The Access Service Network in WiMAX: The Role of ASN-GW

Dr. Mustafa Ergen
mustafaergen@wichorus.com
WiChorus, Inc.

Introduction

Rising demand for multimedia applications and mobile usage requires new paradigm to shift voice-oriented cellular architecture into data-oriented networks in order to serve bandwidth hungry packet based applications which include but not limited to multimedia gaming, mobiTV, streaming media, P2P, etc. Data oriented network requires 20-fold fatter air link and backhaul as compared to typical voice communication. To meet this demand, the next generation networks considers OFDMA with MIMO support for air link and all-IP end-to-end system for backhaul at the behest of lower OPEX and CAPEX requirement of operators.

These two coalesce in **WiMAX**. Long Term Evolution (LTE) out of Third Generation Partnership Project, and Ultra Mobile Broadband (UMB) out of 3GPP2 also clearly project toward the same direction, of course with slight deviations. It is considered that all three technologies form basis for 4G along with next generation Wi-Fi.

Key features desired from 4G wireless network include open architecture for productivity, increased end-user throughput, reduced latency, support for full mobility and end-to-end QoS.

The 4G networks will also make extensive use of femtocell, picocell and microcell technologies to deliver very high data rates in high-usage areas along with macro cells. These will facilitate to cover more limited areas, but at much greater throughput. Thanks to IP technology and access gateway, remotely maintaining different size of base stations and efficiently backhauling the 4G traffic will be feasible.

WiMAX Architecture

WiMAX is the pioneering and most talked OFDMA based IP technology and is ready to deploy worldwide. WiMAX is based on IEEE 802.16e-2005 standard and WiMAX Forum Network Working Group (NWG) specification. IEEE 802.16e-2005 standard specifies the PHY and MAC of the radio link. This alone is not adequate to build an interoperable broadband wireless network. Interoperable network deals with end-to-end service such as IP connectivity and session management, security, QoS, and mobility.

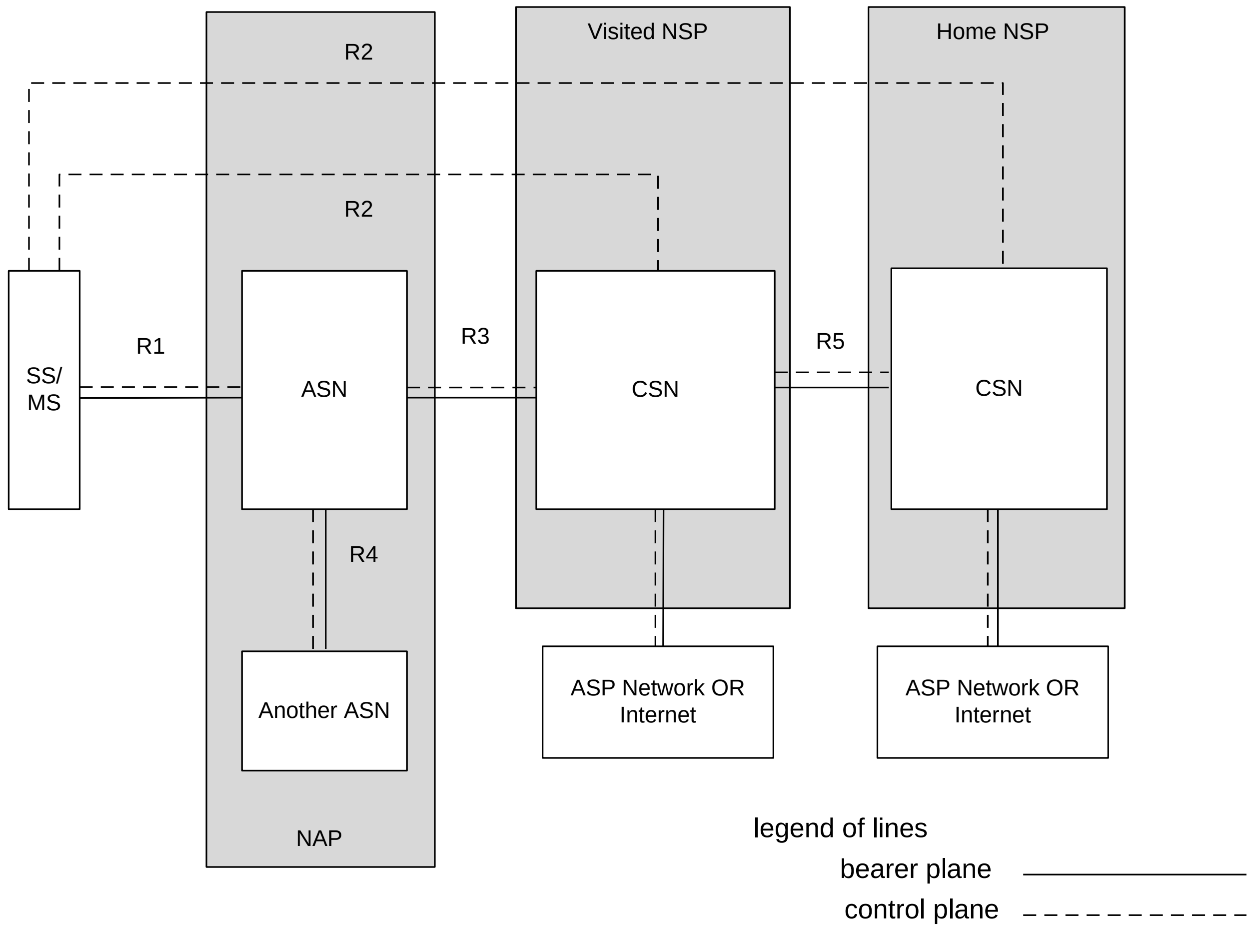

Figure 1 - Network Reference Model[1]

The WiMAX NWG defines the end-to-end architecture in three-stage standard; stage 1 is for use case scenarios and service requirements and defined along with Service Provider Working Group; stage 2 describes the architecture; and stage 3 details the architecture.

Design principles that WiMAX considers include the following;

- The architecture shall be decomposed in to functions and well-defined reference points between functional entities for multivendor interoperability.
- The architecture shall provide modularity and flexibility in deployment. Multiple types of decomposition topologies may coexist such as distributed, centralized, and hybrid.
- The architecture shall support fixed, nomadic, portable, and mobile operation and evolution path to full mobility.

---

[1] Dashed/Dotted line represents the Control Plane, Normal line represents Bearer Plane

- The architecture shall support decomposition of access network and connectivity network; access network is radio -agnostic and connectivity network provides IP connectivity.
- The architecture shall support sharing of the network with variety of business models;
    - Network Access Provider (NAP) owns the network and operates.
    - Network Service Provider (NSP) owns the subscriber and provides service. NSPs shares the NAP or a NSP uses multiple NAPs.
    - Application Service Provider (ASP) provides application services.
- The architecture shall support internetworking with 3GPP, 3GPP2, WiFi, and wireline networks using IETF protocols.

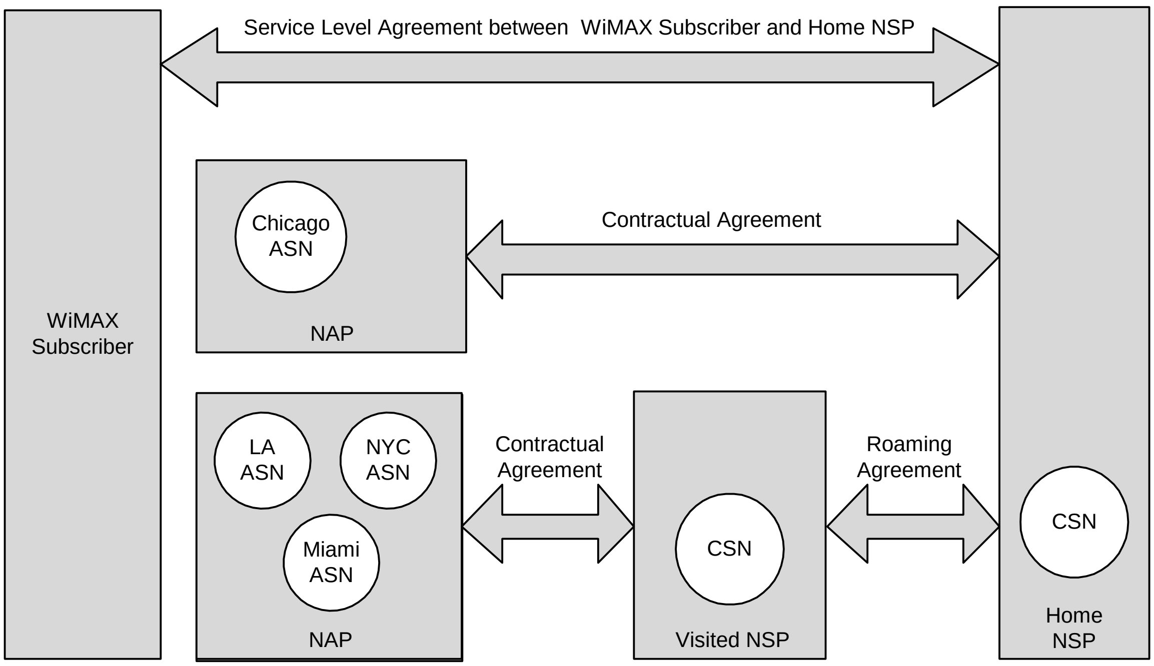

Figure 2 - Business Relationship Between WiMAX Subscriber, NAP, and NSPs

Figure 1 shows the WiMAX network reference model (NRM). The figure illustrates the reference points and functional entities. The NRM is composed of three logical parts: mobile stations, Access Service Network (ASN) which is owned by NAP, and the Connectivity Service Network (CSN) which are owned by NSPs. Business relationship between WiMAX subscriber, NAP and CSN is depicted in Figure 2.

The reference points as seen in Figure 1 are conceptual links that connects two functional entities. The reference points are;

- **R1**: Reference point between MS and BS: implements IEEE 802.16e-2005.
- **R2**: Reference point between MS and ASN-GW or CSN: logical interface used for authentication, authorization, IP host configuration and mobility management.
- **R3**: Reference point between ASN and CSN: supports AAA, policy enforcement, and mobility –management capabilities. Implements tunnel between ASN and CSN.
- **R4**: Reference point between ASN and ASN: used for MS mobility across ASNs.

- **R5**: Reference point between CSN and CSN: used for internetworking between home and visited network.
- **R6**: Reference point between BS and ASN: implements intra-ASN tunnels and used for control plane signaling.
- **R7**: Reference point between data and control plane in ASN-GW: used for coordination between data and control plane in ASN-GW.
- **R8**: Reference point between BS and BS: used for fast and seamless handover.

Access service network (ASN) provides means to connect mobile subscribers using OFDMA air link to IP backbone with session continuity. ASN comprises base stations (BS) and access gateways named ASN-GW. The interface between the ASN and mobile subscriber is through BS with IEEE 802.16e-2005 (IEEE 802.16-2004 for some previous fixed configurations) standard.

An Access Service Network is a set of network functions that include;

- Network discovery and selection of the preferred CSN/NSP,
- Network entry with IEEE 802.16e-2005 based layer 2 connectivity and AAA proxy,
- Relay function for IP Connectivity,
- Radio Resource Management,
- Multicast and Broadcast Control,
- Intra-ASN mobility,
- Foreign agent functionality for Inter-ASN mobility
- Paging and Location Management,
- Accounting assistance,
- Data forwarding,
- Service flow authorization,
- Quality-of-Service,
- Admission Control & Policing.

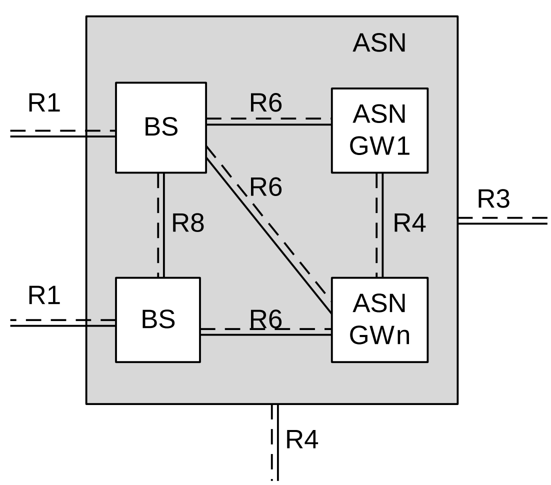

Figure 3 - ASN Reference Model containing multiple ASN-GW

Figure 3 shows that an ASN may be composed of one or more BS and one or more ASN-GWs. The WiMAX NWG Release 1 defines three profiles that classifies the distribution of functions among BS and ASN-GW: Profile A, Profile B, and Profile C. Figure 4 shows the distribution of functional entities in ASN for Profile C. Only difference in Profile A is the RRM and HO controller which resides in the ASN-GW and corresponding RRM and HO agent resides in the BS. Profile B does not expose R6 reference point and functional entities in BS and ASN-GW can be distributed freely. Profile B only complies to R1, R2, R3, and R4 interfaces. The WiMAX NWG has decided to continue with Profile C and Profile B in the upcoming Release 1.5.

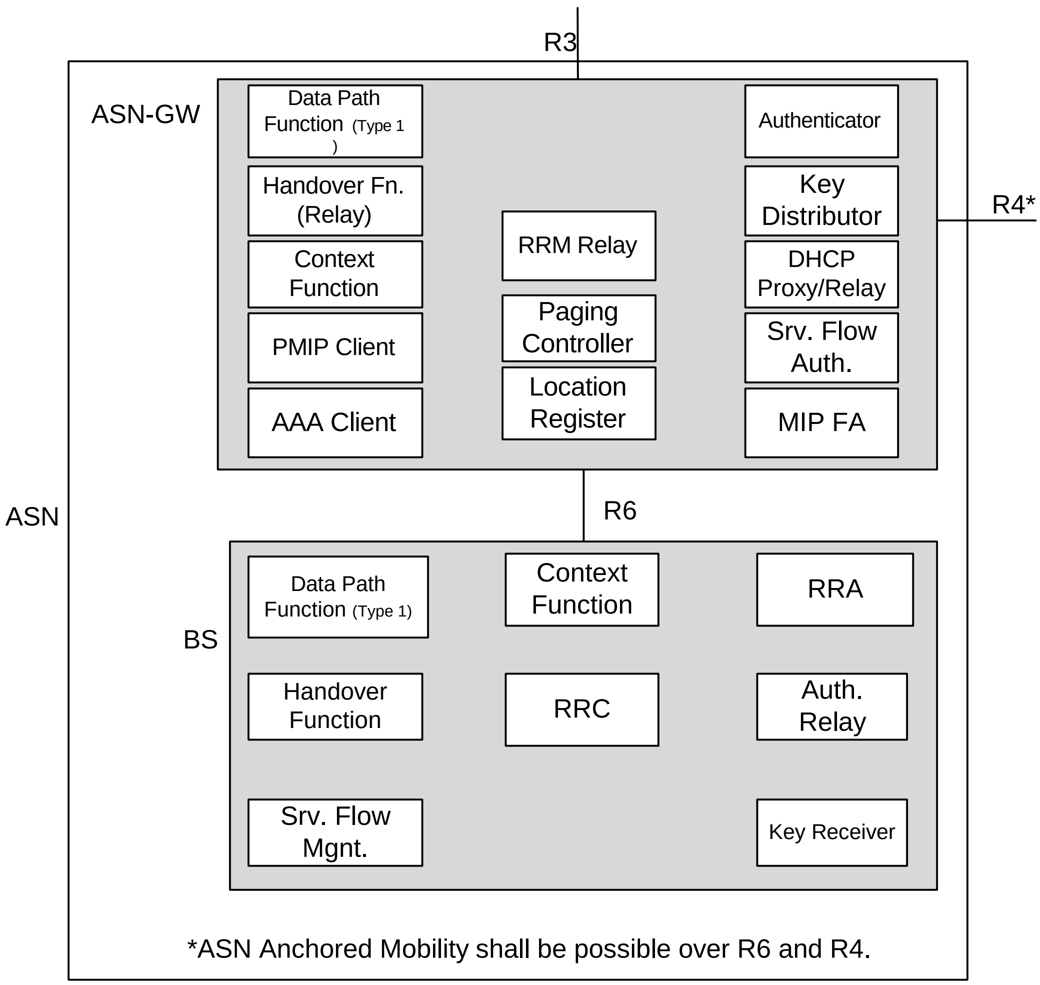

Figure 4 - WiMAX NRM architecture for Profile C

CSN complements ASN with IP related connectivity. AAA or Home Agent residing in CSN allocates the IP address. AAA also performs authentication, authorization, and accounting. Communication is through RADIUS protocol. Data packets arriving Home Agent are tunneled to ASN and data path shift to new ASN is executed when inter-ASN mobility is executed. Policy server residing in ASN is responsible to store the policy and QoS info of each subscriber which is communicated to ASN during service flow creation. CSN is also responsible to access other IP networks; Location Based Services, Peer-to-peer, VPN, IP multimedia services, Law enforcement, Messaging, etc. Network Management Services and Element Management Services also reside in the CSN for network and equipment configuration.

Access Service Network Functional Protocols

Protocol Layering of WiMAX considers end-to-end protocol layering. Data and control packets are forwarded from the MS to the CSN in uplink. The traffic is concentrated in the ASN-GW and forwarded to the CSN and same way, concentrated in the ASN-GW for downlink and distributed to the MSs residing in different BSs. IP packets use IP convergence sublayer (IP-CS) or Ethernet convergence sublayer (ETH-CS) over IEEE 802.16e. The IP-CS with IP-in-IP encapsulation between BS and ASN-GW is considered in most designs. Bridging is also another way of routing packet within ASN.

Network Discovery and Selection implements manual or automatic selection of the appropriate network. MS first discovers all the NAPs where each has an Operator ID embedded into Base Station ID and transmitted with DL-MAP of each frame. And MS continue to listen the channel for SII-ADV signal which system identity information advertisement to advertise NSP IDs. The MS selects one NSP from the list according to an algorithm and performs network entry and provide its identity and its home NSP domain with a network access identifier (NAI). The ASN selects the next AAA hop from the realm portion of the NAI.

IP Address Assignment is done through DHCP or AAA: ASN hosts DHCP relay or DHCP proxy respectively. In order to deliver the point of attachment IP address to MS. For IPv6 there is access router in ASN to obtain globally routable IP address. The MS gets the care-of-address (CoA) from ASN and home address (HoA) from CSN.

Authentication and Security Architecture implements 802.16e security with IETF EAP framework. AAA framework is used for service flow authorization, mobility management and policy control. AAA framework is based on pull model in which supplicant sends a request to ASN and ASN forwards it to AAA server. The AAA return with appropriate response to ASN which set up the service and inform the MS. The elements are depicted in Figure 5.

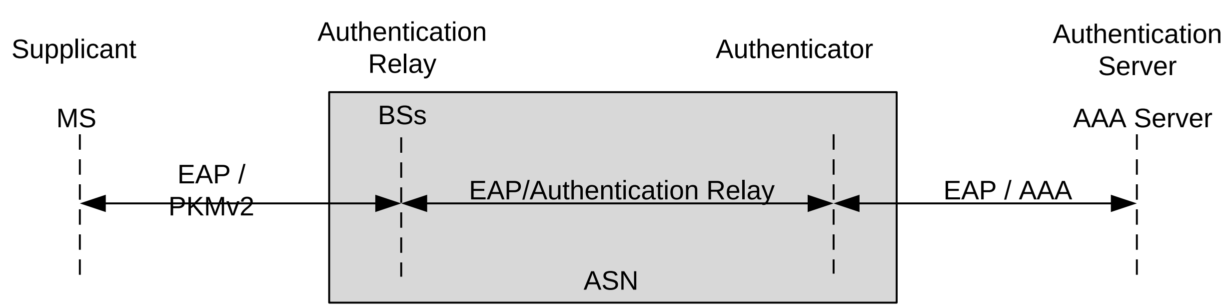

Figure 5 - Authentication Relay Inside the ASN

User and device authentication is supported with PKMv2 and EAP. PKMv2 is between MS and BS and BS relays this EAP messages to ASN-GW where AAA client encapsulates the EAP and forwards to AAA server in the CSN over RADIUS. EAP-AKA, EAP-TLS, EAP-SIM, EAP-PSK, EAP-TTLS are the supported EAP types. Both user and device authentication is performed with double-EAP and device credentials are in the form of digital certificate, secret key, or X.509 certificate.

Quality of Service Architecture in WiMAX complements the QoS framework in IEEE 802.16e-2005 QoS model. The QoS provides rich set of variety: per user and per service flow basis differentiated levels; admission control; bandwidth optimization. QoS provides static and dynamic service flow creation. For each service there is provisioned, admitted, and active states. When flow is in active state it starts getting the service. Entities are Policy function and AAA server residing in CSN, Service flow management residing in BS, and Service flow authorization residing in ASN-GW. QoS functional architecture is depicted in Figure 6.

Mobility Management implements mobility with the ASN and across the ASNs as seen in Figure 7. ASN-anchored mobility is when MS moves within the same Foreign Agent domain residing in ASN-GW. Control signals use R6 and R8 reference points and data path shift happens in ASN-GW with new R6 to target BS when handover is complete. CSN-anchored mobility additional to ASN-anchored mobility triggers the FA change through Home Agent. Now, R3 and R4 reference points also become active.

Radio Resource Management is responsible to fully utilize the network by information gathering and implementing decisions. The information such as radio-related measurements; base station spare capacity reports are concentrated to assist handover decision and load balancing decisions.

Paging and Idle Mode Operation is responsible to maintain a track and alert for MS when it is in idle mode for battery power saving reasons. Paging is executed to alert MS when there is an incoming message. Figure 8 illustrates the paging operation along with paging and idle mode elements in the system. MS is tracked when it is in the idle mode and information is stored to a location register (LR). Granularity of track is bigger than cell size since a paging group (PG) is composed of multiple cell and when a MS moves across paging groups, location update occurs via R6 and/or R4. Paging Controller (PG) in ASN-GW retrieves the location from LR and alerts the paging agent in (PA) in BS to signal to MS.

Base Station

The BS implements IEEE 802.16e interface to the MS and defined by one sector with one frequency. The air link scheduler resides in BS for uplink and downlink resource allocation, traffic classification, and service flow management as seen in Figure 6. BS provides the tunneling to ASN-GW and relaying functionality for services like authentication, reception and delivery of traffic encryption key and key encryption key.

Base station has the local control of the network and gets assistance from ASN-GW for some features and implements the decision of the gateway for others.

ASN-GW

ASN-GW is placed at the edge of ASN and it's the link to the CSN. ASN-GW assists mobility and security in the control plane and handles the IP forwarding. The Figure 9 gives an overview of the feature set together with which reference points (Ri) ASN-GW uses to communicate with other entities in ASN and CSN.

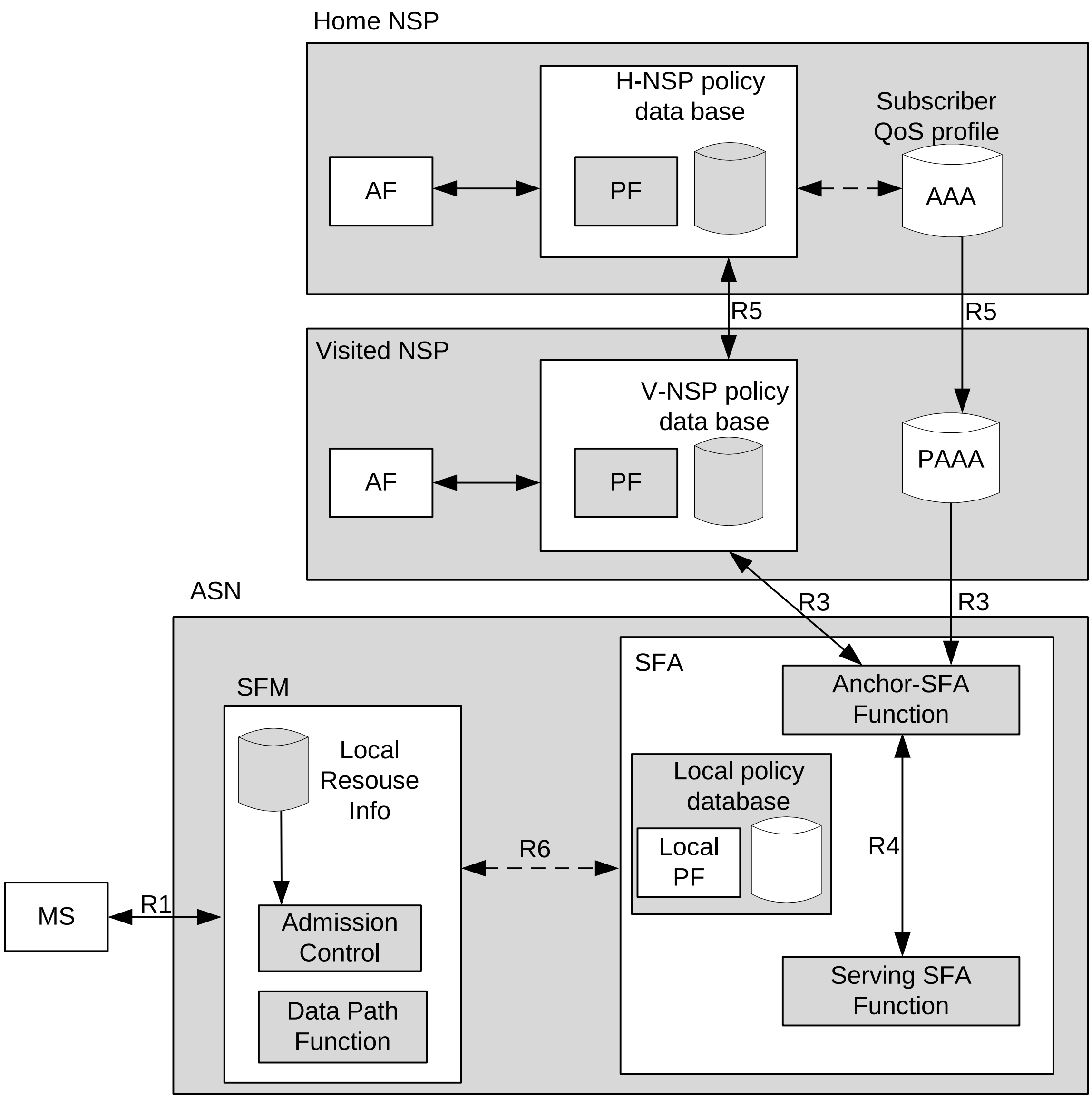

Figure 6 - QoS Functional Elements

ASN control is handled by ASN-GW and BS. ASN-GW Control plane handles all the radio-independent control and feature set includes authorization, authentication, and accounting (AAA), context management, profile management, service flow authorization, paging, radio resource management, and handover. Data plane feature set includes mapping radio bearer to the IP network, packet inspection, tunneling, admission control, policing, QoS and data forwarding.

ASN-GW has the authenticator and key distributor to implement AAA framework along with AAA relay in order to transmit signals to AAA server wherein the user credentials during network re/entry are verified with EAP authentication. Security context is created during AAA session and keys (MSK and PSK) are generated and shared with BS and MS. AAA module in the ASN-GW provides also flow information for accounting since every single detail about a flow such as transferred or received number of bits, duration, and applied policy is present and directly retrievable from the data plane.

ASN-GW is responsible for profile management together with policy function residing in the connectivity network. Profile management identifies the user and its subscribed credentials such as allowed QoS rate, number of flows, type of flows, etc.

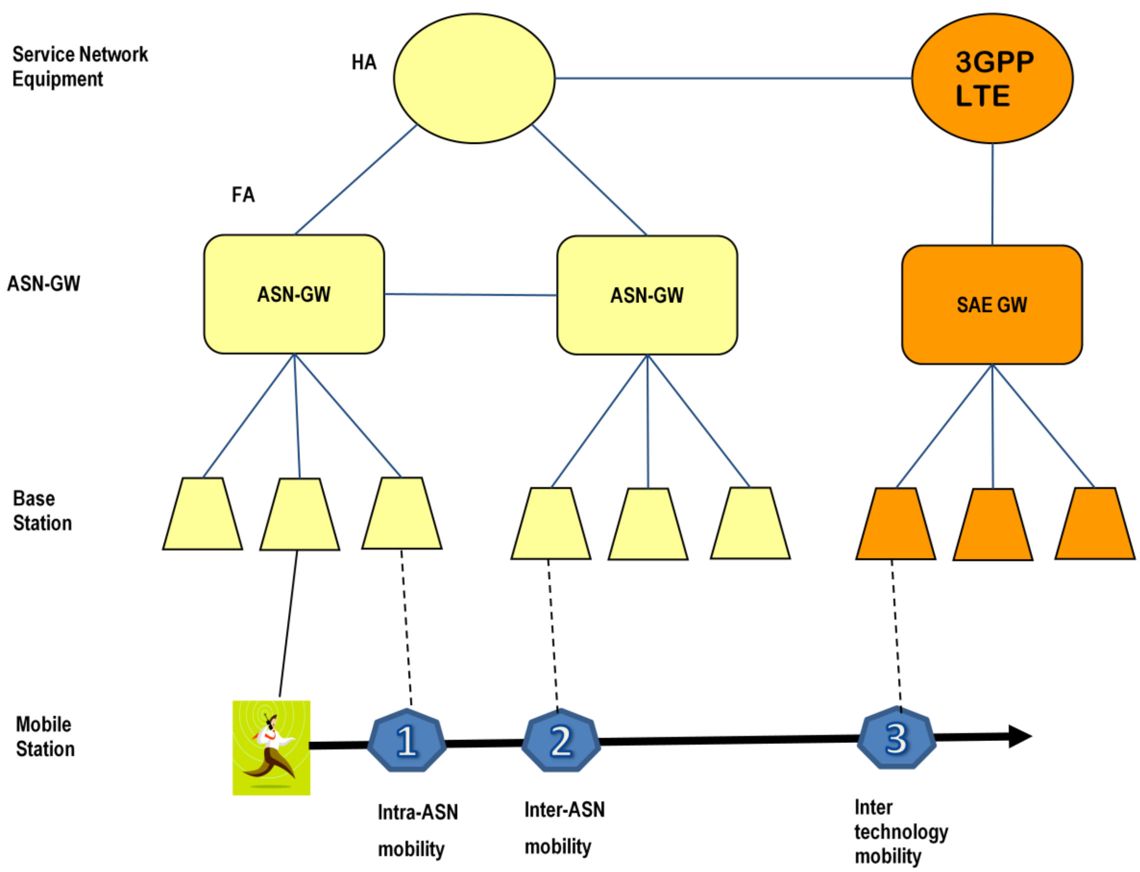

Figure 7 - ASN Reference Model containing multiple ASN-GW

Along with profile management, ASN-GW maintains context per mobile subscriber as well as per BS with higher granularity. Context of each subscriber keeps its profile, security context and characteristic of mobile device. This context is retrieved and exchanged between serving BS and target BS during handover and it moves as mobile subscriber moves to another ASN-GW.

ASN-GW is responsible to authorize service flows according to the subscriber's profile. Admitted service flows and active service flows can change over time and ASN-GW is responsible to provide admission control for downlink traffic. ASN-GW creates a GRE tunnel per service flow and encapsulates downlink traffic along with IPSec.

During handover, ASN-GW is responsible to provide context to base stations and when requested it changes the data path. In order to minimize the latency and packet loss, ASN-GW implements data integrity either by implementing bi/multi-casting and/or buffering. At the same time, foreign module is responsible to maintain the IP connectivity if mobile subscriber performs inter-ASN handover. ASN GW shall support either Proxy-Mobile IP (PMIP) or Client-Mobile IP (CMIP) in order to communicate to Home Agent.

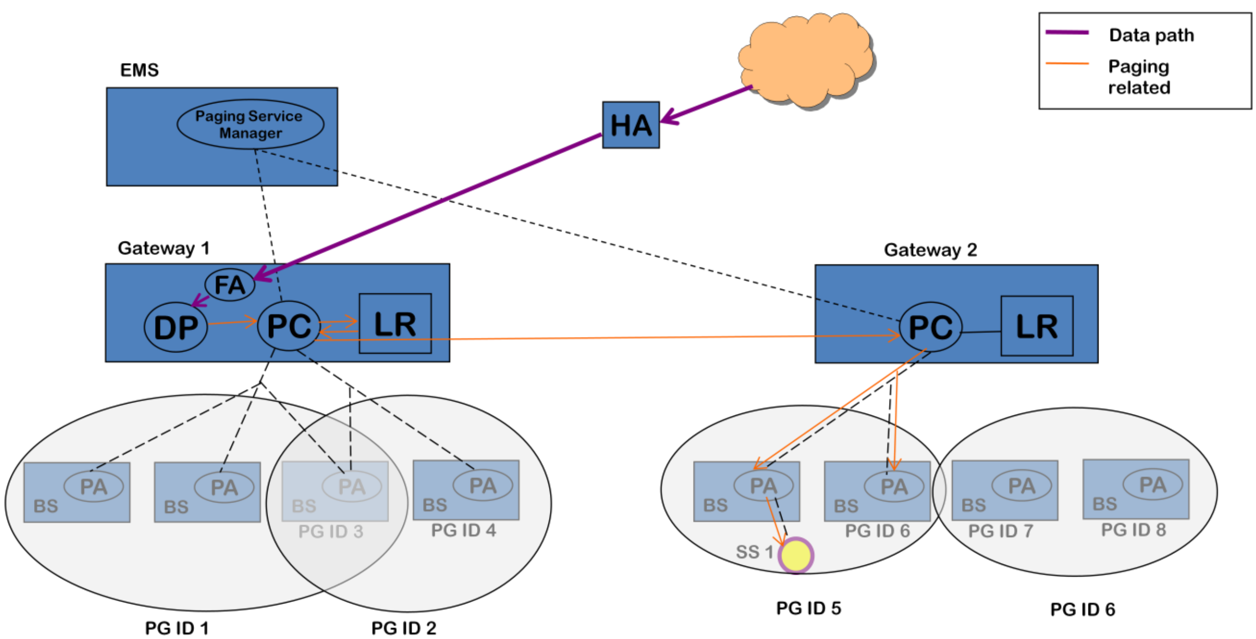

Figure 8 – Paging operation

ASN-GW has the location information provides paging service as well. Paging service tracks subscriber when it is operating in the idle mode. Paging signal is broadcasted when downlink traffic is received. During active operation also location information is updated as mobile subscriber moves to new BS.

The next generation network is a convergence of different technologies. Inter technology mobility is a must and it is being designed in WiMAX, 3GPP, 3GPP2, DSL, and WiFi. Interworking of these technologies increase the importance of ASN-GW since for instance in WiMAX connectivity to 3GPP, 3GPP2, DSL and WiFi are provided via ASN-GW. Interworking may provide common billing and seamless inter-technology handover.

Intelligent ASN Core

Unique position of ASN-GW in the network is a leverage to provide performance enhancements with the inherited information and decision set.

In some configuration handover decision and control may also reside in the ASN-GW (Profile A of WiMAX NWG Release 1.0). Handover decision module requires populating physical signal readings of mobile subscriber. This is used to decide for handover. This decision module also works in conjunction with load balancing module which has the spare capacity report of each BS. Together they manage handover due to mobility or due to load balancing. Note that if handover controller and radio resource management reside in the base station, ASN-GW may still assist load balancing module residing in the Base station by only utilizing the spare capacity information since BS only has limited neighboring information but ASN-GW on the other hand has the information of all BSs.

ASN-GW data plane may provide backhaul optimization in order to reduce the OPEX. Backhaul between base station and ASN –GW is an IP backbone. Due to the multipath fading environment in the wireless channel, utilization of BS may fluctuate and BS starts to buffer incoming packets. An intelligent ASN-GW may stop forwarding packets during this time in order to minimize the backhaul usage. The same phenomena may occur if backhaul is wireless or error prone in which ASN-GW may kick in and reduce downlink forwarding until the link is up.

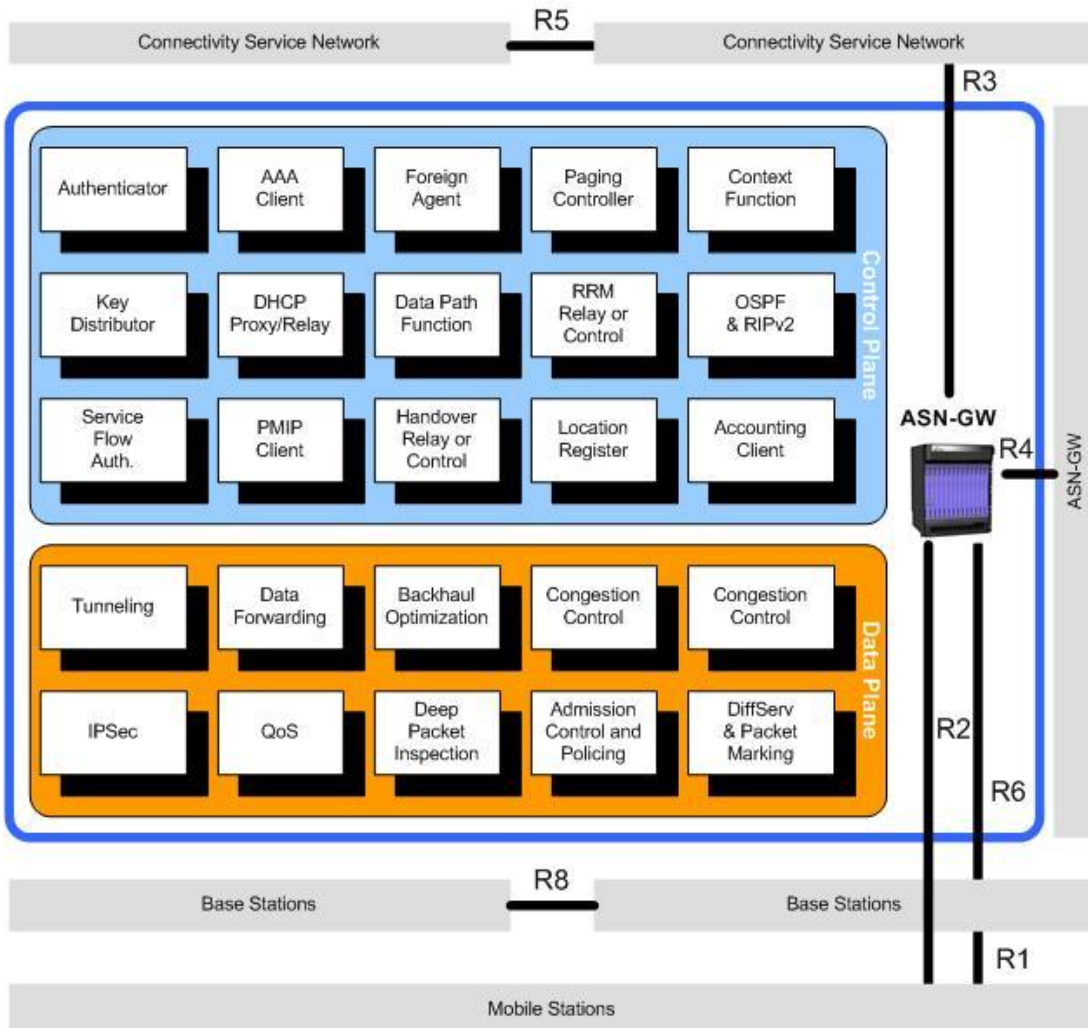

Figure 9 – Intelligent ASN-GW Reference Model

ASN-GW data plane may provide deep packet inspection so that it can identify the type of flow such as peer to peer, online gaming, etc. This way operator directly allows or filters certain type of flows. Deep packet inspection capability also provide information about user since URLs requested by user, and keyword based search is possible. This type of information may be used to build up a behavior index for user in order to customize advertisements.

Figure 10 – ASN-GW, source: WiChorus, Inc.

ASN-GW data plane also assists end-to-end QoS through Diffserv by marking the IP packets with Diffserv codes.

Scalability is fulfilled with additional blades that can be plugged into a chassis to meet more demand as seen in Figure 10. The system can also be customized with this scalable architecture to concurrently address gateway functionality for existing 2G, 3G, and other coming 4G technologies.

Upcoming Features in Release 1.5

The development of WiMAX architecture is an ongoing process. The material in this paper is adapted from [1, 2, 3]. Some highlights about ongoing work which could go into Release 1.5 include the following;

1. **MBS**: Multicast Broadcast Scheme is used in order to provide multimedia content. MBS implements a centralized server to distribute the content and a centralized controller is discussed to synchronize BSs.
2. **Emergency Services**: Emergency call placement is provided with location information. Location information could be cell based, or with GPS.
3. **HO Data Integrity:** It is being designed to reduce the packet loss during handover. Considered approaches are buffering, bi-casting with and without ARQ support flows. Sophisticated handover schemes like Fast-Base-Station-Switching and Macro-Diversity-Handover are considered as well.
4. **IWK**: Dual mode device interworking is being designed for multi radio device with cdma 2000 and WiMAX chips to leverage both cdma2000 EVDO/Rev A and WiMAX networks. This could be data card/USB/Handset. It is designed to maintain the session continuity.

5. **Lawful Intercept**: It is mandated by several national regulations. The basic idea is for the LIS to first identify the MS in question based on the input from the law enforcement agency and then traffic is copied to Law Enforcement Agency by encapsulation.
6. **Location Management**: It is a value-added service that uses information about the location of a user device. Examples are: locating the position of a user on a map, identifying nearby facilities etc. This architecture is facilitated with the ASN along with application servers.
7. **OTA:** Over-The-Air-provisioning is being designed to manage the subscriber before accepting to the network. OTA describes solutions to configure activate, enable subscription for, and manage these device types.
8. **PCC:** PCC describes the dynamic policy and charging control features with interfaces to 3GPP/3GPP2/TISPAN/ IMS network services. PCC encompasses policy control decision and flow based charging control.
9. **ROHC/PHS:** Packet header suppression is introduced in PHS in 802.16e standard. ROHC is a new method which can reduce the IP header
10. **Simple IP**: Simple IP is being designed for operator who would want to deploy fixed WiMAX. This feature does not require a Home Agent.
11. **USI**: Universal Services Interface is a framework for specifying required WiMAX network interfaces towards trusted third party ASPs and iASPs. These network interfaces allow exposure of WiMAX network capabilities and mobile user information between the SP and ASP in a secure and controlled manner. It reuses network intelligence being built into WiMAX to create more revenue.

Conclusion

Fourth-generation networks will emerge from open IP-OFDMA based architecture model to enable horizontal system integration from best suppliers. A different variety of base stations are connected to access gateway to meet the extended coverage with high speeds and end-to-end throughput and all traffic run through these gateways.

Emergence of OFDMA based access in ASN and IP based connectivity in wired domain emerged the need for an IP based radio agnostic gateway to connect these two networks.

The relationship between ASN-GW and BSs is few-to-many which make it critical and rich in information point of view. If we also consider the trend of lighter and lighter base stations with picos and femtos, one can easily realizes the indispensable responsibilities of ASN-GW as a central controller in order to provide the proposed features of 4G. The similar centralized controller is available in DSL, WiFi, 2G, and 3G.

Access gateways play a pivotal role to meet these performance criteria and put a premium on scalability, availability, and manageability. It is an entity in the flat IP architecture with centralized sink, source and algorithms. Its responsibilities include uninterrupted operation of mobile subscriber when it is active or idle with full mobility. It provides security mechanism for IP flows as well as overall network level backhaul management and assistance to air link management.

References

[1] Air Interface for Fixed Broadband Wireless Access Systems". IEEE Std 802.16e-2005, published on 28 February 2006.

[2] “Network Working Group Stage 2 Specification, Release 1.1,” published by WiMAX Forum, September 2007.

[3] “Network Working Group Stage 3 Specification Release 1.1,” WiMAX Forum, September 2007.