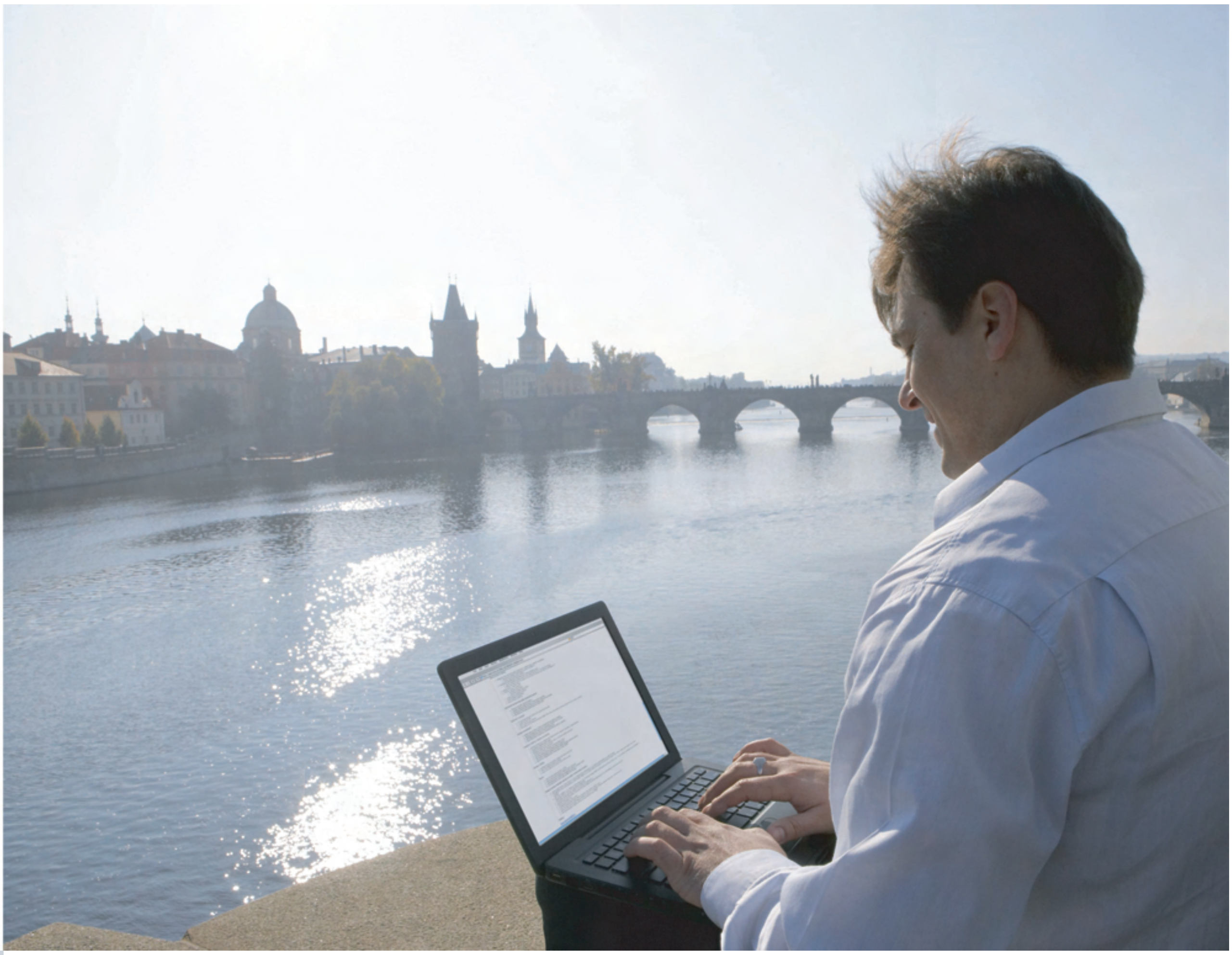


A Broadband Wireless Solution from Cisco and Redline

The Intelligent Access Service Network
Serving Fixed and Mobile Applications

Introduction

WiMAX (Worldwide Interoperability for Microwave Access) is a promising, standards-based technology for delivering advanced fixed and mobile broadband wireless services in emerging, high-growth and developed markets. Cisco Systems and Redline Communications have collaborated to build a WiMAX-based intelligent gateway solution – the Intelligent Access Service Network (I-ASN).

The solution was designed to assist service providers in building efficient, long-lasting infrastructures on which they can offer unique and differentiated services to their target markets. These systems will rapidly generate revenue while protecting network investments with an open, interoperable architecture and an evolution strategy for supporting the portable and mobile applications of tomorrow.

This document provides a detailed description of the key components of the solution, the Cisco/Redline architecture roadmap that service providers can use to bring services to market, and background information on WiMAX.

In accordance with WiMAX Forum and industry practice, the document refers to the IEEE 802.16-2004 system as ‘Fixed WiMAX’ and the IEEE 802.16e-2005 based systems as ‘Mobile WiMAX’.

Many of the abbreviations and acronyms that are used in the document are written in full on their first appearance. However, a reference list is provided in the glossary at the end.

The Intelligent Access Service Network Solution

Solution Overview

The Intelligent Access Service Network (I-ASN) solution has been designed as a result of close collaboration between Cisco Systems and Redline Communications. The I-ASN addresses the need for a flexible and cost-effective method of deploying last mile access to residential and business customers.

The solution is built on two pillars – WiMAX and Metro Ethernet – that are compliant with both the WiMAX Forum and Metro Ethernet Forum specifications. Open standards and interfaces are the cornerstones of the solution, enabling network-wide Quality of Service (QoS) and comprehensive security based on IEEE and IETF models. Ensuring interoperability between Cisco and Redline, these pillars serve as the foundation for a number of revenue-creating services.

Redline and Cisco have developed a three-phase architecture roadmap that gives service providers a strategic approach to help them begin deploying and generating revenue from stationary broadband wireless service today. It also provides a framework for evolving their network infrastructures to support nomadic, portable and mobile services with a low total cost of ownership and good investment protection.

Cisco and Redline have leveraged an open network concept to enable this, and they are developing an ASN gateway to support full mobility applications. This strategy will give service providers the same interoperability on the core side as they have demanded on the access side, avoiding many of the vendor-lock situations common in the 3G world. The ASN gateway will put the key building blocks in place to begin offering portable and mobile services.

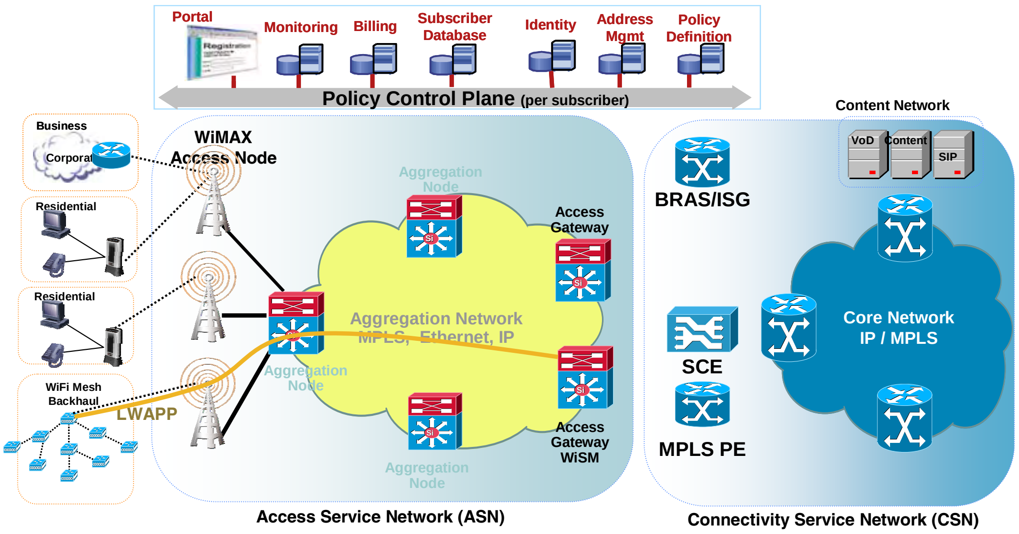


Figure 1: The Intelligent Access Service Network

The Access Service Network

The Access Service Network (ASN) is the radio access network segment of the WiMAX network architecture and consists of the following elements:

- WiMAX base stations that enable broadband wireless access to the subscribers based on Fixed WiMAX technology today and – when product testing and certification are completed – Mobile WiMAX. The WiMAX access network provides Layer 2 transparent bridging capabilities between the subscriber and the network, allowing seamless service interoperability with the Carrier Ethernet network. The centralised scheduler in the base station ensures that service levels can be met in licensed spectrum, allowing operators to deploy carrier grade services.

- WiFi Mesh is a complementary technology to WiMAX that allows client devices to connect to the network using unlicensed spectrum. WiFi Mesh addresses a market in which many client devices have 802.11 technologies built in and therefore reduces the overall acquisition cost for operators by avoiding the need to subsidise client devices. Hot zones are created based on Mesh technology to extend the traditional hotspot concept to outdoor environments for public access. At the same time, operators can create secure virtual private networks for closed communities over the same network. The traffic from the WiFi Mesh network can be backhauled using WiMAX to the wired network.

- The Carrier Ethernet network provides base station aggregation functionality and intelligent network services, while transporting user traffic (such as comprehensive security and network-wide QoS and resilience) to ensure service levels can be met. At the same time it allows service providers to deploy Carrier Ethernet services based on either WiMAX or Ethernet access. Other access technologies such as DSL can utilise the same network by leveraging the aggregation function it provides. This segment of the network is often referred to as the aggregation network.

- The Access Gateway is the demarcation point between the ASN and the CSN (Connectivity Service Network) and is utilised for the aggregation of the access Ethernet rings. The Access Gateway can handle the allocation of IP addresses to subscribers and can enforce security policies. It is also one of the key elements that will allow the I-ASN solution to evolve to Mobile WiMAX in the near future by adding the ASN Gateway module into the platform. The same platform can host the Wireless Controller module for the WiFi Mesh access network; hence there is a unified platform that controls the WiMAX and WiFi Mesh access networks. The access gateway is also referred to as the distribution node.

The Connectivity Service Network

The Connectivity Service Network is a set of network elements that provides the IP connectivity to the service layer. The service layer provides the foundation for enabling the delivery of rich services, subscriber identification and policy enforcement and is an integral part of the Cisco IP Next Generation Network (IP NGN) vision. Cisco is helping service providers evolve towards network convergence through its comprehensive IP NGN vision, architecture and networking solutions.

- The service layer enables WiMAX service providers to optimise application-specific traffic while adding presence and a complete suite of subscriber-aware capabilities. WiMAX operators can effectively address a variety of concerns that confront next generation networks today – such as access reach and management, traffic optimisation, mobile service management and fixed-to-mobile convergence. In addition, the service layer also supports the IP multimedia subsystem (IMS), simplifying and accelerating the delivery of Session Initiation Protocol (SIP) applications.

- Voice network elements such as the soft switch and media gateways are part of the Connectivity Service Network and deliver one of the key applications for WiMAX, namely voice.

Voice Architecture

Voice over IP (VoIP) network architecture characteristics needed for good voice quality require the network to be engineered so that voice packets do not incur more than 150 ms of end-to-end one-way delay (per ITU G.114). This calls for careful capacity planning on the access side as well as a minimised number of bearer traffic 'hops' in the network to reduce network latency and jitter effects.

Different VoIP architecture models can be implemented over a WiMAX network, such as:

- **Point-to-point voice networks**

In the model the voice gateways are interconnected with each other without central call control. This model can be applied in small networks, but does not scale very well because a full mesh of point-to-point IP links is required.

- **Softswitch-based**

Much like Time-Division Multiplexing (TDM), call and application control is centralised; however, the bearer path is decoupled and distributed, enabling better scaling of voice path connections.

- **IMS-based**

Like the softswitch architecture, IMS further decouples call control from the application layer and creates a common SIP-based infrastructure over which other services than voice can also be delivered. Different standards bodies are 'tweaking' the specifications depending on the access medium:

- 3GPP and 3GPP2 for wireless
- ETSI TISPAN for wireline
- PacketCable 2.0 for cable

The WiMAX forum is in the process of aligning with 3GPP regarding IMS.

In the early days of VoIP, point-to-point networks were most widely used. They are still in operation today, due in part to the considerable cost savings they generate when compared with traditional TDM circuit-switched networks, particularly for the brokering of international voice traffic.

Most VoIP networks providing local services today are based on some type of softswitch architecture. IMS networks have not been as widely deployed yet and most vendors are basing the heart of the session control on their existing softswitch offerings.

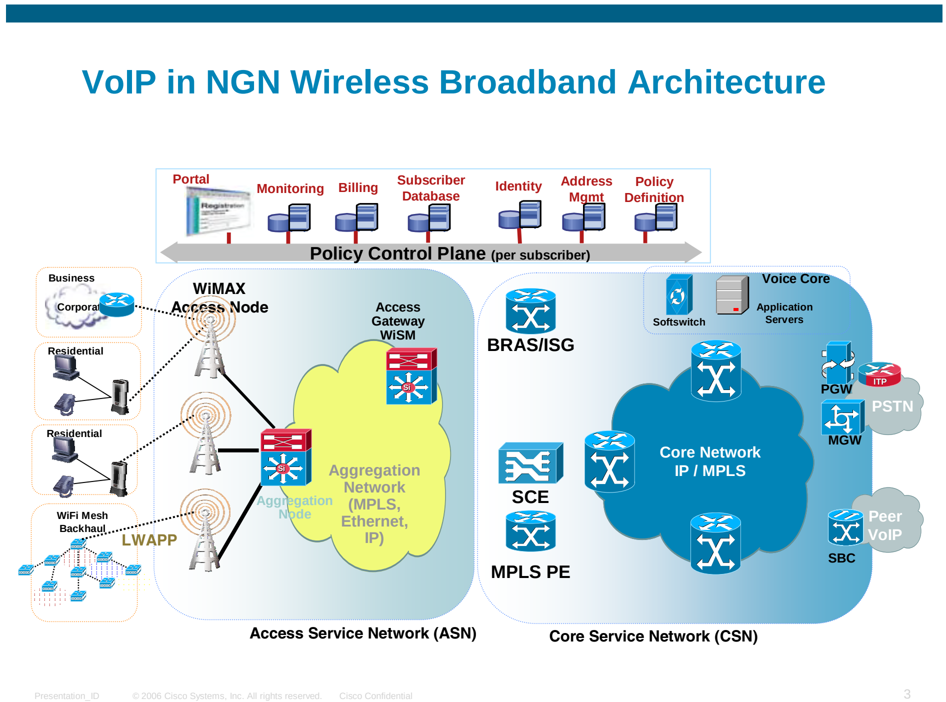


Figure 2: how voice can be added onto a WiMAX network using softswitch technology

Key Components of the Solution

Market-leading, end-to-end WiMAX Forum Certified™ solutions from Redline Communications are combined with best in class IP architecture from Cisco Systems to provide stationary, fixed, nomadic, portable and, eventually, full mobility services.

Subscriber Stations

The Redline RedMAX family includes the all-outdoor SU-O and the SU-I, an indoor subscriber unit that will be submitted to Cetecom (a WiMAX Forum laboratory) in 2007 for certification.

The SU-O and the SU-I are initially being introduced for compliance with the 802.16-2004 standard. A variant of each, the SU-Oe and the SU-Ie, will be introduced in Q2 of 2007, offering software upgradeability to the 802.16e standard and the capability for software selectability between the two standards.

All-Outdoor Unit

The SU-O is an integrated customer premise device that can be easily installed by the subscriber and can be used for indoor or outdoor installations in most countries.

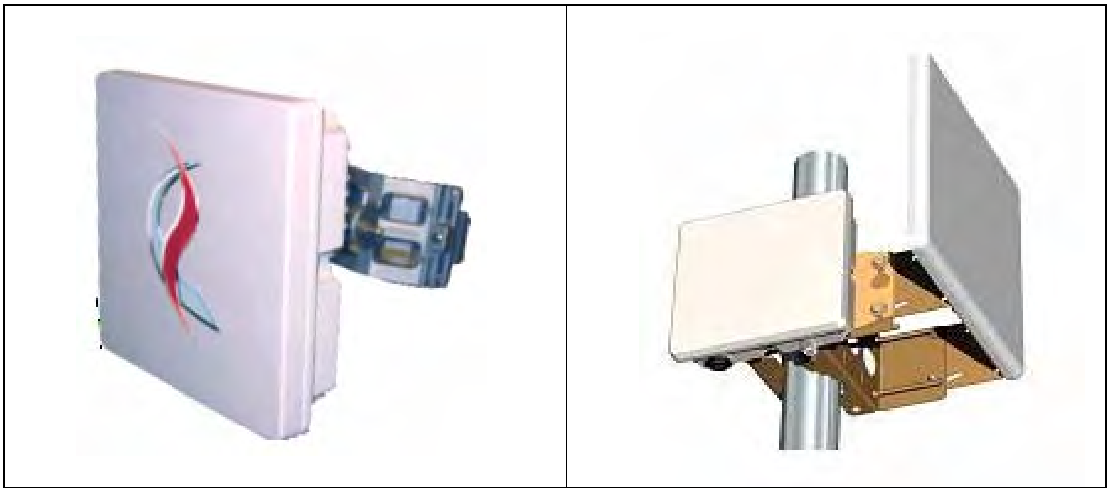
The system is easy and economical to deploy, allowing service providers to quickly provision new services with bandwidth comparable to xDSL. This outdoor unit, with a fully integrated flat panel antenna, or optional external antenna, includes an audible installation tool for quick and simple alignment. An indoor Power over Ethernet (PoE) adaptor provides power for the outdoor unit and an interface for the user's Ethernet network access port.

Initially operating in the 3.4 - 3.6 GHz band, Redline's built-in, third generation of Orthogonal Frequency-Division Multiplexing (OFDM) non-line of sight (NLOS) technology helps overcome typical urban obstacles, such as trees and buildings, while maintaining high reliability. Rugged design standards and sophisticated techniques – including advanced forward error correction – combine to deliver wireline-equivalent high availability.

The very low latency of Redline's RedMAX SU-O ensures reliable delivery of delay sensitive, mission-critical services such as circuit-switched voice traffic, video, VoIP and prioritised data traffic. WiMAX-based compatibility, high performance, and easy installation all combine to make the RedMAX SU-O an excellent choice when deploying wireless broadband for business and residential point-to-multipoint (PMP) access.

Dynamic provisioning will allow for rapid installation with minimum human interaction. New customer premises equipment (CPE) will undergo a ranging process to attempt to enter a network. Initially, the CPE will scan its pre-programmed frequencies to locate a base station sector controller that it can use. It can be configured to scan all available channels for the signal strength RSSI and CINR. The CPE will then lock on to a channel as soon as it receives valid maps including validation of an approved CPE within the network using its X.509 digital certificate.

The SU-O can be installed with its integrated antenna or with a larger external antenna as shown in Figure 3.



Integrated Antenna **External Antenna**

Figure 3: The SU-O can be installed with its integrated antenna or with a larger external antenna

All-Indoor Unit

The RedMAX SU-I is an indoor broadband wireless subscriber access product designed to WiMAX Forum Certified™ specifications.

The SU-I (see Figure 4) is the WiMAX industry’s easiest and most economical indoor access solution to deploy, allowing service providers to quickly provision new service offerings with bandwidth comparable to or greater than xDSL or cable. Simple self-installation and an integrated antenna with signal strength LEDs for quick setup make the RedMAX SU-I the ideal solution for both enterprise and residential applications.

Figure 4: The SU-I shares all the characteristics of the SU-O

Operating in several RF bands, Redline's integrated third generation OFDM, NLOS technology helps overcome typical urban obstacles such as trees and buildings while maintaining high reliability. Stringent design standards and sophisticated techniques, including advanced forward error correction, combine to deliver wireline-equivalent high availability.

The very low latency of Redline's RedMAX SU-I ensures reliable delivery of delay-sensitive services such as video, VoIP and prioritised data traffic. The RedMAX SU-I supports VoIP interfaces to deliver toll-quality voice and data traffic with service level agreements and guaranteed QoS.

Residential Gateway

The residential gateway plays an important role in delivering voice and data services to the same subscriber. The residential gateway offers connectivity to residential peripherals such as analogue phones, personal computers and gaming consoles. Network features such as 802.1Q for service traffic segmentation and application layer gateway for correct network address translation (NAT) operations, plus an optional PPPoE client, are common in such a platform. The residential gateway is deployed behind the WiMAX CPE and is a key requirement for multi-service delivery to residential subscribers.

Business CPE

The Cisco Integrated Service Router (ISR) platforms deliver combine intelligent network services, security and wireless technology in a single, resilient system for fast, secure and scalable delivery of mission-critical business applications. The routed CPE is positioned for Layer 2 and Layer 3 VPN services and is an integral part of the service provider managed service proposition.

WiMAX Access

The RedMAX™ AN-100U Base Station is the world’s first WiMAX Forum Certified™ base station. It leverages Redline’s expertise as the world leader in 802.16-based systems.

RedMAX supports multiple traffic classifiers that give the operator the ability to offer distinct services based upon traffic type. RedMAX can distinguish between VoIP traffic (identified by DSCP or TOS bits, for example) and basic Internet traffic.

The RedMAX AN-100U Base Station is based upon a 1U rack-mounted sector controller, of which each unit comprises a sector. Multiple sector controllers can be hosted in a single rack to create a multi-sector base station and can be used in a single sector or combined for up to six sectors (6 x 60 degree coverage).

Due to the base station being completely modular, operators can deploy RedMAX equipment in order to maximise their network usage and capital expenditure, and simply extend their network to suit their business needs and customer growth patterns.

QoS on a RedMAX Network

A RedMAX network has three logical components which determine Class of Service and Quality of Service in the network: Service Class, service flow and Classifier.

The service class is the high-level set of parameters that determine QoS for traffic. Service class comprises four types of services:

- **Unsolicited Grant Service** (UGS) is the functional equivalent of CBR in the Asynchronous Transfer Mode (ATM) world. This service is guaranteed, regardless of traffic utilisation or network utilisation. It is considered inefficient for most traffic except for true TDM (E1 or T1) replacement services.

- **Real-time Polling Service** (rt-PS) is the near equivalent of VBR-RT in ATM. It allows the operator to specify both a peak throughput rate as well as a guaranteed minimum throughput rate, in addition to guaranteed latency numbers. rt-PS is best suited to VoIP services, as well as any other applications which are sensitive to latency and jitter.

- **Non Real-Time Polling Service** (nrt-PS) is similar to VBR-nRT in ATM. It allows an operator to specify a minimum throughput rate, in addition to a peak throughput rate. Latency, however, cannot be guaranteed. nrt-PS is best suited to applications that are not sensitive to latency or jitter, but it does require a minimum level of data throughput (such as FTP). This is an excellent service for differentiated business services.

- **Best Effort** (BE) is nearly identical to UBR in the ATM environment. BE allows an operator to specify a peak throughput rate, but with no guarantees of minimum throughput rates or minimum latencies. This service best lends itself to applications such as low-end business Internet access or residential Internet access.

Service flows are the logical connections between the RedMAX base station and each RedMAX subscriber station. A service flow consists of a subscriber identification (MAC address, for example) and an assigned Service Class. Multiple service flows (with different Service Classes) can be created for each RedMAX subscriber station.

The final element of the solution is the classifier. Each service flow, by default, will not pass any traffic without a classifier being associated with the service flow. Classifiers are the logical component that determines what type of traffic will flow onto the various service flows. Classifiers can be based upon Layer 2 (VLAN ID, MAC address, Ethertype,) or Layer 3 (IP address/subnet, port, DSCP, TOS). Classifiers also support Boolean logic, which means that multiple classifiers can be assigned to a single service flow. These can be in an AND situation (both classifiers must be met for traffic to pass), or an OR situation (either classifier must be met for traffic to pass).

It is important to note that the RedMAX base station will act upon traffic parameters passed to it (DSCP, for example), but will not implement QoS parameters on its own. The RedMAX base station can read and act upon QoS parameters, but will not add them, nor will it strip them off. The CPE is required to implement QoS parameters, should they be required by the operator.

The Aggregation Network: Carrier Ethernet

The aggregation network, based on the Cisco Carrier Ethernet solution, is built on three layers, each with a distinct function:

- The access layer comprises WiMAX base stations and Cisco Metro Ethernet access switches based on the Cisco ME 3400 or the Cisco ME 3750 platforms.
- In larger deployments the second layer performs high-capacity aggregation, when other access technologies such as DSL are being aggregated within the same Carrier Ethernet network. The Cisco 7600 Series router platform is positioned to perform this function in the second layer.
- The third layer is the distribution layer where the access gateways are deployed, based on the Cisco 7600 Series platform. The distribution layer is the demarcation point between the aggregation network and the core network (including the service edge) from an IP network perspective. But it also represents the demarcation point between the ASN and the CSN from a WiMAX Network Reference Model perspective.

The physical topology of the access layer is deployed from the distribution nodes, using Gigabit Ethernet rings, to reach the cell sites within a geographical area. The rings are formed by the access switches and connect the RedMAX sector controllers. An alternative to the ring is a ‘hub and spoke’ topology. The choice of the physical deployment model depends on the fibre layout and availability, bandwidth requirements and the related costs. In areas where there is no fibre availability the traffic is backhauled using wireless point-to-point links.

Depending on the base station sector configuration, there would be a maximum of six sector controllers per access switch. The physical connection between the sector controller and the access switch is based on Fast Ethernet. The RedMAX sector controller has dual Fast Ethernet interfaces, one for the data plane and the second for out-of-band management. In-band management is also supported via the data plane port.

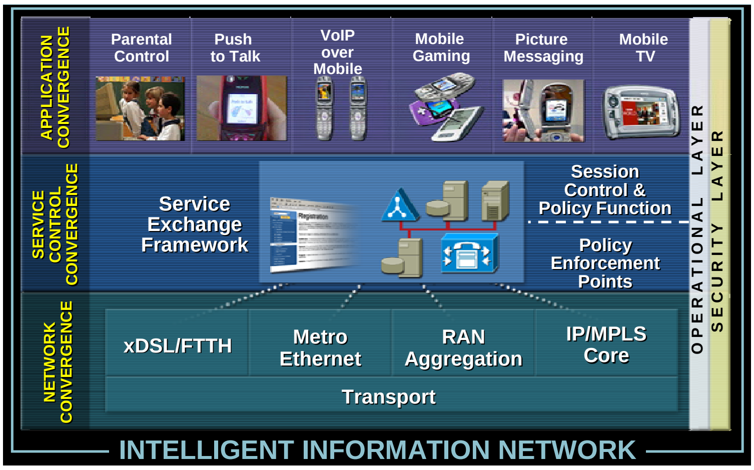
The access layer is deployed as Layer 2 bridge domains and uses STP (RSTP/MST) in ring topologies and FlexLink for hub and spoke to achieve resilience in the network. The WiMAX base station sector controllers are connected to the access switch using 802.1Q trunk on the link layer to allow multiple VLANs to be transported over the WiMAX network. No Layer 2 control protocols, such as STP, are exchanged between these two network elements. The WiMAX network is a transparent bridge that forwards the Ethernet frames unmodified. Alternatively, the access network can be implemented using Multiprotocol Label Switching (MPLS) to create a virtualised Layer 2 bridge domain using Ethernet over MPLS point-to-point pseudowires. Point-to-multipoint topology is achieved using Hierarchical Virtual Private LAN Services (H-VPLS) and is an interworking function between the access and distribution layer. The MPLS model is supported using the Cisco Catalyst 3750 Metro Series platform, in combination with the Cisco 7600, and the Ethernet model is supported by the Cisco ME 3400 and Cisco Catalyst 3750 Metro Series. The access layer enforces the QoS policies through shaping and policing to ensure fairness is achieved between different traffic classes and agreed service levels are met. Classification is based on the 802.1P class of service bits and, with the marking and remarking functions, operators can enforce the trust boundaries within the network. The scheduling function, based on priority and class-based weighted fair queuing algorithms, ensures that real-time applications such as voice meet the latency and jitter requirements.

The distribution layer performs the aggregation function of the access rings and is the demarcation point between the access network and the service edge network elements. This layer also has an interworking function with the IP NGN core network. The distribution node delivers the traffic to the service layer elements such as the BRAS (PPP) or ISG (IP model) for subscriber authentication and per subscriber policy enforcement. In deployments where the broadband network gateway elements are not present, the distribution node will perform the allocation of IP addresses to subscribers through a Dynamic Host Configuration Protocol (DHCP) relay function. For business services, the distribution node maps the 802.1AD (QinQ) tagged traffic into EoMPLS pseudowires and transports it across the MPLS network; this network function enables Layer 2 VPN services. A MPLS VPN can be initiated from the distribution node; in larger deployments the traffic is forwarded to a dedicated MPLS PE router.

The Service Edge: Cisco Service Exchange Framework

Today, very few initial WiMAX service offerings are either based on SIP or are planned to be SIP-based. The Cisco Service Exchange Framework (SEF) helps operators quickly and profitably deploy the high-average revenue per user (non-SIP) services needed today, while paving the way for migration to SIP services when they are commercially viable. These include differentiated triple play services – the ability to combine voice, video and data, more securely and more profitably.

A-IMS, a variant of the IP Multimedia subsystem (IMS) framework now being promoted by 3G operators like Verizon Wireless and others, is also being considered by WiMAX operators as a possible strategy for SIP-based application and service delivery. Cisco believes A-IMS will become an important part of WiMAX operators' overall application and service delivery strategies moving forward. IMS is a powerful framework, which has gained momentum largely because of the industry's acceptance of two major technological building blocks – IP and SIP. Cisco has been, and will continue to be, a leader and innovator in both of these protocols, as well as with A-IMS. Working with operators and standards bodies on the A-IMS standard, Cisco seeks to address IMS shortcomings, including complexity, high cost, inadequate security, latency and lack of support for non-SIP applications.



The Cisco SEF provides a comprehensive service delivery approach that helps WiMAX operators quickly and profitably deploy SIP, non-SIP and hybrid services. The ability to identify subscribers and classify applications on the IP network helps ensure that services such as VoIP, video on demand (VoD) and interactive gaming can be prioritised to ensure price premiums. 'Follow me' mobility is another example of how the Cisco SEF can be used to create high-value, high-margin differentiated services. Users can easily maintain the same voice, data or even video connection that they have in the office as they walk to their car, arrive at the airport and finally arrive home. Through the SEF framework, Cisco aims to provide application mobility over the most reliable and cost-efficient network.

The Cisco SEF is cost effective because it protects WiMAX operators' existing infrastructure investments with a flexible, open API solution that supports evolving IMS architectures and new services. Cisco SEF solutions are standalone in-line hardware and software solutions that do not duplicate or interfere with any essential networking functions, such as access or aggregation. This means WiMAX operators can deploy this critical service control layer in a phased approach that meets their business and service needs. With the Cisco SEF, operators can define the unique scope and timing of their service control layer deployment.

Table 1.

Features	SEF Benefit to WiMAX Operators
Usage Analysis	Improve business models – Operators must accurately understand their subscribers' usage in order to develop new business models for revenue generation.
Traffic Optimisation	Improve customer satisfaction, reduce costs – Using state-of-the-art bandwidth management allows operators to dictate how to distribute network resources, resulting in improved subscriber experience and overall satisfaction with network performance as well as reduction in transit costs and costly network upgrades.
Service Security	Improve security, reduce costs – Service control-enabled networks stop and proactively mediate security threats that create unwanted traffic and network congestion while increasing costs.
Tiering and Access Control	Improve customer satisfaction – The Cisco SEF helps ensure that operators can account for usage on an individual subscriber level, while enforcing different policies on a variety of applications or services. This allows operators to provide Bandwidth on Demand services and allows subscribers to select or gain access to the content or resources of their choice.
Content Charging	Increase revenue – The SEF allows operators to finely control and classify traffic so they can charge subscribers in real time based on sophisticated rate plans, allowing them to add prepaid and postpaid content-based services to service offerings.
Premium Service Enablement	Decrease costs – SEF technology helps enable dynamic, real-time provisioning of network QoS based on application activity, greatly simplifying integration and costs associated with multiservice delivery.
Over-the-Top Video, Voice and Gaming	Provide differentiated services – SEF allows service providers to efficiently and equitably identify non-facility service traffic streams for billing, auditing and guaranteed performance.
Mobility Service Enablement	Enhance services, improve customer satisfaction – SEF helps enhance mobility application services by allowing operators to know their users' locations so they can provide mobile users with real-time, personalised, relevant information – such as local times, weather conditions or local news events – on top of the WiMAX 802.16e mobility standards.

Table 1: Cisco SEF Features and Benefits

End-to-End Quality of Service

The Intelligent ASN solution enables network-wide QoS based on IEEE and IETF standards to meet stringent requirements for real-time applications and business-critical traffic while giving fair treatment to other Classes of Service.

The QoS domain follows the IETF Differentiated Services (Diffserv) Model that aggregates traffic flows into several Classes of Service. The WiMAX access network follows the IEEE 802.16 standard that specifies four scheduling classes called service flows which facilitate priority access to the wireless medium. The four scheduling classes address the need for bitstream, real time, non real time and best effort services. The WiMAX scheduling classes are mapped into the Diffserv Expedited Forwarding (EF) and Assured Forwarding (AF) classes.

Residential Voice and Business Real-time Services (and their associated signalling) are classified in two traffic classes that will use the Expedited Forwarding PHB behaviour, described in RFC 3246, due to the stringent latency requirements of these services. The Expedited Forwarding PHB defines a scheduling behaviour that guarantees an upper limit on per hop jitter that can be caused by packets from non Expedited Forwarding services. These traffic classes will be serviced in the aggregation network by different priority queues with the same priority level to enable different service level agreement (SLA) enforcement through policing.

These two traffic classes use the same priority queue in the access network. The Assured Forwarding PHB guarantees a certain amount of bandwidth to an AF class while guaranteeing a certain limit of jitter and latency.

In order to provide differentiated bandwidth guarantees for in contract and out of contract traffic, Business Critical Services are classified in two different classes that use the Assured Forwarding PHB behaviour, described in RFC 2597. These two traffic classes are serviced by a common weighted queue with different drop preferences.

Residential Internet Access and Business Best Effort Services are classified in different classes that use the Best Effort PHB behaviour.

Traffic Class	Core /Edge/ Aggregation			Access	UNI		
	MPLS/IP			Ethernet	DSL, ETTX	DSL	WiMAX
	PHB	DSCP	MPLS EXP	802.1P	802.1P	ATM	802.16
Control Protocols Network Management	AF	48	6	(6)	(6)	VBR-nrt	nrtPS
Residential Voice	EF	46	5	5 and 7	5 or 7	VBR-rt	rtPS
Business Real-time	EF	56	7				
Residential TV and VoD	AF	32	4	4 and 3	4	VBR-nrt	NA
Residential D-Server Video	AF	24	3				
Business Critical In Contract Business Critical Out of Contract	AF	16 8	2 1	2 and 1	2 1	VBR-nrt	nrtPS
Residential HSI Business Best Effort	BE	0	0	0	0	UBR	Best Effort

Table 2: Mapping of the QoS across the different domains

Core network traffic marking is based on MPLS EXP. The core network may use different traffic marking and simpler PHB behaviours, therefore this requires traffic remarking in between the aggregation/edge and core networks.

Securing the network

In order to deliver revenue-generating services for their business and residential customers, it is critical for service providers to maintain network operations and uptime. To sustain service uptime, many factors need to be considered, not the least being infrastructure security. Infrastructure security is the methodology for applying tools and techniques to preserve the integrity of the network.

The WiMAX access network implements device authentication based on privacy key management (PKM) version 1 using X.509 digital certificates. Local switching within the base station is disabled, to protect subscribers from other customers in the network. Subscriber traffic is isolated until a central point within the network where security policies can be applied to mitigate malicious events between subscribers. Confidentiality over the air interface is achieved via encryption-based 3DES or AES. This allows the operator to control when, and if, end users are able to communicate with each other at a Layer 3 level.

Within the Carrier Ethernet network, one of the challenges that service providers are facing is to provide the same level of security as other access technologies, not only in the case of direct Ethernet connection but also when the access is based on WiMAX. To meet this challenge, the I-ASN solution provides a very comprehensive security solution for Carrier Ethernet networks that identifies three areas of security and designs features for each. These three security areas are subscriber security, infrastructure security and network security. The architecture then delivers a complete solution at the access layer of the Carrier Ethernet network.

- **Subscriber security** – one of the biggest concerns about using a shared device for multiple customers is how to prevent customers affecting each other. The architecture addresses this concern by providing features such as DHCP Snooping, Dynamic ARP Inspection and IP Source Guard which help service providers identify each customer based on MAC, IP address and port information. With this information, service providers can prevent malicious users from spoofing fake addresses and launching man-in-the-middle attacks.

- **Infrastructure security** – Cisco Carrier Ethernet switches offer features to protect the CPU and configuration files from attack. The CPU is a critical component of an Ethernet switch. It is responsible for process control protocols such as Spanning Tree Protocol and routing updates. If the CPU is under DoS attack, those control packets could be dropped and result in a network outage. Features such as Control Plane Security and Storm Control protect the CPU against malicious attacks. Port Security is another important feature that allows service providers to control the number of MAC addresses each subscriber is allowed. This feature prevents the network from overwhelming the switch memory.

Network security – the features designed for this area filter all incoming traffic to help ensure that only valid traffic is allowed through the network.

Go to Market Guide

Applications and Services

Some typical applications for WiMAX point-to-point (PTP) and point-to-multipoint (PMP) arrangements are shown in Figure 5 with a general PMP system.

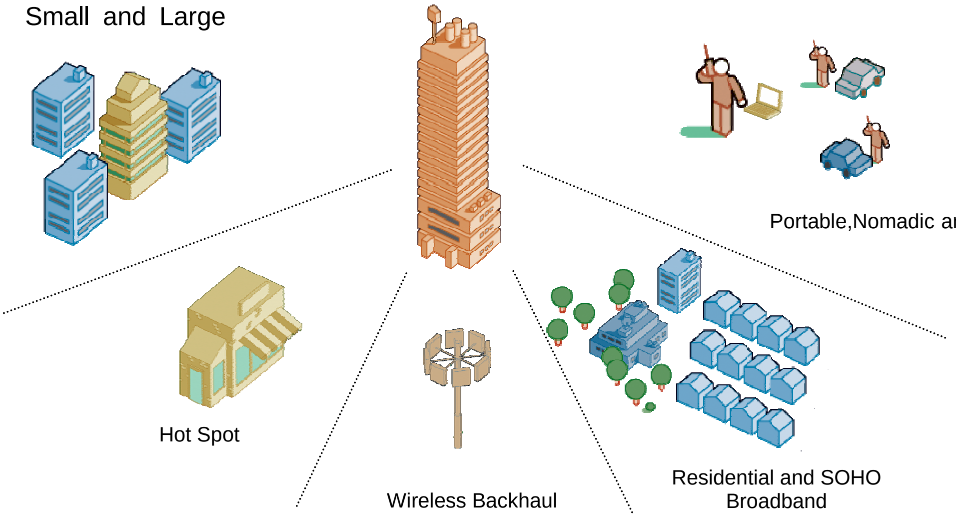


Figure 5: Typical applications for WiMAX PTP and PMP arrangements

Business Services

Business services are typically high-margin, revenue-generating services that address the ongoing need for interconnecting enterprise offices through secure, reliable virtual private networks (VPNs). Managed services like security, voice and video are a solid source of revenue for service providers.

Virtual Private Networks

The market for VPNs continues to grow along with the need for organisations to share confidential information over a public network. For a fraction of the cost of traditional leased lines, organisations can confidently share sensitive information with remote offices, telecommuters and business partners. With WiMAX and the Cisco Carrier Ethernet solution, VPN services can easily be provided using MPLS technology. The Cisco and Redline solution allows the operator to deploy Layer 2 Ethernet-based services or Layer 3 VPNs to address the market requirements.

Managed Services

IT managers must clearly demonstrate a rapid return on their capital investments and minimise operating expenses while delivering productivity services that are essential to the business. Network consolidation tends to simplify the deployment and ongoing management of converged communications services. The migration process, however, can overwhelm already scarce capital and human resources. The same applies to security – the number of new threats and corresponding security technology developments is increasing every day. In the face of these challenges, organisations are increasingly turning to service providers with the expertise, infrastructure and resources to reduce deployment time and complexity. This has resulted in a growing need for managed services that enable WiMAX operators to capitalise on opportunities to increase their overall value proposition in the market. Two examples of managed services are outlined below.

- Managed security – this is the out-tasked management and monitoring of network and customer premises security devices, systems and processes according to a business's security policy. Managed security services include all the provisioning, installation, maintenance, monitoring, operations and administrative functions associated with managing a secured network environment. The primary benefit is 24-hour service that improves network security and lowers costs.

- Managed voice – where service providers offer end-to-end converged network services to organisations of all sizes worldwide. Service offerings typically include business voice service, site-to-site voice services, PSTN access, unified messaging and enhanced IP services. In addition to networked communications, service providers can provision, monitor, maintain and troubleshoot business voice infrastructures.

Residential Services

The residential market requires a different service delivery approach and go-to-market strategy. The self install capability of the Cisco and Redline solution is one of the key enablers for addressing mass market opportunities. It is critical for service providers that the provisioning cost per new subscriber is significantly reduced and that there is simplified and accelerated service activation. This can be achieved by having the subscriber perform self installation without operator intervention.

Internet access is probably the most popular service for residential subscribers and can be offered through WiMAX as an asymmetrical service with different bandwidth profiles that address multiple market segments. Multiple connection models such as IP and PPP are supported to give the operator the flexibility to choose the preferred method that meets its requirements. The IP model is typically deployed in a direct model, while PPP tends to be the favourite in wholesale models. Subscriber awareness and identification are key requirements for both models and are addressed in the solution.

The residential voice market represents another viable opportunity for service providers to deliver voice services over WiMAX access networks. Operators that choose to deploy WiMAX can leverage low-cost CPE devices and built-in QoS to ensure that latency requirements are met for delivering bandwidth-intensive services and applications.

The Architecture Roadmap: Serving Fixed and Mobile Applications

The Cisco and Redline architecture roadmap is designed to enable service providers to smoothly evolve their networks with newer and enhanced versions of the standards, when they are available and certified for conformance and vendor interoperability. The evolution of the architecture has been designed to minimise impact on the network and related services. This strategy enables operators to generate revenue today and gain competitive advantage by capturing market share and ensuring network investment protection going forward.

Phase I: Time to Revenue Advantage

With this first phase, Cisco and Redline give service providers a time-to-revenue advantage to capitalise on the opportunity of underserved markets. For the radio packet infrastructure, the RedMAX™ AN-100U Base Station leverages Redline’s expertise as the world leader in 802.16-based systems.

The system is based on Time-Division Duplex (TDD) technology, which allows operators to adapt spectral use to traffic patterns consistent with IP, increasing spectral efficiency, for an increasing IP application requirement.

In addition, Redline has released the RedMAX SU-O, the world’s first WiMAX Forum Certified™ client device based on the Intel® PRO/Wireless 5116 broadband interface.

Underlying these is Redline’s RedMAX Management Suite (RMS), which enables service providers to monitor and control high-capacity networks and ensure high service availability. RMS incorporates an open architecture for third party integration and management as well as seamless integration into an existing operational support system (OSS). RMS is an essential element of any true carrier-class network and an essential tool throughout the three phases of evolution.

The RedMAX AN-100U, SU-O and RMS provide unparalleled performance in terms of high throughput, spectral efficiency, low latency and superior system manageability. Together they will help service providers to take full advantage of the opportunity to be first to market and, ultimately, to capitalise on a high return on investment.

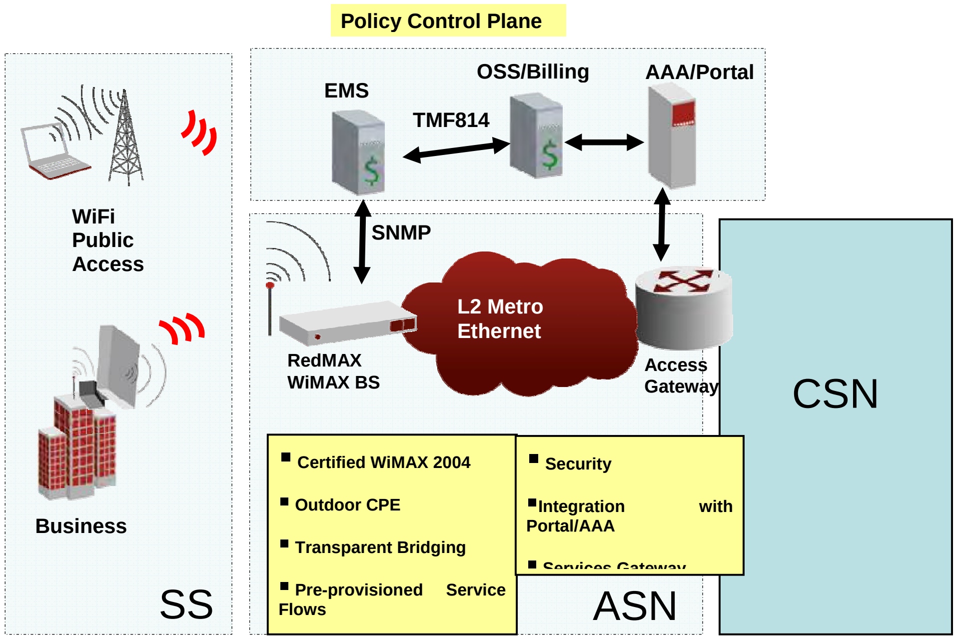


Figure 8: Phase I Architecture

In this phase, the network is built with the vision of being upgraded later to a NWG-compliant architecture. Operators can start by building an all-IP infrastructure and use RedMAX 802.16-2004 to provide fixed services. As illustrated in Figure 8, the main components of the ASN will be the RedMAX AN-100U in three or six sectors, a BS configuration that is connected to a Metro Ethernet access network and, finally, IP traffic aggregated to the core network via the access gateway.

The packet radio service flows between the BS and CPE (indoor and outdoor) which are initially compliant with the 802.16-2004. Service Flow QoS is controlled by the MAC layer and pre-provisioned via SNMP/802.16 WMAN MIBs using the RMS Element Management System (EMS). The connection is identified by the QoS service class (UGS, rt-PS, nrt-PS or BE) and the IP classification attributes (Layer 2 and Layer 3) for routing IP traffic over the service flows.

To automate the provisioning of services, the RMS (EMS) provides a CORBA North Bound Interface compliant with the TMF814 service model commonly used in provisioning DSL networks.

The access gateway platform is based on the Cisco 7600 Series router and performs the following functions:

- In the first phase the Cisco 7600 enables the intelligent transport services for the WiMAX traffic and aggregates the Carrier Ethernet rings.
- The Cisco 7600 acts as a gateway for mapping the data path to a MPLS connection as part of a Layer 2 or Layer 3 VPN.
- The 7600 also provides a gateway to BRAS or other SEF components residing in the ISP infrastructure.

Phase 2: System Enhancements

The second phase of the architecture roadmap provides system enhancements to the packet radio infrastructure, such as uplink sub-channelisation and high power radios at the base station. Working in concert with this, Redline's patent-pending distributed antenna systems (DAS) architecture will enable the ubiquitous indoor coverage service level required by service providers at industry-leading levels of reliability.

As the WiMAX ecosystem matures, many different vendors will introduce portable devices like notebooks with WiMAX PCMIA cards and mobile integrated devices. These will be available initially in 802.16-2004 and later in the 802.16-2005 standard. To accommodate the diversity of devices, Redline will have base station products based on both standards.

Redline will introduce a macro-cell base station architecture housed in a µTCA chassis. This allows service providers to leverage a standards-based chassis platform for scalability and evolution of chassis modules.

On the CPE side, Redline has designed and will market dual mode CPEs that support both standards to allow for a seamless network evolution through software upgradeability. In order to take full advantage of the infrastructure and increase return on investment, Redline will be integrating VoIP capabilities to allow for seamless voice activation. The voice service will have toll quality as it leverages the built-in QoS mechanisms of WiMAX and allows service providers to increase average revenue per user by offering attractive service bundles to end users.

The offerings for Phase 2 will become available in the second half of 2007 and throughout 2008.

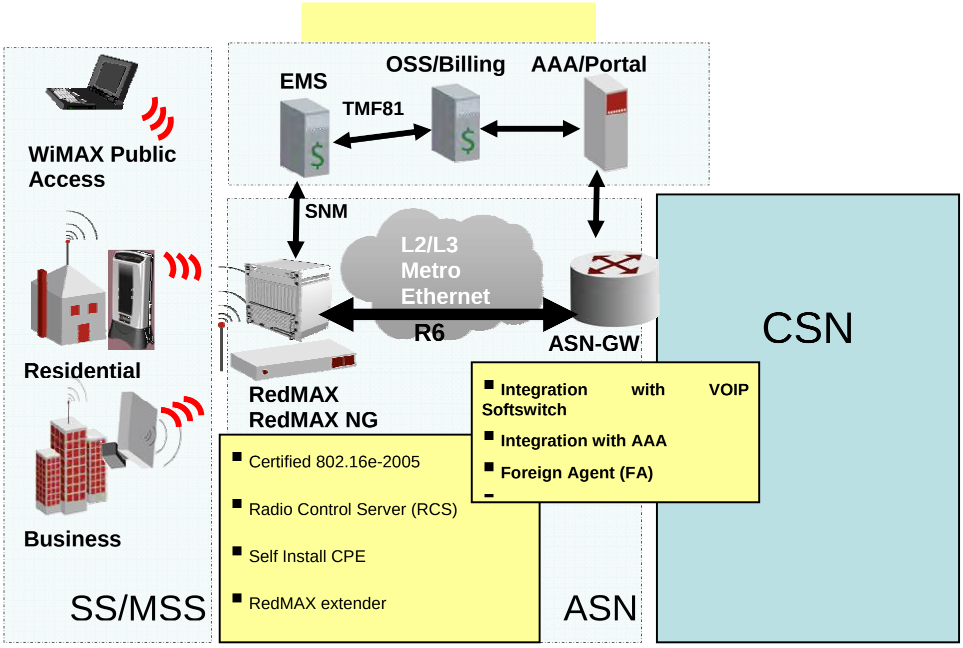


Figure 9: Phase 2 Architecture

In this phase the network will evolve to a partially WiMAX NWG-compliant architecture. Operators can leverage the all-IP infrastructure built in Phase 1 and start to overlay a RedMAX NG 802.16-2005 network to provide large-scale fixed, nomadic and portable services.

The main advantage of this evolutionary architecture is that it does not require operators to discontinue the services and the architecture established in Phase 1. The RedMAX NG supports the coexistence of Phase 1 and Phase 2 architectures as well as ASN-GW functions as specified in the NWG architecture Release 1.0.

ASN Data Plane Functions: The QoS data path between the router and the BS will be controlled by the implementation of the R6 interface. The R6 interface enables the Cisco 7600 platform to dynamically setup the QoS data path (GRE tunnels) based on signed up services. The R6 interface also enables the Cisco 7600 to control the RedMAX NG BS in order to dynamically establish, modify and delete service flows with the QoS parameters required for a particular service. Classifiers for mapping the IP traffic over services flows are also passed through this interface to the BS. This evolution provides a better framework for more dynamic QoS enforcement and better utilisation of radio resources suitable for nomadic and portable services.

ASN Gateway Control Functions: In this phase the Cisco 7600 will evolve to support standard interfaces to the AAA and policy control layer. The User Network Entry procedure is based on the PKMv2/EAP process. The process automates the procedure of installing, authenticating and provisioning end-to-end service for users taking advantage of fixed-to-mobile convergence.

The Cisco 7600 will also dynamically examine the user traffic by performing Deep Packet Inspection. Based on pre-provisioned polices for VoIP and video traffic, the Cisco 7600 will dynamically establish end-to-end connections with the proper QoS parameters. Connections will be deleted or deactivated at the end of the call. This will tremendously increase the utilisation of the network radio resources, and hence the network capacity, and provide the QoS required for services.

Phase 3: Personal Broadband System

The third phase of the joint Cisco and Redline evolution strategy allows service providers to roll out a personal broadband system. This mobile and portable service is very attractive in markets that are already well served by DSL and cable because it offers a broadband connection that can be taken anywhere. This is a very compelling story for both consumers and business customers.

Given the need for ubiquitous coverage in a mobile environment – which will enforce the requirement for tight frequency reuse necessary to provide large capacity – this phase will see the introduction of advanced physical layer technologies. These will include multiple input-multiple output (MIMO) and an Advanced Antenna System (AAS) that implement Spatial-Division Multiple Access (SDMA) for capacity-limited environments and MIMO/AAS-based link budget enhancements for situations in which coverage represents the chief constraint.

The offerings for Phase 3 will become available in the second half of 2008 and throughout 2009.

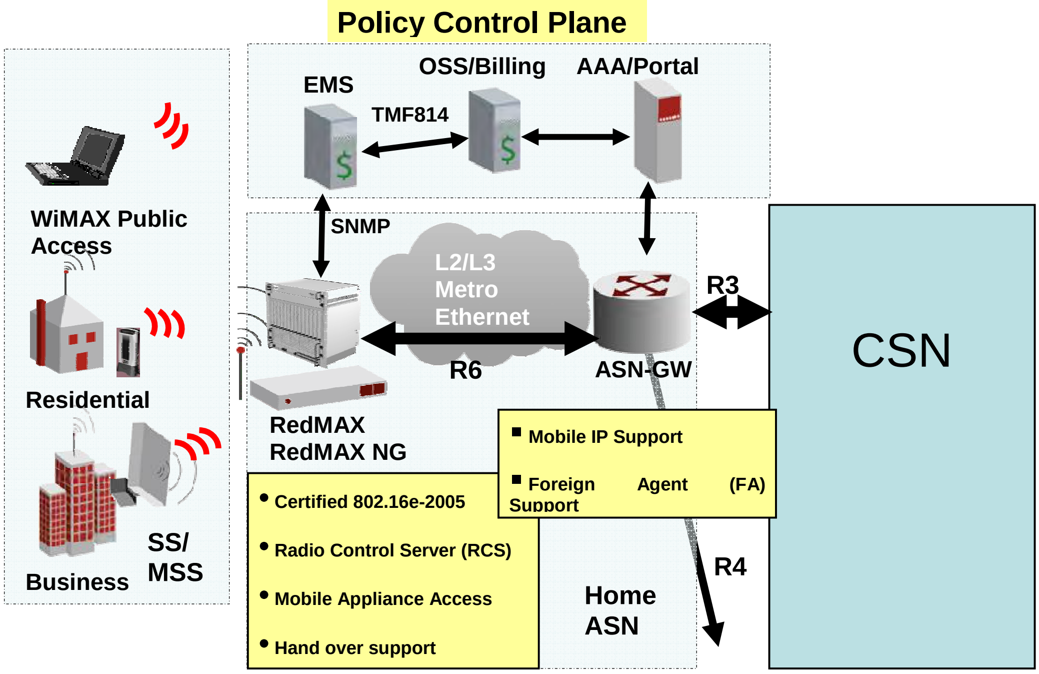


Figure 10: Architecture Phase 3

In this phase, the network will evolve to a fully NWG-compliant network architecture. Operators can leverage the all-IP network infrastructure and radio packet infrastructure built in Phases 1 and 2, and evolve to mobile services as well as business and residential services. As illustrated in Figure 10, the main components of the ASN will be the RedMAX NG in three or six sectors. The BS configuration is connected to a Metro Ethernet Access network and IP traffic is aggregated to the core network via a Cisco 7600 Series router (ASN-GW).

The RedMAX NG supports the coexistence of Phase 1, 2 and 3 architectures.

In Phase 3 the RedMAX NG BS will be software upgradeable to fully support the R6 interface and the RRM function as defined by the NWG architecture, to support fixed, nomadic, portable and mobile services. The R2 interface will also evolve to support Paging, Power Control and Hand Off functions required for mobility support. The BS will also be upgraded to support multicast functions required for more efficient video and streaming services.

ASN Data Plane Functions: In this phase the Cisco 7600 (ASN-GW) will be upgraded to support multicast services and data plane requirements for Hand Over.

ASN Gateway Control Functions: In this phase the Cisco 7600 (ASN-GW) will evolve to support macro-mobility functionality at the IP level and will act as the mobility anchor point. Mobile IP functionality is required to support seamless mobility of IP flows. The Cisco 7600 will also support FA/HA functions and the R3 Interface to the home network. Finally, the Cisco 7600 will support the R4 interface to other ASN networks to support Inter-ASN Hand Over Scenarios.

WiMAX Forum Defined Architecture

Having described the three phases of the roadmap in more detail, this document will now discuss how the WiMAX Forum Network Reference Model maps with the Cisco and Redline architecture.

The WiMAX forum (www.wimaxforum.org) defines the reference architecture for solutions utilising WiMAX products and provides scenarios covering Fixed, Nomadic, Portable and full Mobility similar to today's cellular network deployments.

The reference architecture also defines the interfaces between the different logical entities.

The Cisco and Redline WiMAX solution is equivalent to the ASN with the defined reference points of R6, R3 available for interworking with other network components such as other ASNs and system elements within the core network (CSN). The Redline/Cisco ASN is a combination of the RedMAX NG BS and the ASN-GW function, with part of the Cisco router providing bearer plane access to the network.

Figure 6 shows the definition of the WiMAX Forum-defined reference architecture, followed by a representation in Figure 7 of the Cisco and Redline embodiment of the reference architecture and its evolution.

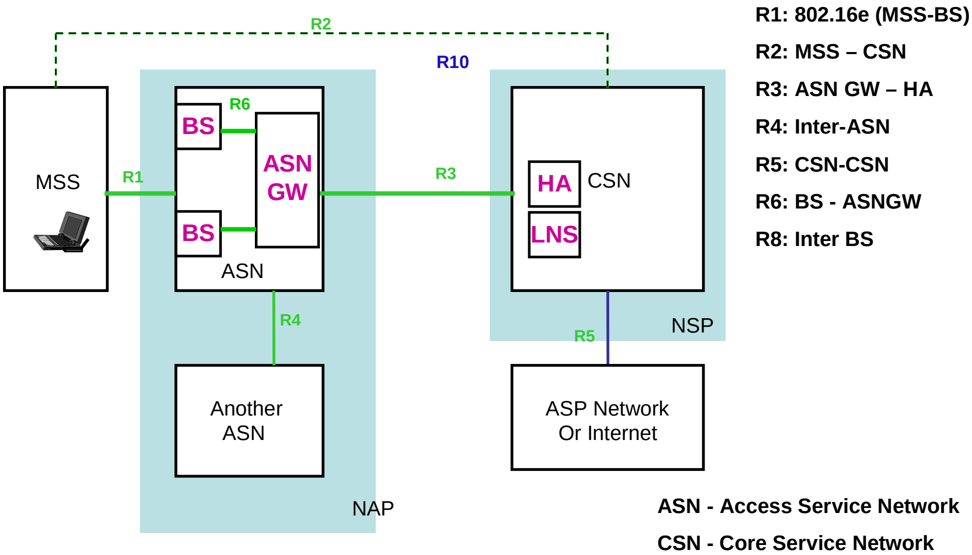


Figure 6: WiMAX reference architecture

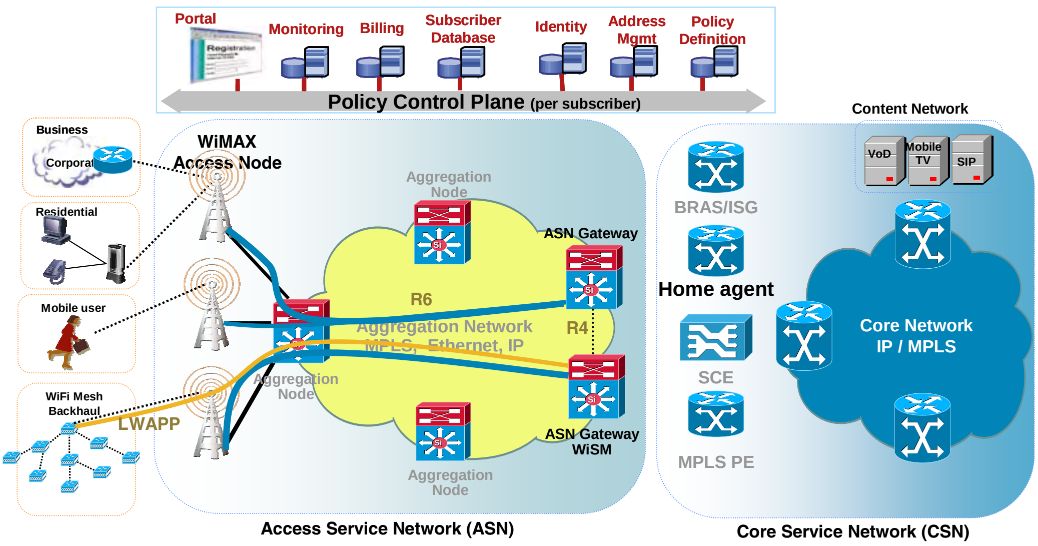


Figure 7: Mapping of the Cisco and Redline architecture to the WiMAX reference architecture

A brief description of the various entities and interfaces of the architecture illustrated in Figure 7 is provided below.

SS (Subscriber Station) or CPE: This is the subscriber device that provides connectivity to the network through the RedMAX NG BS. The SS may host one host or multiple hosts that interface to servers in the core network for applications such as VoIP, IPTV, etc. The SS can be outdoor or indoor.

MSS (Mobile Subscriber Station): This is the subscriber device that provides connectivity to the network through the

RedMAX NG BS. The MSS may host clients that interface to servers in the core network for applications such as VoIP, IPTV, etc.

RedMAX NG BS: BSs are part of the Access Service Network and interface with the end user devices over the air as well as with the rest of the network using interfaces such as Ethernet or other backhaul methods. The BS uses standard-based interfaces, the IEEE 802.16e-2005 air interface and WiMAX Forum R1 and R6 interfaces (R1 to communicate with SS/MS, and R6 interface to communicate with ASN-GW). It complies with WiMAX Forum architecture and contains, among others, Key Receiver and Authentication Relay (security), SF Management (QoS) and RRA functions (RRM)

R1: The Redline RedMAX NG interfaces with the user devices over the air interface as defined in the 802.16e specification.

R6: The Redline RedMAX NG interfaces to the Cisco ASN-GW for certain functions from a control and data plane perspective and to the Router/FA part of the ASN-GW for bearer traffic. The Redline/Cisco R6 interface is a fully standard interface based on the NWG Release 1.0 specification.

ASN-GW: Part of an operator's ASN providing bearer plane transport and routing for data traffic. The foreign agent (FA) provides mobility support through the use of mobile IP. The Router/FA can be considered equivalent to the ASN Enforcement Point (ASN-EP) logical entity as defined in the WiMAX Forum reference architecture. The ASN-GW also provides the control plane handling. Functions such as mobility support, handover coordination, security and paging controller are handled by the ASN-GW. This entity maps to the ASN-Detection Point (ASN-DP) logical entity of the WiMAX Forum reference architecture. The ASN-GW may perform other functions such as those performed by DNS/DHCP/NTP servers. These are Internet-specific functions/entities that are used for domain name searches, IP address allocations and network time synchronisation. The ASN-GW interfaces to the core network CSN via the R3 interface, enabling interoperability with different CSN networks (DSL, MPLS and mobile).

HA: In a mobility scenario, HA provides the Mobile IP Home Agent functionality. The R3 interface ensures the interoperability between the Redline/Cisco ASN and the third party CSN.

BRAS/ISG: In a fixed DSL services scenario, the ASN-GW acts as an interoperability point between the ASN and the DSL core network CSN via R3. This enables interoperability with multiple operators in a wholesale scenario.

MPLS PE: In a fixed MPLS VPN scenario, the ASN-GW acts as an interoperability point between the ASN and the MPLS core network.

Policy Control Plane: The Authentication, Authorisation and Accounting (AAA) server hosts the subscriber data profiles (security, admission control, QoS policy, etc) which are sent to relevant nodes when users register with the network. Accounting/Billing support can also be provided through the AAA server.

Content Servers: These offer services to the end users which typically host the clients to interface with these servers. These servers could be part of the IMS domain or standalone servers providing services such as VoIP, push-to-talk, etc.

RMS: The RMS Element Management System is responsible for the management of the network elements via FCAPS (fault, configuration, accounting, performance and security) management. It communicates with the OSS using TMF NBI.

WiMAX Briefing

WiMAX Overview

WiMAX is an innovative technology that will allow service providers to build last mile wireless broadband access networks to offer fixed broadband, nomadic and, eventually, mobile services with new applications that produce a content-rich, personalised broadband user experience.

WiMAX is a robust, reliable, standards-based technology capable of supporting LOS and NLOS connectivity to the base station with long reach, high bandwidth and high spectral efficiency. It supports different applications and triple play (voice, data, video) with different QoS for different service classes.

WiMAX will bring fixed and nomadic broadband wireless services to residential and business markets first, with portability and mobility to follow. Fixed broadband wireless access relates to fixed CPE locations, typically outdoor and desktop indoor devices, while nomadic service provides the ability to reconnect in multiple locations using the existing fixed infrastructure. Fixed and nomadic include both PTP and PMP applications and are based on the IEEE 802.16-2004 standard, which was ratified mid-2004.

Portable service provides the ability to maintain connection while moving within and across neighbouring base stations with limited handover. Mobile service provides the ability to maintain connection while moving across base stations with full roaming capability. With mobility, all QoS and SLAs are maintained during handovers. Full mobility operation is optimised for latency-intolerant applications at vehicular speeds. Portable and mobile broadband access is based on the emerging IEEE 802.16e-2005 standard.

In both its Fixed and Mobile versions, WiMAX is based on a next-generation, all-IP core network which offers low latency, advanced security, QoS and worldwide roaming capabilities. Service providers benefit from the low costs associated with a technology based on open standards, vendor interoperability and favourable intellectual property rights.

WiMAX Forum Certified™ Systems will provide the only true standards-based broadband wireless services in the marketplace, based on the IEEE 802.16 standard rather than proprietary solutions. This means that volume production, commoditisation and economies of scale will bring the CPE down to affordable and competitive pricing. These systems will ensure flexibility between data, video and voice services, while maintaining carrier-class QoS for each of these services.

WiMAX Forum Overview

The WiMAX Forum is an organisation of more than 400 leading operators and manufacturers of communications components and equipment. It was established in June 2001 to help remove some of the barriers to widespread adoption of Broadband Wireless Access (BWA) technology. It was clear that a standard alone was not enough to incite mass adoption of the technology. The Forum is working to certify equipment based on the technology and ensure that WiMAX Forum Certified™ products meet service provider and customer requirements for performance and interoperability.

To achieve its goals, the WiMAX Forum created a number of working groups to address the technical, marketing, regulatory and other requirements for widespread deployment of broadband wireless systems. Some of the working groups include:

- **Technical Working Group:** a working group that specified the technical parameters for mobile networks. These parameters are grouped into what is commonly referred to as a ‘system profile’ which is a subset of the IEEE 802.16e-2005 standard. The TWG (formerly know as the Mobility Task Group) has selected the Scalable-OFDMA physical layer.
- **Enhanced Technical Working Group:** a working group that specifies the technical parameters for fixed and portable systems based on the OFDM physical layer as defined in 802.16-2004 and 802.16e-2005.
- **Certification Working Group:** a working group that specifies system certification requirements and profiles. A certification profile is a set of parameters that include, among other things, frequency bands and channel bandwidths. To achieve WiMAX Forum Certification status, base station and CPE devices must undergo a number of tests covering conformance to the IEEE standard (protocol and radio conformance testing) and interoperability testing between different vendor equipment.
- **Network Working Group:** a working group that addressed the requirements of the access and core networks at a higher protocol stack level than the IEEE 802.16 standard. The requirements developed by this working group enable the interoperability between the infrastructure network elements such as switches (since WiMAX is an all IP network) and WiMAX base stations.

IEEE Standard Overview

The IEEE 802.16 is an evolutionary air interface standard that has been in development since 1999. As an air interface standard, it specifies the first two layers of the Open System Interconnection (OSI) networking stack (the physical and medium access control layers). The standard is commonly called the ‘WirelessMAN’ (wireless metropolitan area network) standard, indicating the target scale of a deployment which is about the size of a city. The aim of IEEE 802.16 technology is to provide wireless broadband access, thus bridging the gap between the core infrastructure network and the user. This gap has been traditionally bridged with wires or fibres which are costly to install and maintain. Broadband wireless access leverages advancement in technology to bypass such limitations and provide a compelling, cost effective solution.

As an evolutionary standard, IEEE 802.16 underwent some iterations. The original standard (802.16-2001) addressed the LOS scenario in the 10-66 GHz frequency range (December 2001). In January 2003, the 802.16a-2003 added physical layer support for frequencies below 11 GHz and targeted NLOS, PTP applications. This was later refined with the 802.16-2004 (June 2004) standard which rendered the original 802.16-2001 version obsolete. This version of the standard then underwent a ‘corrigenda’ process (Cor1) whereby corrections to the standard were made. This process was completed in November 2005. The IEEE 802.16-2004 standard addresses fixed access and allows for a significant level of flexibility such as providing nomadic services.

In December 2005, an amendment to the standard for mobile wireless broadband was completed. This version of the standard is commonly referred to as IEEE 802.16e-2005. This version enables roaming for portable devices such as laptops and personal digital assistants (PDAs) in the licensed frequency bands under 6 GHz.

At present, the IEEE 802.16e-2005 is undergoing a corrigenda process (Cor2) of its own. In December 2006, a new IEEE PAR (Project Authorisation Request) was approved by the IEEE executive committee to begin work on a new amendment to the 802.16 standard to address ITU-R (International Telecommunication Union – Radio Communications Sector) requirements for 4G networks, mainly providing mobile broadband services with throughput of 100 Mbps in over 80 per cent of area coverage. This amendment is commonly referred to as IEEE 802.16m and is expected to be completed in 2008 or 2009.

Cisco and Redline are active members of the 802.16 standards committee. Redline was instrumental in helping to put together the original standards for the 802.16 document and has been active in recommending and writing new amendments to the standard.

WiMAX Certification Process

Certification of equipment constitutes a major activity for the WiMAX Forum and is designed to ensure compliance to the standard and interoperability among equipment. Certification fosters a competitive ecosystem of base station and subscriber devices from various vendors. This promises an accelerated and widespread adoption of WiMAX.

The WiMAX Forum certifies equipment in certain ‘certification profiles’ which specify system parameters related to frequency band, channel bandwidth and access mode (see Table 1?). Certification tests are scheduled to occur in waves with each subsequent release adding additional mandatory technical features and capabilities. There are currently two defined certification waves for Fixed WiMAX and two certification waves for Mobile WiMAX.

Redline was the first company to receive end-to-end Wave 1 system certification in January 2006 with its Fixed WiMAX system, RedMAX. Wave 2 certification, which includes additional tests for QoS, security and Automatic Repeat reQuest (ARQ), is scheduled for completion in the first quarter of 2007. Products are certified once the first conformance wave and interoperability are demonstrated. Subsequent wave testing is then required to maintain the certified status for interoperability.

The WiMAX Forum and ETSI are currently working on writing the appropriate test plans (TPs) for Mobile WiMAX. However, for this process to be completed, the IEEE 802.16 Cor2 process also needs to be finished so that all outstanding errors, omissions and ambiguities are resolved. Thereafter, the WiMAX Forum has to select and prioritise the TPs before beginning work to validate the TPs and the corresponding test bed. The WiMAX Forum has selected Profile 1A (2.3 GHz; 8.75 MHz channel, commonly known as WiBRO) to be the first Mobile WiMAX certified profile to adhere to the Certification Wave 1 system profile. Profile 3A (2.5-2.7 GHz; 5/10 MHz channels) is the second selected certification profile to adhere to the Certification Wave 2 system profile. This adds tests that are primarily targeted at advanced physical layer features, such as MIMO antenna technology.

As Mobile WiMAX requires large networks to provide the ubiquitous coverage and roaming capabilities necessary for mobility, it is Redline’s belief that the testing for compliance and interoperability for Mobile WiMAX must be more rigorous and comprehensive than that for Fixed WiMAX. Since mobile networks require larger investment, operators require a higher level of assurance that the system they are purchasing will meet the specification set by the standard as well as provide them with the option to mix and match systems from different vendors. Given the added complexity of mobility and the necessity of having system compatibility with Certification Wave 2, deployment of Mobile WiMAX systems is not expected until 2008.

Table 2 shows the approved WiMAX Forum certification profiles as of December 2006. As can be seen, certification for Mobile WiMAX centres on the lower frequency bands while certification for Fixed WiMAX centres on the higher frequency bands. This split is not coincidental. Propagation and wall penetration losses are more severe in the higher frequency bands. This results in a higher cell count for higher frequency bands which reduces the financial viability of mobile networks in higher frequency bands in comparison to lower frequency bands.

Table 2.

	Frequency Band (GHz)	Channel Bandwidth (MHz)	Duplex Mode
Fixed WiMAX	3.4-3.6	3.5, 7	TDD, FDD
	5.8	10	TDD
Mobile WiMAX	2.3 – 2.4	8.75	TDD
	2.496 – 2.69	5, 10	TDD

Table 2: WiMAX Forum Certification Profiles (approved as of December 2006)

WiMAX Technology Overview

Fixed WiMAX technology is based on a 256 carrier OFDM physical layer. One advantage of OFDM is that it provides frequency diversity and higher tolerance for multipath fading. In an environment where certain OFDM carriers 'fade', the overall link would still be maintained by other non-faded carriers, due in part to recent OFDM physical layer advancements. In OFDM, communication between the base station and a subscriber is scheduled within defined time intervals using the full channel bandwidth (i.e. all available frequency carriers are assigned to one user). Nevertheless, it is possible for a subscriber to communicate with the base station over a partial number of carriers. This feature is known as 'uplink subchannelisation'. It allows the subscriber unit to increase the transmit power since total power is concentrated over fewer carriers.

Fixed WiMAX systems work in either TDD or Frequency-Division Duplex (FDD) access modes and are both considered to be certifiable profiles. While FDD caters to legacy spectrum allocations, TDD provides improvements in spectral efficiency for broadband services that are characterised by higher downlink traffic (base station to subscriber) than uplink traffic (subscriber to base station). Additionally, having the same frequency for the downlink and uplink facilitates the implementation of throughput-enhancing advanced antenna techniques.

Mobile WiMAX is based on the Scalable-OFDMA physical layer (S-OFDMA). Scalability implies that a higher number of carriers are used as the channel bandwidth increases. For instance, a 5 MHz channel uses 512 carriers, whereas a 10 MHz channel uses 1,024 carriers. In addition, communication between the base station and subscribers can be scheduled in both the downlink and uplink using a partial number of carriers. Therefore, mobile WiMAX implements downlink subchannelisation in addition to uplink subchannelisation. Through downlink subchannelisation, groups of subchannels can be allocated to different sectors of the base station or all the groups can be allocated to one sector. Either way, it is a useful feature for mobile systems as it allows for tight frequency reuse plans which are necessary for optimising large-scale mobile network deployments. However, spreading subchannel groups over multiple sectors reduces throughput, which may be acceptable in a mobile system.

The manner in which carriers are assigned to subchannels is referred to as the permutation mode. There are a number of different modes defined for mobile WiMAX including partial utilisation of subchannels (PUSC), full utilisation of subchannels (FUSC) and adaptive modulation and coding (AMC). The difference between these modes centres around how the carriers are allocated to the subchannels. PUSC and FUSC modes are generally referred to as 'diversity' modes (subchannels composed of non-adjacent carriers) while AMC is referred to as a 'contiguous' mode (subchannels composed of adjacent carriers). The PUSC mode has been preferred for mobile WiMAX because it is most suitable for mobile applications given the relatively higher number of pilot signals and frequency diversity feature. The relatively large number of pilots on the uplink of mobile WiMAX is necessary to estimate channel characteristics in a mobile environment.

Additionally, mobile WiMAX implements features critical to mobility services. For example, handovers allow the user to move between base stations and 'sleep' mode to conserve battery life.

Both Fixed and Mobile WiMAX provide different modulation schemes and the ability to change modulation schemes depending on the quality of the link. Table 3 shows the modulation schemes and coding rates defined by the IEEE standard and mandated by the WiMAX Forum as part of the system profile. The Fixed WiMAX coding schemes illustrated are Reed-Solomon and convolutional codes, whereas convolutional turbo codes are used in mobile WiMAX.

	Fixed WiMAX		**Mobile WiMAX**	
	Downlink	Uplink	Downlink	Uplink
BPSK-1/2	✓	✓	✗	✗
QPSK-1/2	✓	✓	✓	✓
QPSK-3/4	✓	✓	✓	✓
16QAM-1/2	✓	✓	✓	✓
16QAM-3/4	✓	✓	✓	✓
64QAM-2/3	✓	✓	✓	✗
64QAM-3/4	✓	✓	✓	✗

Table 3: WiMAX modulation and coding schemes

Another key feature of WiMAX is the availability of different QoS levels. This allows the system to carry different types of services including voice, video and data. The WiMAX base station dynamically allocates downlink and uplink radio resources according to the traffic load and subscriber QoS demand. Table 4 summarises the available QoS levels.

Service	Description	Application	QoS Service Flow Parameters
Unsolicited Grant Service (UGS)	Real-time data streams of fixed size packets issued at periodic intervals	VoIP (without silence suppression) E1/T1	Maximum Sustained Traffic Rate, Maximum Latency, Tolerated Jitter, Request/Transmission Policy Minimum Reserved Traffic Rate parameter = Maximum Sustained Traffic Rate
Real Time Polling Service (rt-PS)	Real-time data streams of variable-sized data packets issued at periodic intervals	VoIP Video MPEG	Minimum Reserved Traffic Rate, Maximum Sustained Traffic Rate, Maximum Latency, Request/Transmission Policy
Non-Real Time Polling Service (nrt-PS)	Delay-tolerant data streams of variable-sized data packets for which a minimum data rate is required	FTP	Minimum Reserved Traffic Rate, Maximum Sustained Traffic Rate, Traffic Priority, Request/Transmission Policy
Best Effort (BE)	Data streams for which no minimum service level is required	HTTP (web browsing, data transfer)	Maximum Sustained Traffic Rate, Traffic Priority, Request/Transmission Policy

Table 4: WiMAX QoS levels

In addition to the above, Mobile WiMAX adds a fifth QoS level – enhanced rt-PS – which combines certain features of UGS and rt-PS to support certain applications such as VoIP with silence suppression.

WiMAX security includes support for mutual device/user authentication (EAP-based), flexible PKMv2, strong data encryption (AES), and control and management plane protection (CMAC and HMAC).

Working with Leaders

Cisco and Redline together offer a broad range of solutions based on their extensive networking and radio portfolios. Their combined expertise and proven technology leadership help service providers to deploy performance-leading, WiMAX Forum Certified systems.

For further information, please visit:

Cisco Systems, Inc.: www.cisco.com
Redline Communications Inc.: www.redlinecommunications.com

Glossary of Acronyms

API	application program interface
ASN	Access Service Network
ATM	Asynchronous Transfer Mode
BRAS	Broadband Remote Access Server
CINR	Carrier to Interference-plus-Noise Ratio
CORBA	Common Object Request Broker Architecture
CPE	customer premises equipment
CSN	Connectivity Service Network
DHCP	Dynamic Host Configuration Protocol
EAP	Extensible Authentication Protocol
ETSI	European Telecommunications Standards Institute
FDD	Frequency-Division Duplex
FTP	File Transfer Protocol
H-VPLS	Hierarchical Virtual Private LAN Services
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Taskforce
IMS	IP multimedia subsystem
LOS	line of sight
MAC	Media Access Control
MIMO	multiple input-multiple output
MPLS	Multiprotocol Label Switching
NAT	network address translation
NLOS	non-line of sight
OFDM	Orthogonal Frequency-Division Multiplexing
OSI	Open System Interconnection
OSS	operational support system
PKM	privacy key management
PMP	point-to-multipoint
PoE	Power over Ethernet
PPP	Point-to-Point Protocol
PPPoE	Point-to-Point Protocol over Ethernet
PTP	point-to-point
RSSI	Received Signal Strength Indication
SEF	Service Exchange Framework
SIP	Session Initiation Protocol
SLA	service level agreement
STP	space-time processing
TDD	Time-Division Duplex
TDM	Time-Division Multiplexing
VoIP	Voice over IP
WiMAX	Worldwide Interoperability for Microwave Access