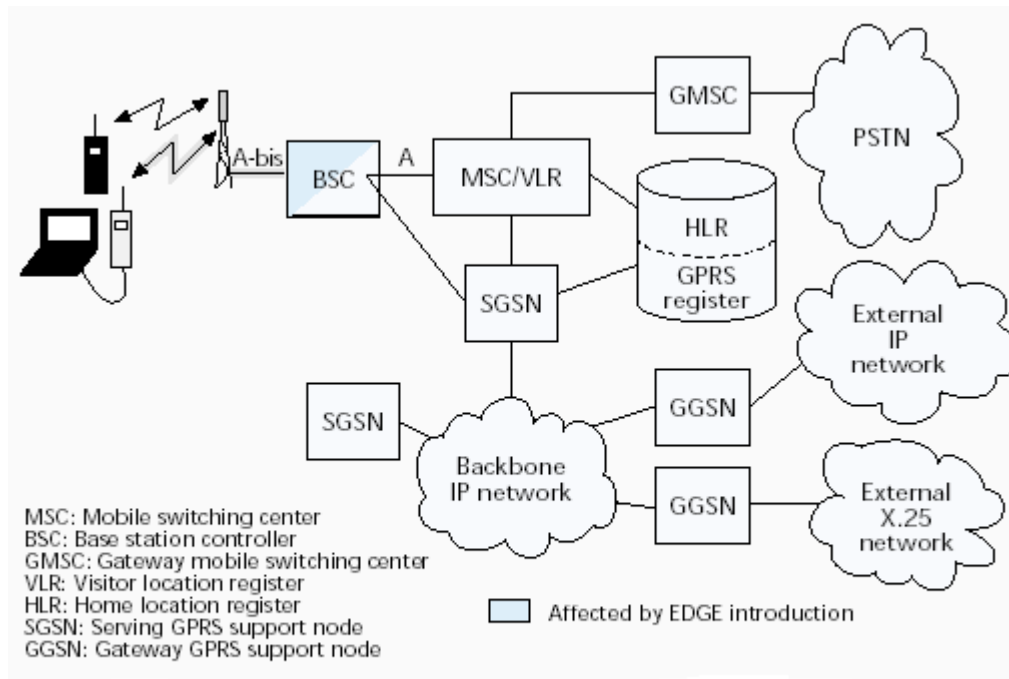
GSM/GPRS network architecture. Only the shaded nodes and interfaces are affected by the introduction of EDGE.

Figure. 7

An apparent bottleneck is the A-bis interface, which today supports up to 16 kb/s per traffic channel. With EDGE, the bit rate per traffic channel will approach 64 kb/s, which makes allocation of multiple A-bis slots to one traffic channel necessary. Alternative asynchronous transfer mode (ATM) or IP-based solutions to this problem can also be discusses. One important fact is, however, that the 16 kb/s limit will be exceeded already by the introduction of two coding schemes (CS3 and CS4) in GPRS, which have a maximal bit rate per traffic channel of 22.8 kb/s. Consequently, the A-bis limitation problem is being solved outside the EDGE standardization, and it is therefore a GPRS related, not EDGE-related, modification. For GPRS-based packet data services, other nodes and interfaces are already capable of handling higher bit rates, and are thus not affected. For circuit-switched services, the A interface can handle 64 kb/s per user, which is not exceeded by EDGE circuit-switched bearers.

- ***Impact on GSM Radio Network Planning:***

An important prerequisite, which to a large extent will determine the success of EDGE in GSM, is that a network operator be able to introduce EDGE gradually. For initial deployment, EDGE-capable transceivers will supplement standard GSM/GPRS transceivers in a subset of the existing cells where EDGE coverage is desired. Hence, an integrated mix of GSM, GPRS, and EDGE users will coexist in the same frequency band. To minimize effort and cost for the network operator, radio network planning (including cell planning, frequency setting of power and other cell parameters) must not require extensive modification.

- *Coverage Planning :*

One characteristic of non-transparent radio link protocols that include automatic repeat request (ARQ), is that low radio link quality only results in a lower bit rate for the user. Hence, low SIR for a user does not result in a dropped call, as for speech, but in a temporary decrease of user bit rate.

For transparent bearers, which typically offer a constant bit rate, link quality control must be extended to incorporate resource allocation, in the sense that the number of dynamically allocated time slots fits the bit rate and bit error rate (BER) retirements. Transparent bearers, will thus be available in the entire GSM cell, but require fewer time slots in the center of the cell (where 8-PSK coding schemes can be used)


- *Frequency Planning:*

Most mature GSM networks of today have an average frequency reuse factor of around 9 (meaning that available frequencies are divided into nine frequency groups). However, there is also a trend toward tighter reuse factors. With the use of frequency hopping, multiple reuse patterns (MRP), and discontinuous transmission (DTX), reuse factors as low as 3 become feasible. EDGE supports a variety of reuse patterns. In fact, by its use of link quality control, EDGE can be introduced in an arbitrary frequency plan, and benefit from high SIR closer to the base stations.

EDGE can be introduced in an existing GSM frequency plan, and that it also supports future high-capacity solutions based on tighter frequency reuse.

- *Channel Management:*

In EDGE, a cell typically includes two types of transceivers: standard GSM and EDGE transceivers (**Figure. 8**). Each physical channel (time slot) used for traffic in the cell can be viewed as being one of at least four channel type

  ➢ GSM speech and GSM circuit-switched data (CSD)
  ➢ GSM packet data (GPRS)
  ➢ GSM speech and circuit-switched data (CSD and ECSD)
  ➢ Packet data (GPRS and EGPRS)
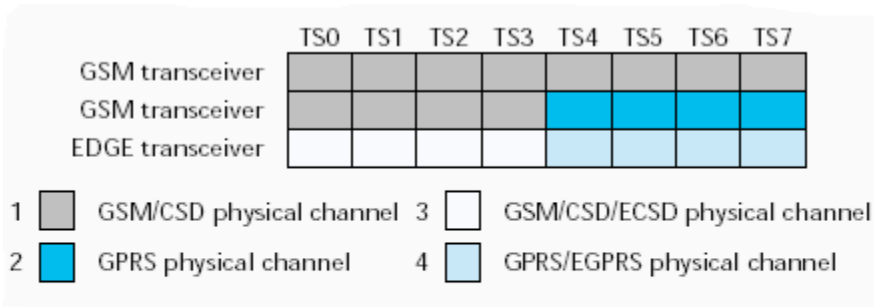
An example of transceiver and channel plan in one cell. Both standard GSM and EDGE transceivers exist, and the physical channels (time slots) are dynamically defined according to the current capacity need in the cell. Time slots used for control signaling are not included in the example.

Figure. 8

While standard GSM transceivers support only the first two channel types, EDGE transceivers support all four. Physical channels are dynamically defined according to the need in the cell. For example, if a large number of speech users are currently active, the number of channels of the first and third types is increased, at the expense of fewer GPRS and EGPRS channels.

End Note:

With the continuous globalization of telecommunication standards, the convergence of TDMA/136 and GSM is a logical next step. The common access of data services for TDMA/136 and GSM can be offered to over 230 million subscribers of both standards, and will thereby create huge market potential. Due to the convergence of the systems, roaming between both communities will be possible. Furthermore, the smooth introduction of EDGE in TDMA/136 and GSM will allow operators to improve services and capacity on demand. Regarding performance, the presented packet data simulation results show that compared to standard GSM, EDGE enables significantly higher peak rates, and approximately triples the spectral efficiency. Also, the packet bit rate coverage of the EDGE concept is improved compared to standard GSM, enabling existing sites to be reused.

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