Mobile WiMAX Network Architecture

RedMAX 4C Network Architecture Overview

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Introduction

Mobile WiMAX introduces a number of new technologies that increase performance and lower the cost of deploying wide-scale wireless networks. Chief among these technologies is an approach to the physical layer termed Scalable OFDMA (Orthogonal Frequency Division Multiple Access) which reduces the expense of implementing novel techniques that increase the spectral efficiency of the air interface such as MIMO antenna techniques.

Another highlight of the technological innovations brought about by WiMAX is a full end-to-end IP network architecture that sets it apart from the circuit switched architecture of second generation wireless networks and the mixed circuit-packet switched architecture of third generation wireless networks.

The IP network architecture of WiMAX enables multitude of applications brought about by the Internet revolution and allows seamless integration between existing wireline IP networks and wireless networks based on the WiMAX technology. These applications are the vehicle for revenue growth of wireless network operators who have long relied on voice services for the bulk of their revenues. WiMAX allows these operators to address the falling average revenue per user (ARPU) by providing content rich services and data applications.

In addition to contributing to increase the revenue side of the profit equation, an all-IP network architecture helps in driving the capital and operational cost of the core network to new lows by leveraging off-the-shelf routers and existing IP infrastructure. Hence, WiMAX promises to become a disruptive technology which enhances the value proposition of wireless network operators by allowing the delivery of more and better services at lower cost.

This white paper addresses the Redline's Mobile WiMAX Network Architecture and highlights the different deployment possibilities available to network operators to enable them to take full advantage of WiMAX by aligning the network architecture with the service offering.

Mobile WiMAX Reference Architecture

The Network Working Group of the WiMAX Forum has developed the Network Reference Model (NRM) which identifies the functional entities and reference points over which interoperability is achieved between the functional entities.

The NRM is divided into three functional entities: the mobile station (MS), the Access Service Network (ASN) and the Connectivity Service Network (CSN). The Access Service Network includes the set of functions allowing a WiMAX subscriber access to the radio network. The Connectivity Service Network is defined as the set of network functions that provide IP connectivity services to a WiMAX subscriber. Figure 1 shows the network reference model.

The grouping and distribution of functions into physical devices within the functional entities is left to the equipment vendor to decide as long as the implementation meets the functional and interoperability requirements. This is leads to different profiles defined by the particular mapping of the functions to network elements. In one network architecture, the functions are mapped onto two network elements: The base station (BS) and the ASN Gateway (ASN-GW). Other functional mappings and network architectures are possible as well.

The base station performs the radio related functions of the ASN: it includes the WiMAX physical (PHY; Layer 1) and medium access control (MAC; Layer 2) layers. The ASN-GW

performs control functions as well as other functions related to subscriber data such as routing and bridging.

The CSN typically includes the Authentication Authorization and Accounting (AAA) Server, Policy Control Server, Mobile IP Home Agent (HA), Dynamic Host Configuration Protocol (DHCP) Server, and other servers and interworking gateways.

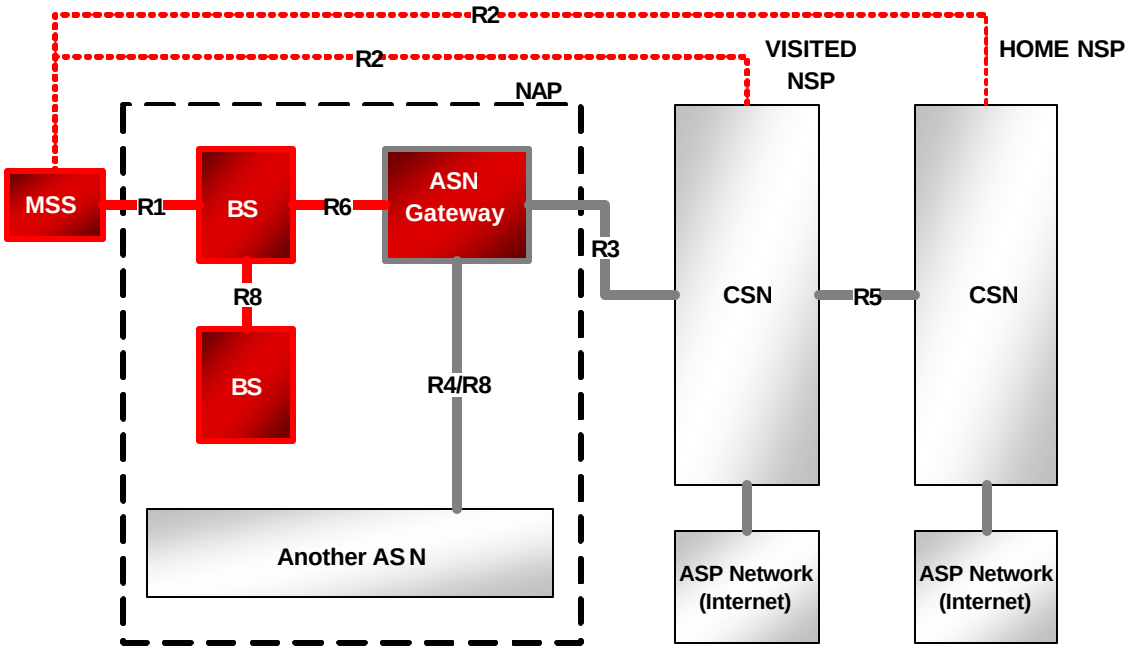


Figure 1 Mobile WiMAX Network Reference Model.

Network Architecture Reference Points

The reference points represent the interface between different functional entities of the WiMAX Network Reference Model. Protocols run between functional entities across the reference points which are used as anchors for interoperability testing. There are two types of reference points: Inter-ASN reference points and Intra-ASN reference points.

Inter-ASN Reference Points

R1: consists mainly of the IEEE 802.16 protocol between the MS and the BS (Layers 1 & 2).

R2: consists of the protocols and procedures between the MS and the CSN mainly associated with Authentication, Services Authorization and IP Host Configuration management.

R3: consists of control plane protocols as well as the IP data plane between the ASN and the CSN.

R4: consists of control and data plane procedures between ASNs and ASN Gateways particularly to support mobility services.

R5: consists of control and data plane protocols needed to support roaming between the CSN operated by a home Network Service Provider (NSP) and that operated by a visited NSP.

Intra-ASN Reference Points

Decomposing the ASN into base station and ASN GW entities give rise to the following reference points:

R6: consists of control (e.g. QoS, security, paging and other mobility related protocols) and data plane protocols between the base station and the ASN-GW.

R7: an optional reference point resulting from the decomposition of the ASN-GW itself into a decision point and enforcement point functions. The enforcement point includes all data plane functions while the decision point includes all the non-data plane functions.

R8: an optional reference point that consists of the set of control plane messages between base stations for handover purposes.

Access Service Network Profiles

An ASN profile defines a particular mapping of functions into base station and ASN GW and exposes reference points over which protocols and messages are defined.

Three basic profiles have been defined by the WiMAX Forum NWG:

Profile A

Profile A is essentially a centralized profile where the ASN GW includes both radio dependent and independent functions. The key features of this profile include the following:

- Handover (HO) Control function is in the ASN GW.
- Radio Resource Control (RRC) function is in the ASN GW that allows Radio Resource Management (RRM) among multiple base stations.
- ASN Anchored mobility among base stations is achieved by utilizing R6 and R4 physical connections.

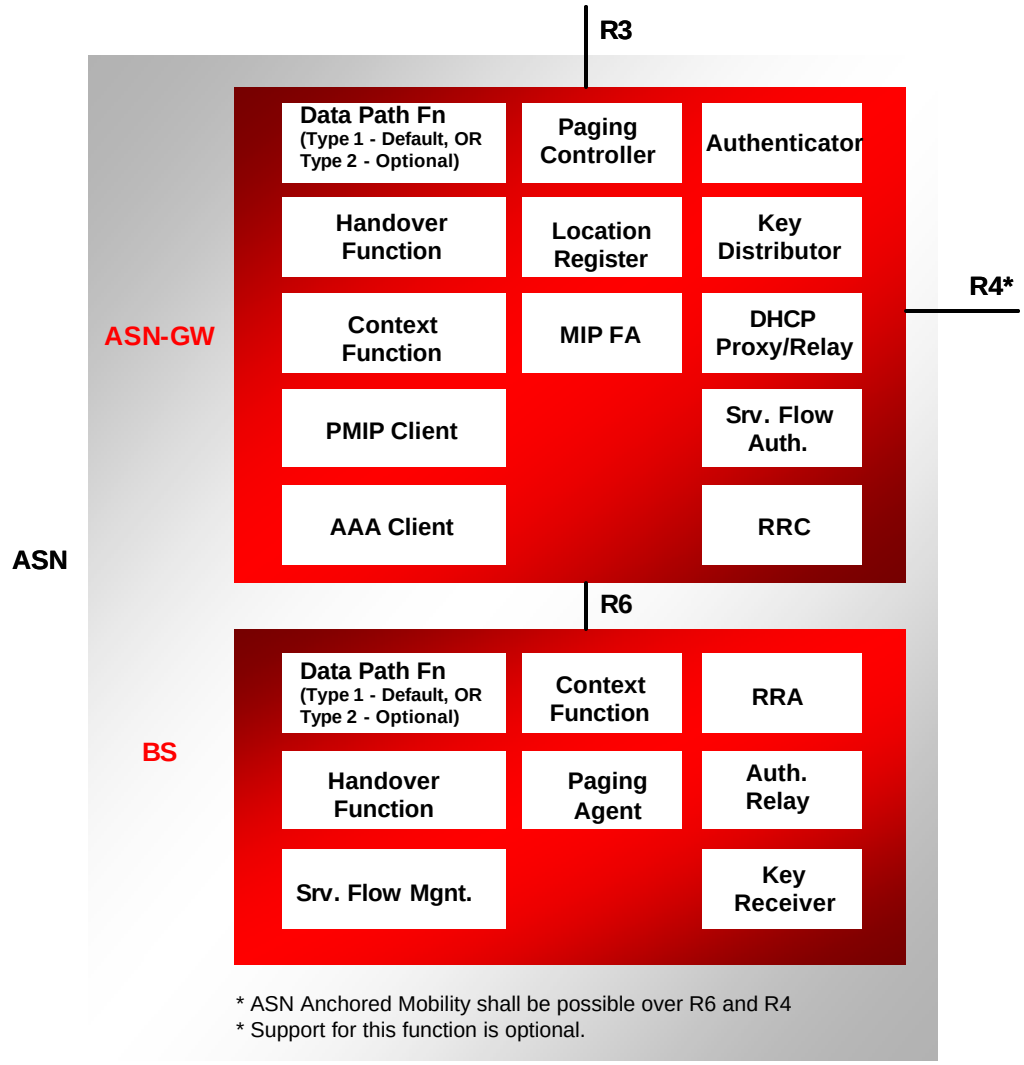
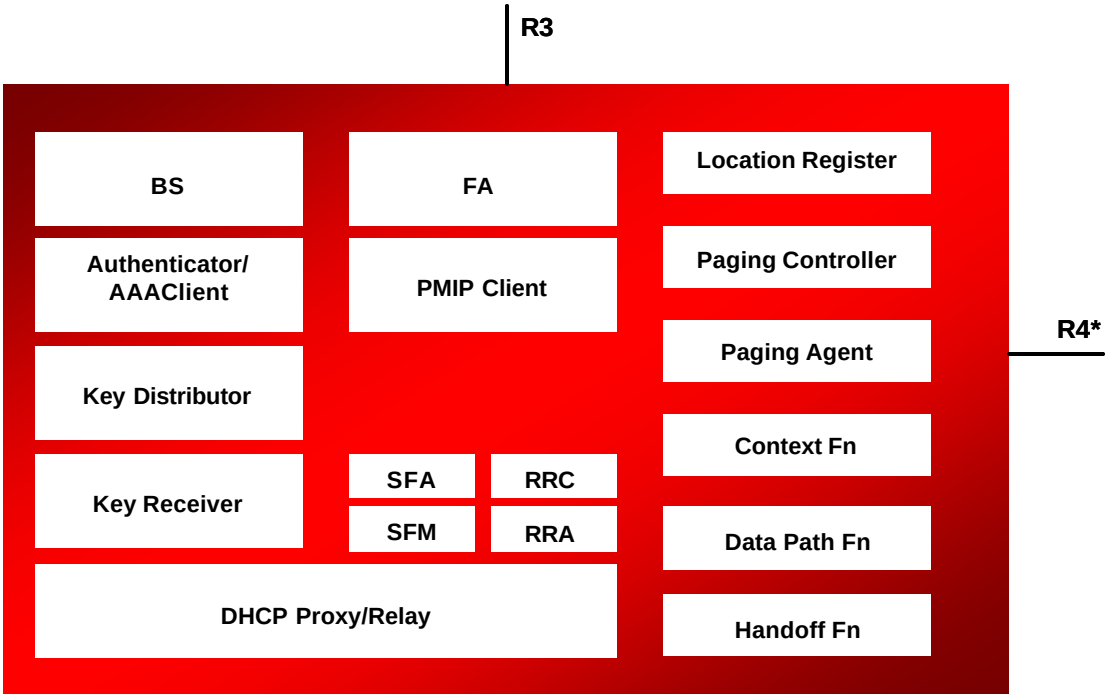


Figure 2 Profile A Functional Decomposition.

Profile B

Profile B can be qualified as an ASN with unexposed (i.e. proprietary) intra-ASN interfaces: The ASN is a black-box where intra-ASN interoperability is not specified. Furthermore, mapping of the ASN functions is not specified which results in different realizations of Profile B implementation. Hence, it is possible to arrive at an implementation where all the ASN functions are located within a single physical device (namely the base station) or an implementation where the functions are spread over multiple physical devices.

Profile B ASNs must be capable of interoperating with other ASNs of any profile over the R3 and R4 reference points to enable multi-ASN networks.



Notes:
1. No assumption made on physical co-location of functions within an ASN.
2. Allows centralized, distributed or hybrid implementations. Intra ASN interfaces are not exposed in this profile..

Figure 3 Profile B Functional Overview.

Profile C

Profile C features a base station that contains radio dependent functions and an ASN GW that includes radio independent functions. The key features of this profile include the following:

- Handover Control is in the Base Station.
- RRC is in the base station that would allow RRM within the base station. A “RRC Relay” is in the ASN GW to re-lay the RRM messages sent between base stations via R6.
- As in Profile A, ASN Anchored mobility among base stations is achieved by utilizing R6 and R4 physical connections.

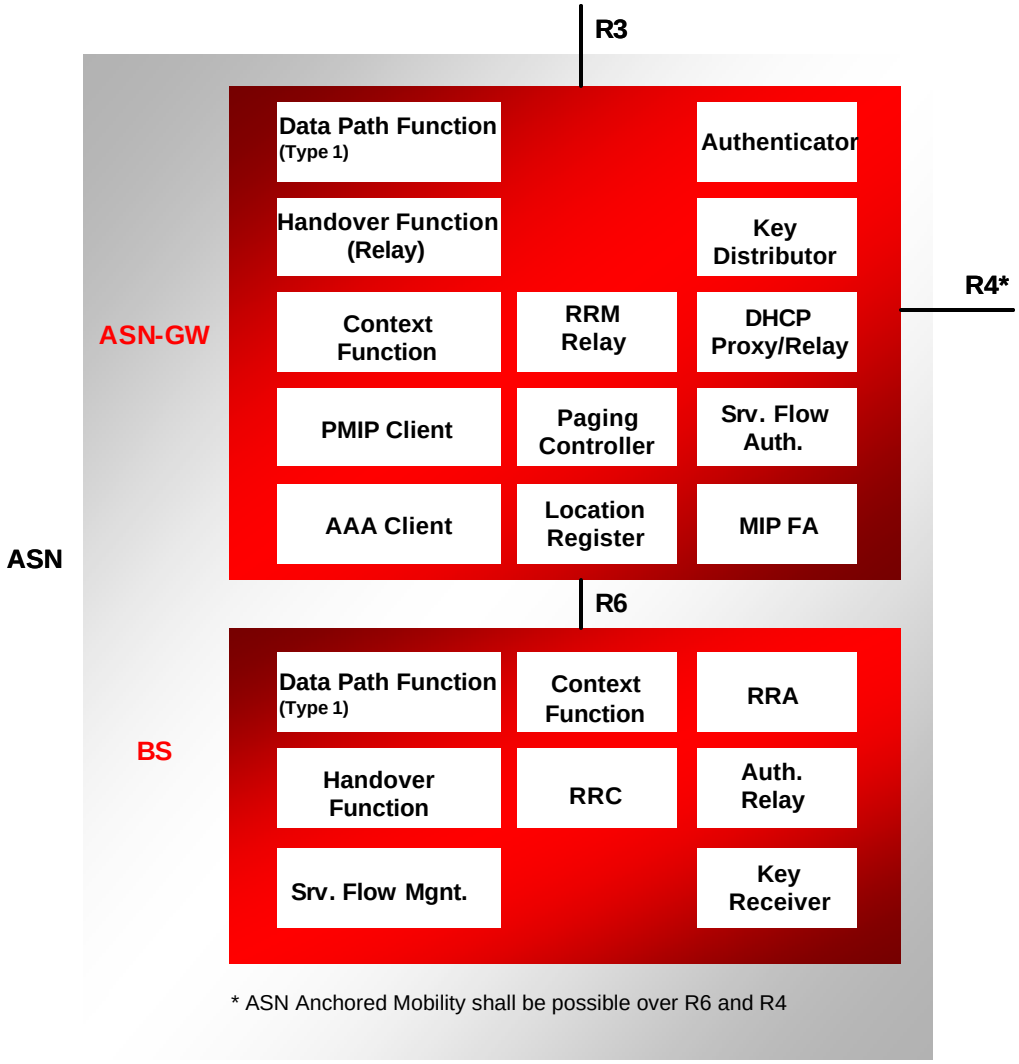


Figure 4 Profile C Functional Decomposition.

Table 1 Profile A & C Functional Comparison.

Function Category	Function	Profile A ASN Entity		Profile C ASN Entity	
		Base Station	ASN Gateway	Base Station	ASN Gateway
Security	Authenticator		✓		✓
	Authentication Relay	✓		✓	
	Key Distributor		✓		✓
	Key Receiver	✓		✓	
Intra-ASN Mobility	Data Path	✓	✓	✓	✓
	Handover	✓	✓		
	Context Server & Client	✓	✓	✓	✓
L3 Mobility	Mobile IP Foreign Agent		✓		✓
Radio Resource Management	Radio Resource Control		✓	✓	
	Radio Resource Agent	✓		✓	
	Radio Resource Control Relay	n/a	n/a		✓
Paging	Paging Agent	✓		✓	
	Paging Controller		✓		✓
QoS	Service Flow Authorization	✓		✓	
	Service Flow Management		✓		✓

RedMAX 4C Network Architecture

Redline's RedMAX 4C SC1000 Mobile WiMAX base station operates in two network architectures, each with certain characteristics that are optimized to deliver fixed and mobile services.

The first network architecture is termed 'Centralized Network Architecture' (CNA) as it features an ASN Gateway that controls a number of base stations. This network architecture is suitable to provide a number of Layer 3 (IP) services such as residential broadband wireless access and personal broadband mobility.

The second network architecture is termed 'Distributed Network Architecture' (DNA) where the base station is connected directly to the core network without the intervention of an ASN Gateway. This network architecture is geared to provide Layer 2 (Ethernet) or Layer 3 (IP) fixed broadband wireless services.

RedMAX 4C Centralized Network Architecture

This network architecture features the RedMAX 4C base station connected to an ASN Gateway over a NWG standardized R6 reference point which allows interoperability with a number of different ASN gateways allowing the network operators maximum flexibility in selecting the right solution to deliver on the planned services and applications.

The CNA is shown in Figure 5. GRE (Generic Routing Encapsulation) protocol runs over the R6 interface and a GRE tunnel creates a point-to-point connection between the base station and the ASN Gateway where all packets are encapsulated with a GRE header.

This network architecture adheres to Profile C functional decomposition where the ASN Gateway includes the "RRC Relay" to relay RRM messages sent between base stations via the R6 reference point.

The centralized network architecture enables IP services as well as Ethernet services subject to the capability of the different ASN Gateways in supporting these types of services. These services include the following

1- Fixed Residential Broadband Wireless Connection: Allows users to connect to the internet for web surfing, email applications, Voice over IP, video download and other applications.
2- Fixed Corporate Services: Allows small and medium enterprises (SMEs) as well as large corporations to connect to the internet providing a host of applications common to the IP platform which runs over the WiMAX network.
3- Mobile Personal Broadband Services: Provides services to handheld devices such as phones, PDA's, laptop computers and other hosts of portable electronic devices that allow the user to connect to the internet anywhere there is WiMAX RAN coverage.

To provide mobility services in the centralized network architecture, the ASN Gateway is complemented by the ASN Controller which is a server hosting Radio Resource Control and Handover Control functions. The ASN Controller communicates with the base station over the R6 control interface. The ASN Controller is not required in this architecture if the goal is to provide fixed services only or mobile services where uncontrolled handover is sufficient (i.e. uncontrolled handover occur when a mobile station arrives at the target base station without prior notification).

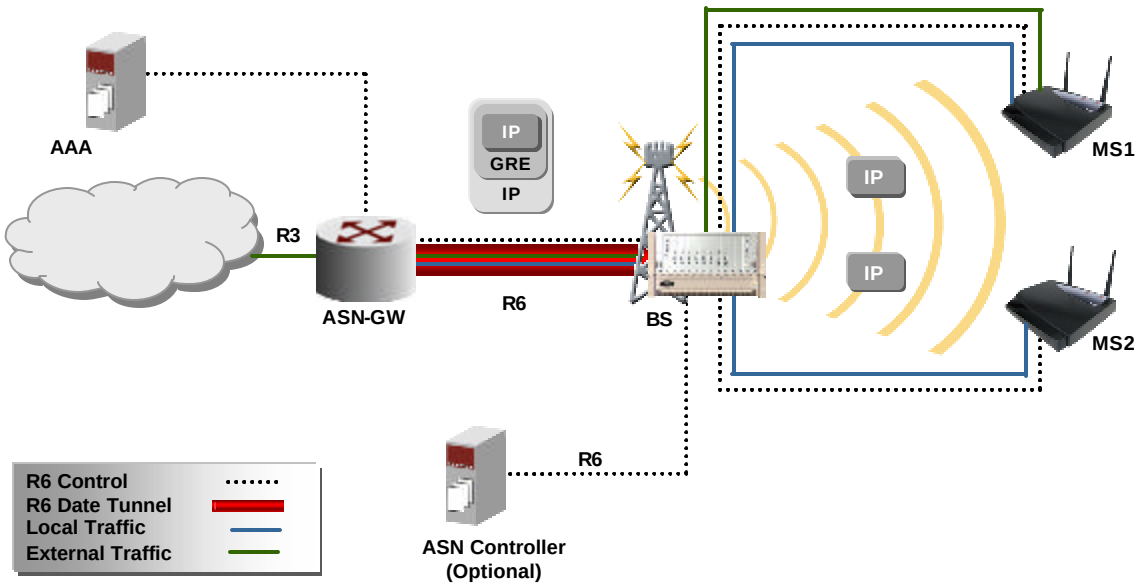


Figure 5 RedMAX 4C Centralized Network Architecture.

RedMAX 4C Distributed Network Architecture

In this network architecture, the RedMAX 4C connects directly to the core network over the R3 interface, hence, no ASN Gateway is required as shown in Figure 6. To enable the subscriber station to access the network, an ASN Controller provides the functions required to establish a data path which include the following

- Authenticator
- Key Distributor
- Service Flow Authorization
- Data Path Function

Most importantly, the ASN Controller does not operate on any bearer paths (i.e. user data), but its function is limited to the control path for the purpose of establishing a link between the subscriber station and the network. The interface between the ASN Controller and the base station is the R6 control interface. Hence, all the interfaces in the DNA are compliant with the WiMAX Forum NWG specifications.

The Distributed Network Architecture allows delivery of fixed and nomadic IP and Ethernet services. These are similar to the ones described above for the Centralized Network Architecture with the exception of the mobility feature. However, the DNA provides a more comprehensive suite of Layer 2 services including the following:

1- Residential PPPoE: Used typically to extend DSL services in areas hard to reach by copper wires, operators can use WiMAX with the same DSL infrastructure to extend and complement existing service.
2- Business Layer 2 Services: Allows Layer 2 Virtual Private Networks (L2VPNs) which is popular due to its cost effectiveness and scalability. In this case, a Metro Ethernet core can be used.
3- Virtual LAN Services: VLAN, which is defined by IEEE standard 802.1Q, allows logical segmentation of entire LAN into different broadcast domains for large networks typically seen in enterprises that may have computers distributed at various physical locations.

Some of the added value provided in the Distributed Network Architecture includes the ability to perform intra-sector, intra-base station packet forwarding which enables partitioned networks for enterprise applications. This is a useful feature that saves on the costs of backhaul while allowing secure, safe and robust communication for corporate offices spread over small or large geographic areas.

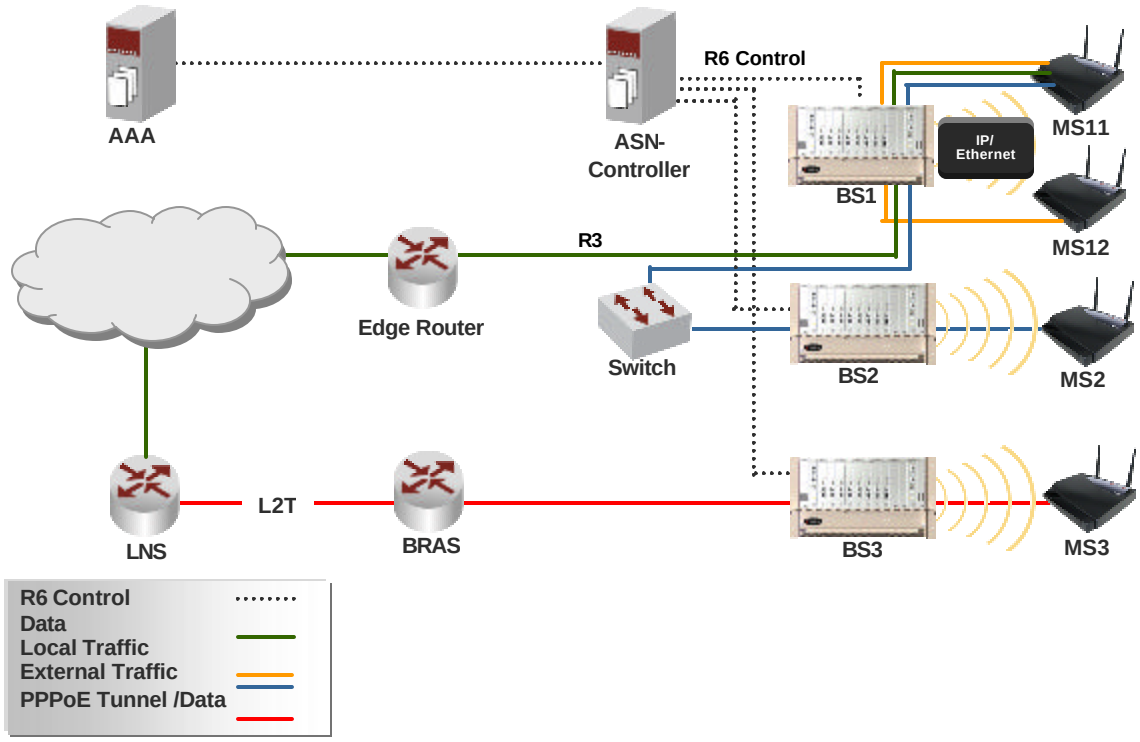


Figure 6 RedMAX 4C Distributed Network Architecture.

Comparative Analysis between CNA and DNA

The Centralized Network Architecture leverages the full extent of Mobile WiMAX network by allowing fixed and mobile services for personal, residential and enterprise market segments. Redline's products feature WiMAX Forum NWG compliant interfaces which are interoperable with ASN Gateways available from different specialized vendors. This enables the network operator to select the ASN Gateway that best fit the operational model and price point that allows a profitable operation.

The ASN Gateway provides key functions that enhance service delivery, profitability and compliance with local regulations including the following functions which many ASN Gateways support:

- Enhanced accounting and billing: The ASN Gateway has the ability to generate detailed billing records (e.g. billing per service flow, billing based on data content, billing per visited web page, etc.). This allows the operator to uniquely price services to maximize profit while allowing the customers to enjoy better services.
- Lawful intercept: The ASN GW includes the necessary hooks to relay information required by law enforcement agencies.
- Location services: The ASN Gateway connects to location servers to pin-point the mobile subscriber in the net-work and generates location specific services.
- Deep packet inspection: The ASN is able to examine the content of the traffic flowing through it on a packet-by-packet basis. Hence it is possible to act on each packet independently. This provides a very fine lever to control the overall network traffic and processes it in a manner most suitable to the network operator for billing or service delivery purposes.

The CNA is most suitable for Greenfield operators seeking to provide fixed and/or mobile services today.

Alternatively, the Distributed Network Architecture is targeted at a network operator intending to deploy fixed services today with migration to mobility in the future. This can be accomplished by simply adding an ASN Gateway to support mobility and upgrading the ASN Controller to include the Radio Resource Management and Handover Control functionality. The DNA is also targeted at carriers seeking to provide enhanced Layer 2 services such as VLAN services for corporate customers or to extend current DSL network by providing residential PPPoE service.

The DNA enables a low cost Mobile WiMAX network deployment because it does not include the ASN Gateway. Hence, it is a useful network architecture as an entry point to roll out IP and Ethernet services which can use the innovations brought about by WiMAX such as Quality of Service assurance, high data rates and low cost of wireless infrastructure.

The Benefits of Open Interfaces

RedMAX 4C base stations feature NWG standardized interfaces and belong to “Profile C” category. This is critical for burgeoning WiMAX networks as it eliminates vendor lock. Standardized interfaces allow network operator to select the best products from various equipment vendors: This includes ASN Gateways and various types of base stations such as macro, pico and femto base stations which are required to ensure wide coverage, high capacity and high performance for indoor applications. Proprietary implementations as characterized by Profile B limits the choices available to the network operator to a single vendor for the complete infrastructure thereby increasing the risk associated with single-source equipment and limiting the network operator to follow a particular vendor roadmap.

Correlated with negating vendor lock, open and standardized interface contribute to lowering the overall cost structure for the network operator as more vendor options are available to choose from. The advantages of open standards clearly place a large burden on operators with proprietary network implementation to compete effectively: it will be challenging meeting the cost points and product variety available from a competitive ecosystem in comparison to a single vendor.