Building End-to-End WiMAX Networks

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Introduction

After years of intense interest and high expectations, Mobile WiMAX is now ready to be deployed. As of April 2007, products are becoming commercially available and certification is under way. Network operators worldwide are busy evaluating or planning for these deployments, selecting vendors, identifying the appropriate network architecture and often deciding how to integrate Mobile WiMAX within their legacy infrastructure.

As we move towards the implementation stage, attention is gradually widening beyond its initial focus on the radio interface. It was the natural place to start, as it is the main building block of a WiMAX network and is responsible for most of the spectrum efficiency and cost savings that WiMAX promises.

As they start to plan end-to-end networks, however, network operators have increasingly been looking beyond the air interface, to the entire Access Service Network (ASN) and the Connectivity Service Network (CSN). The ASN coordinates traffic across multiple Base Transceiver Stations (BTS) and supports security, handoffs and Quality of Service (QoS). The CSN manages core network operations through Internet Protocol (IP) servers, Authorization, Authentication and Accounting (AAA), Voice over Internet Protocol (VoIP) and Public Switched Telephone Network (PSTN) gateways, and it provides an interface to legacy core networks and other operators' networks.

The open IP architecture which is at the core of WiMAX marks a pivotal innovation among non-proprietary mobile technologies. It is set to decrease the complexity and cost to network operators, while increasing the flexibility in developing new services and applications and the freedom in selecting the best suited vendors. Furthermore, according to Rick Galatioto, Product Line Manager at Cisco, an ASN and IP solutions vendor, "the adoption of an open IP architecture by network providers represents a crucial step towards empowering end users and giving them more control in choosing applications."

If network operators want to reap the full benefits that WiMAX and its all-IP architecture can deliver, they need to carefully select the ASN and CSN solutions that best suit their requirements and provide all the functionality required while avoiding unnecessary complexity in their network.

Each operator has to carefully identify its own requirements, dictated by the type of services offered, the market segments targeted, the spectrum available, and the topography of the coverage area. There is no single solution that works for all, and operators need to make key choices about the management and core networks as they plan for their WiMAX networks.

This paper aims to assist network operators in understanding what lies beyond base stations in a WiMAX network, and what options are available to them as they move forward along one of the most exciting technological frontiers in a still largely uncharted territory.

A standard-based technology

WiMAX, as with many new technologies, is based on an open standard. While standards increasingly play a crucial role in driving adoption, they are not sufficient to guarantee success. A standard-based technology will succeed only if a solid ecosystem of operators, vendors, and solution and content providers emerges to support it, as is the case with WiMAX.

There is more to a technology than a standard. Mobile WiMAX is based on the 802.16e-2005 version of the IEEE 802.16 standard, but this only includes specifications for the Physical (PHY) and Medium Access Control (MAC) layers, as is customary for IEEE standards. This approach gives WiMAX additional flexibility in the network management. It also means that different products that comply with the standard may have substantial differences in performance and in the implementation of the layers beyond MAC and PHY.

These are considerations that network operators have to keep in mind during vendor selection. They have profound implications for the way their WiMAX networks can be implemented and managed, and the services they will be able to support.

Interoperability in a WiMAX network

As a standard-based technology, WiMAX enables inter-vendor interoperability which brings lower costs, greater flexibility and freedom, and faster innovation to operators.

Within the WiMAX industry there is a strong commitment to ensuring full interoperability, both through certification and ad-hoc testing between vendors. It is important for network operators to realize how interoperability is established and what it covers so that they understand how different products, solutions and applications from different vendors can coexist in the same WiMAX network.

Standard compliance alone does not guarantee interoperability. Two products may comply with the WiMAX IEEE 802.16e standard, but nevertheless not interoperate. Extensive tests are required to demonstrate interoperability among vendors.

Interoperability can be established at different levels. The WiMAX Forum Certification program verifies interoperability at the PHY and MAC layers, which are responsible for essential over-the-air transmission, the management of connections, and security and mobility management, including handoffs, power control and QoS. Only the subscriber devices—known as Mobile Stations[1] (MS)— and the base stations can be certified. Interoperability is established between the MSs and the BTSs so that each certified MS can work within any WiMAX network that operates at the same frequency and channel width.

Operators may also want to mix BTSs from different vendors within the same network because of different configurations and requirements, for price concerns or other reasons. As a result, the same ASN gateway may need to manage a diverse set of BTSs and coordinate traffic management and handoffs among them.

Furthermore, operators that intend to support roaming need to be able to interoperate at the CSN level with

1. In Mobile WiMAX all the subscriber devices are referred to as MS, even though, strictly speaking, they may not be mobile, like laptops, desktop modems or units with outdoor antennas.

other operators to ensure that subscribers can connect to different networks or can retain their connection as their devices move across areas covered by different networks.

The WiMAX Forum Certification program does not verify this type of interoperability today, but the WiMAX Forum Networking Working Group (NWG) specifications extend interoperability to elements in the ASN and CSN. Vendors that follow NWG specifications can provide interoperable solutions and demonstrate full interoperability through testing with vendors that focus on other network components.

The rest of this paper will focus on how interoperability can be achieved at the ASN and CSN level, the challenges that network operators face, the benefits that they should expect, and how this forms the basis for a WiMAX ecosystem to emerge.

Moving beyond the radio interface

The architecture of a typical Mobile WiMAX network is shown in Figure 1. MSs and BTSs sit at the network edge and responsible for over-the-air transmissions.

Further into the network, the ASN interfaces the BTS and the all-IP core network—the CSN. Typically the ASN includes numerous BTSs with one or more ASN gateways. The ASN manages radio resources, MS access, mobility, security and QoS. It acts as a relay for the CSN for IP address allocation and AAA functions. The ASN gateway hosts the Mobile IP Foreign Agent (FA).

The CSN performs core network functions, including policy and admission control, IP address allocation, billing and settlement. It hosts the Mobile IP Home Agent (HA), the IP and AAA servers, and PSTN and VoIP gateways. The CSN is also responsible for

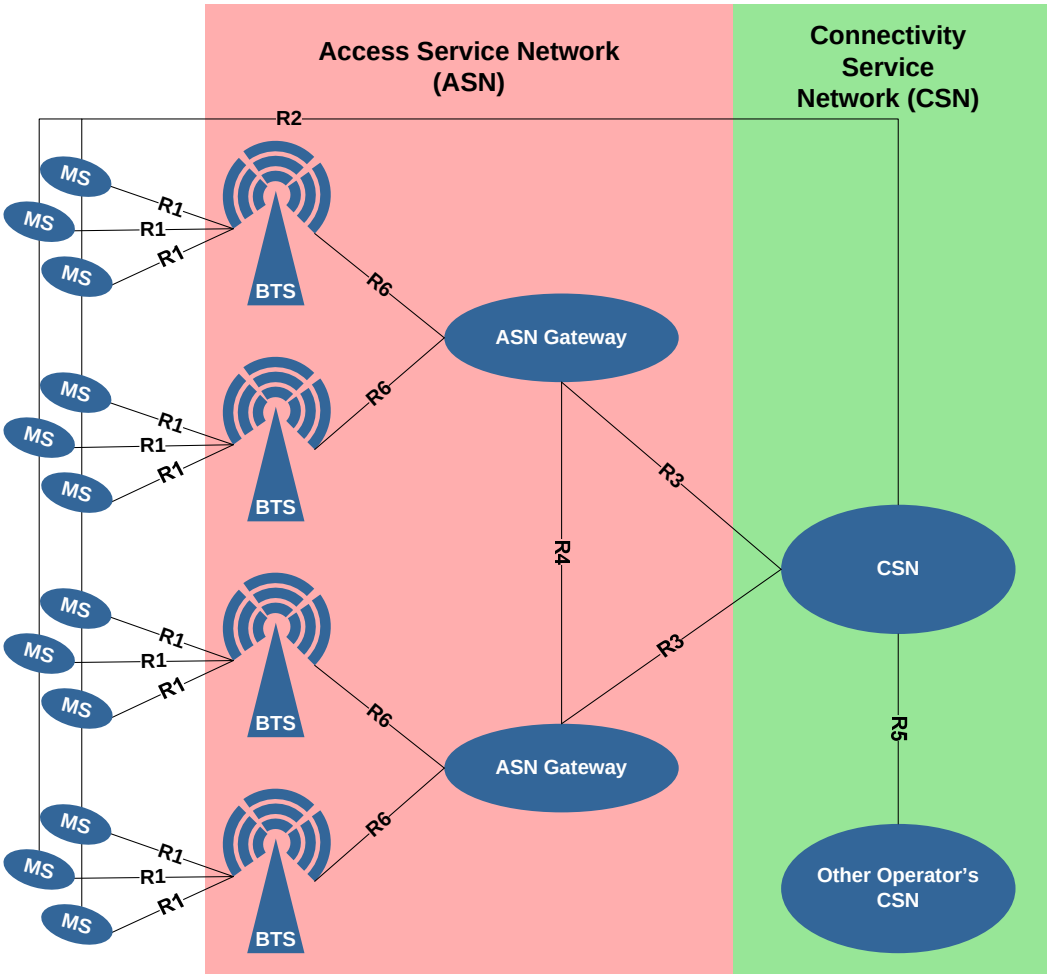

Figure 1. WiMAX Network Architecture

internetworking with non-WiMAX networks (e.g. 3G, DSL) and for roaming through links to other CSNs.

The specifications being developed by the NWG within the WiMAX Forum define the role of the ASN and CSN and ensure that WiMAX networks can interwork with other networks, using WiMAX or other wireless or wired access technologies such as cellular, Wi-Fi, DSL, cable or fiber. In addition, the NWG specifications are designed to enable network operators to enjoy the benefits of vendor interoperability at the infrastructure level, to rely on a consistent client interface and, if they desire, to open their network to virtual operators, akin to existing cellular Mobile Virtual Network Operators (MVNOs).

To fulfill these goals, the NWG specifications define interfaces (Table 1) for the Reference Network Model (RNM) between key elements of the ASN and CSN. To comply with the specifications, vendors are required to leave most of these open (Table 2).

Table 1. Reference network model interfaces	
R1	Interface between the MS and the ASN. Functionality: air interface.
R2	Interface between the MS and the CSN. Functionality: AAA, IP host configuration, mobility management.
R3	Interface between the ASN and CSN. Functionality: AAA, policy enforcement, mobility management.
R4	Interface between ASNs. Functionality: mobility management.
R5	Interface between CSNs. Functionality: internetworking, roaming.
R6	Interface between BTS and ASN gateway. Functionality: IP tunnel management to establish and release MS connection.
R8	Interface between BTSs. Functionality: handoffs.

Three different ASN profiles, A, B and C (Table 2), have been defined to accommodate varying network operator requirements and the vendors' preference for different network architectures. Interoperability among ASN elements (BTSs and ASN gateways) is supported among all products that comply with the specifications for the same ASN profile. ASN interoperability has to be demonstrated by vendors or network operators through independent testing, as the current WiMAX Forum Certification program does not cover it.

Profiles A and C both use a hierarchical model with a topology similar to that used in cellular networks and that is well suited to support full mobility. In profile A, the RRM entirely resides at the ASN gateway and this increases its workload. Profile C instead relies on the BTS for the RRM and effectively separates the radio functionality—residing in the BTS—from the network management—residing in the ASN gateway. This contrasts with profile A where both functions coexist in the ASN gateway. The separation of the radio functionality and network management facilitates inter-vendor interoperability as it allows network operators to select a different vendor for each function and so avoid conflicts and duplications.

In addition, fixed operators may decide not to deploy an ASN gateway and instead use their existing Broadband Access Server (BRAS) and AAA server with tunneling protocols such as Point-to-Point Protocol over Ethernet (PPPoE). Profile C facilitates this approach because it does not require a separate ASN gateway for the radio management functions.

Table 2. ASN profiles	
Profile	Key features
A	Hierarchical model, with more intelligence located at the ASN gateway. The ASN gateway is involved in the Radio Resource Management (RRM)and hosts the Radio Resource Controller (RRC). It also handles handoffs between BTSs. Open interfaces: R1, R3, R4, R6.
B	Flat, distributed model, with BTSs playing a more substantial role in managing traffic and mobility. The ASN network acts as a black box, with R6 being a closed interface. Open interfaces: R1, R3, R4.
C	Centralized model similar to A, but BTSs are responsible for all the RRM, including the RRC and Radio Resource Agent (RRA), and the handoffs between BTSs. Open interfaces: R1, R3, R4, R6.

To better meet the operators' demand for flexibility, an increasing number of vendors has elected to support ASN profile C or plans to do so and we expect it to become the dominant one.

In profile B, more processing is required at the BTS and this may increase their complexity and cost. This solution may be attractive to small network operators focusing on fixed or nomadic services. As profile B essentially leaves the R6 interface closed, it can be implemented as a solution in which there is no ASN gateway (each BTS performs the ASN gateway role) or with a proprietary ASN gateway that manages only BTSs from the same vendor and acts as a black box. Network operators who want to deploy BTSs from another vendor would only be able to do so by deploying another end-to-end ASN network for the new equipment.

The value of an open architecture to network operators

The ASN and CSN provide the functionality that is essential to the basic operations of any Mobile WiMAX network. As such, network operators want to be able to take advantage of interoperability not only between MSs and BTSs, but also among ASN and CSN elements. They can do so by deploying products that leave the RNM interfaces open and that, as a result, can easily be integrated into existing WiMAX networks.

The advantages that interoperability brings are multiple.

First of all, network operators are able to select the network components that are best suited to their requirements, from best-of-breed vendors in each area. The deployment size, market segments covered, services supported, integration with legacy systems and roaming expectations define the operator's unique needs. For instance, a small operator that offers mostly fixed data services to residential customers will require a less sophisticated VoIP gateway than that used by a nationwide operator that plans to support VoIP in mobile end user devices.

Flexibility when choosing the appropriate network elements is particularly valuable to operators that need to integrate their WiMAX network with a legacy 3GPP, 3GPP2 or fixed wireless network and, understandably, want to retain and re-use as much of the existing infrastructure as possible, as they gradually migrate their cellular networks towards an IP-based architecture.

The ability to choose among vendors allows operators to benefit from the strengths of the open IP architecture and from the large selection of off-the-shelf or customized solutions that are already available and proven in the market. Operators can then explore multiple options and have more flexibility when planning their network. Of course this results in increased competition among vendors, which is likely to lead to lower pricing and more aggressive product development, and reduce the dependence of the operators on a single vendor.

Interoperability also ensures that the operator will always have access to the latest cutting-edge technology regardless of the vendor. This will also have the effect of encouraging aggressive technological advances from vendors.

An open architecture makes it easier for operators to roll out new revenue-generating services and applications as they can rely on a wider pool of suppliers. Gideon Gilboa, Product Marketing Manager at NDS, a company that develops digital pay-TV solutions including WiMAX TV, points out that, "one of the first questions operators will face is how to generate new revenues from applications such as paid-for video, in addition to the flat monthly fees charged for mobile broadband access."

Creating a WiMAX ecosystem

Performance is one of the key elements that sets WiMAX apart from other technologies and makes it unique. However, a successful WiMAX deployment that delivers the services promised in a cost-effective way requires much more than a spectrally efficient, high-throughput, low-latency radio interface.

A WiMAX ecosystem is emerging (Figure 2) to meet the demand from operators for efficient, cutting-edge network elements that together will create powerful end-to-end Mobile WiMAX networks, that are appropriately dimensioned to the operator's requirements.

An impressive collection of players is working towards developing new solutions or adding support for WiMAX within their current solutions. Most of them have valuable experience in a specialized area and bring the necessary expertise to ensure that WiMAX operators hit the ground running. System vendors may have a background in Broadband Wireless Access (BWA) or cellular technologies; billing and provisioning companies and system integrators, in fixed or mobile telecoms; and content providers, advertisers, and application developers, in the media and software industry.

Close collaborations between MS and system vendors illustrate how the ecosystem is being shaped. At Accton Wireless Broadband (AWB), a joint venture between Accton, a Taiwanese OEM/ODM, and Alvarion, a WiMAX system vendor, the focus is to develop MSs that are designed to meet specific operator requirements while taking advantage of their manufacturing capabilities. For Cashew Chen, Executive VP at AWB, the key objective is to, "ensure that WiMAX open architecture can deliver cost-effective MS that are fully interoperable with the BTS from different vendors."

As the ecosystem evolves and increases in complexity, it can be challenging for network operators to identify the best of breed for each network element because the landscape is still fragmented. Perhaps even more importantly they need to have assurances that the elements will be able to interoperate in their network and that all the required system integration has been completed.

Network operators often face a difficult choice between sticking to solutions that work within the existing infrastructure, but may not scale well, and future-proof solutions that afford more advanced functionality. "Operators have to do their homework and ensure the components they acquire today provide an upgrade path to next generation technologies," says Colin Urwin, Marketing Manager at Bridgewater Systems, a company that provides carrier-grade policy management solutions. "In the ideal scenario they'll be able to choose network elements, software, customer premise equipment, etc. that lets them minimize their investment during launch and ramp up as customer demand requires it. Of course, an ecosystem of compatible and interoperable products makes that network expansion an easier, more cost effective exercise for all involved."

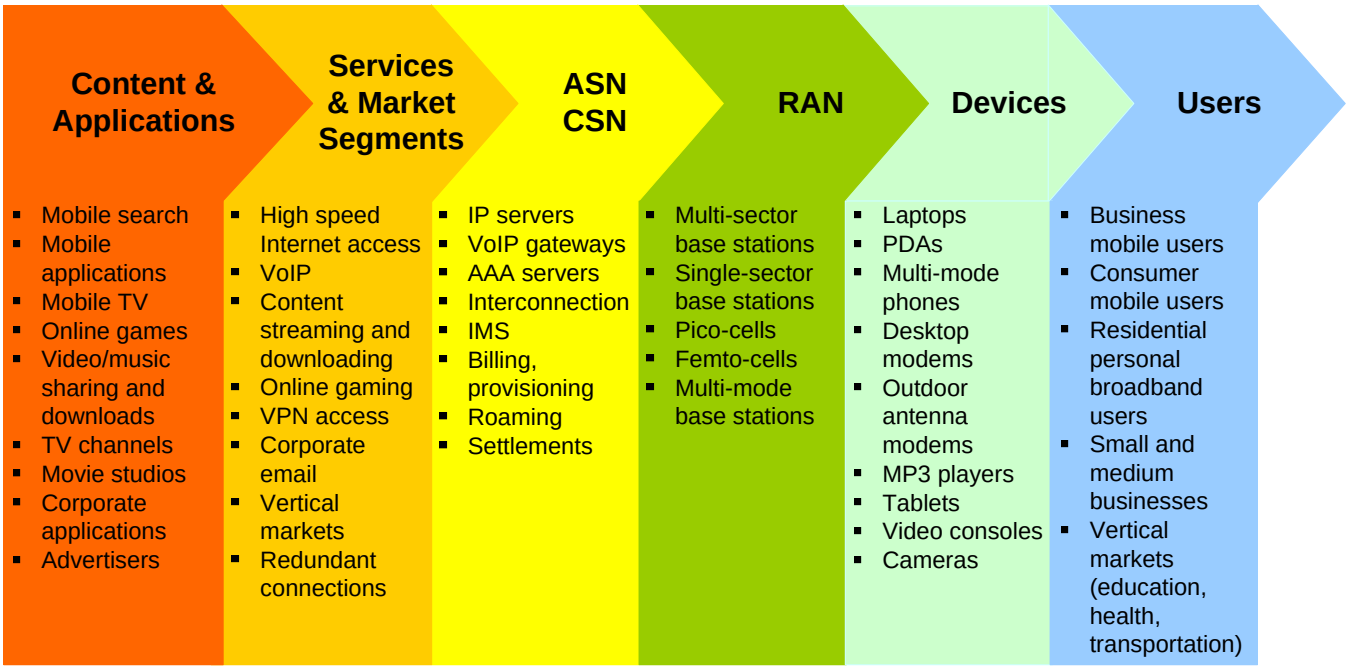

Figure 2. The emerging WiMAX Ecosystem

To assist network operators in this task, some vendors are actively establishing partnerships and conducting extensive tests to ensure full interoperability, above what is required by the standards and by certification programs.

Conclusions

WiMAX is a technology that has the potential to radically change the way fixed and mobile, voice and data services are provided, using a highly spectrally efficient wireless interface.

Network operators that want to take advantage of this opportunity need to quickly move beyond the radio interface, assess their unique requirements for the core network and choose the solution that is best suited to their needs. This is crucial to ensure that they can successfully and cost-effectively roll out both basic and advanced services and meet the expectations of their customers.

The open IP architecture gives network operators great flexibility when selecting solutions that work with legacy networks or that use the most advanced technologies, and in determining what functionality they want their network to support. They can choose from a vertically integrated vendor that provides a turnkey solution or they can pick and choose from a dense ecosystem of best-of-breed players with a more narrow focus.

"Next generation broadband wireless networks are about much more than just deploying the best radios" says Rudy Leser, VP of Corporate Marketing and Strategy at Alvarion. "In order to be able to roll out both basic and advanced mobile broadband services to customers, operators need to implement various systems to address the radio access, core network, back office, end user devices, and even content and applications."

A vibrant WiMAX ecosystem is rapidly emerging to address the needs of network operators. It includes a wide range of players: content providers and application developers, device manufacturers, solution providers and equipment vendors. Many have started to work together to ensure that operators can fully exploit WiMAX capabilities and deliver compelling, cost-effective services to their subscribers.

Acronyms

3G	Third Generation
3GPP	The Third Generation Partnership Project
3GPP2	The Third Generation Partnership Project Two
AAA	Authorization, Authentication and Accounting
ASN	Access Service Network
BRAS	Broadband Access Server
BTS	Base Transceiver Station
BWA	Broadband Wireless Access
CSN	Connectivity Service Network
DSL	Digital Subscriber Line
FA	Foreign Agent
HA	Home Agent
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
MAC	Medium Access Control [Layer]
MS	Mobile Station
MVNO	Mobile Virtual Network Operator
NWG	[WiMAX Forum's] Networking Working Group
ODM	Original Device Manufacturer
OEM	Original Equipment Manufacturer
PHY	Physical [Layer]
PPPoE	Point-to-Point Protocol over Ethernet
PSTN	Public Switched Telephone Network
QoS	Quality of Service
RNM	Reference Network Model
RRA	Radio Resource Agent
RRC	Radio Resource Controller
RRM	Radio Resource Management
VoIP	Voice over Internet Protocol
WiMAX	Worldwide Interoperability for Microwave Access

About Senza Fili Consulting

Senza Fili Consulting provides advisory support on wireless data technologies and services. Our expertise extends to cellular communications, WiMAX, Wi-Fi, and other fixed and mobile Broadband Wireless Access (BWA) technologies. We assist vendors in gaining a better understanding of the service provider and end-user markets. We work alongside service providers in developing a wireless data strategy and in assessing the demand for wireless services. Independent advice, a strong quantitative backing, and an international perspective are the hallmarks of our work.

At Senza Fili we have in-depth expertise in financial modeling, market forecasts and research, white paper preparation, business plan support, due diligence, training, and evaluation of end-user requirements. Our clients are international and span the entire value chain: they include fixed and mobile operators, ISPs, wireless ISPs, other service providers, vendors, solution providers, system integrators, investors, and industry associations.

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