



Briefing Paper

WiMAX Technology Roadmap: The Path to Harmonization of 4G Technology Standards



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Executive Summary

This Heavy Reading Briefing Paper was prepared at the request of the WiMAX Forum, to provide recommendations on the WiMAX technology roadmap and to highlight the best methods for supporting the harmonization of 4G standards for the benefit of WiMAX operators and the related technology ecosystem. It provides an action plan for the WiMAX Forum to take a leadership role by ensuring that WiMAX operators have access to an on-going supply of low cost wireless broadband CPE and devices required to attract investment and sustain their development in developed, rural and emerging markets.

The WiMAX ecosystem is at a critical juncture in 2012. Mobile WiMAX was the first 4G technology supporting all IP, OFDMA wireless broadband networks. WiMAX deployments sparked broadband competition in many countries worldwide. WiMAX networks brought essential wireless broadband to developing country markets and were launched in the developed countries like US and Japan to deliver differentiated mobile broadband services to meet the needs of the data centric customers. As indicated on Figure 1, with more than 500 deployments across 150 countries worldwide WiMAX still represents the most widely deployed, standards-based 4G network solution positioned to meet the rapidly growing demand for wireless broadband services generated by new devices and applications. These significant milestones were achieved amid reports from operators around the world reporting dramatic subscriber growth. As a result, WiMAX operators worldwide reached a total of 25 million subscribers and covered 1 Billion POPS or an estimated 14% of the world's population by the end of 2011.

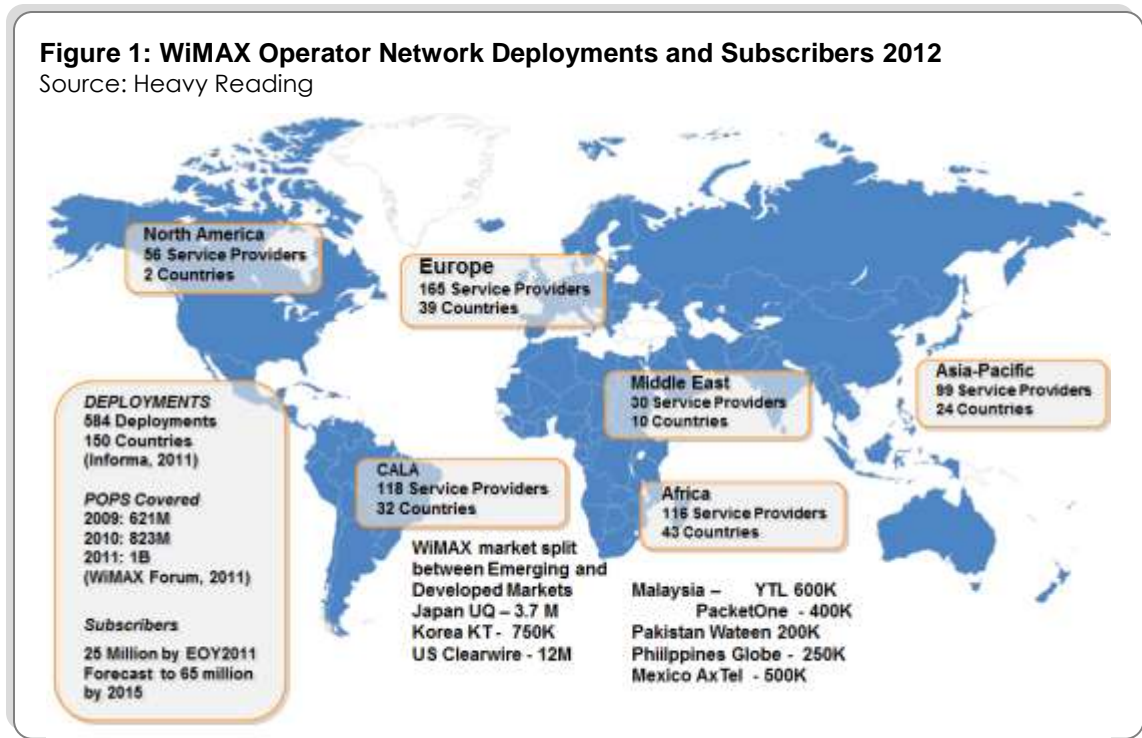
We expect WiMAX coverage to increase rather slowly on a global basis, although this is far behind the 85-90% that are covered by conventional mobile networks. As subscriber counts continue to grow, operators continue to invest in new WiMAX networks and network expansions. WiMAX technology continued to attract operators interested in bringing broadband internet to their customers immediately, and more than 30 different WiMAX networks were either launched or expanded operations in 2011. The WiMAX Forum estimated that total worldwide sales of WiMAX equipment reached \$502.1 million in the first quarter of 2011, which was up 49% from 2010. Although the number of WiMAX deployments remains greater than any other 4G technologies, many of these WiMAX networks are relatively small, serving targeted communities, businesses and private institutions.

Some of the largest WiMAX operators in the world in terms of subscribers and coverage are in developed markets, including large scale WiMAX network deployments by Clearwire in the US, UQ Communications in Japan and KT in Korea. Clearwire has deployed a WiMAX network with national US coverage, and with its primary retail partner Sprint has grown its 4G customer base to some 12 million total subscribers many of which use a dual-mode WiMAX/3G smartphone. Xplornet Communications (formerly Barrett Xplore) is Canada's leading rural broadband provider with 150,000 internet subscribers that operates a fixed WiMAX broadband wireless network using 3.5 MHz spectrum.

In South Korea, both Korea Telecom and SK Telecom provide WiMAX service to some 750,000 subscribers under the service name WiBro. UQ Communications is the fastest growing 4G operator in Japan, as it doubled its subscriber base to one million during the first half of 2011, and passed the two million subscriber barrier just five months before reaching three million subscribers in July 2012. The company recently revealed that it serves some 3.7 million subscribers and its WiMAX network now covers 90% of Japan's population. UQ's consumer device line-up includes wireless modems suitable for both mobile and nomadic usage, as well as WiMAX-enabled tablet computers and a dual-mode personal WiFi hotspot enabling roaming on cellular networks outside of UQ's coverage zones. KDDI, UQ's largest investor and MVNO, has recently started selling HTC EVO smartphones along with other dual-mode WiMAX/3G devices.

Figure 1: WiMAX Operator Network Deployments and Subscribers 2012

Source: Heavy Reading



Many of the over 500 existing WiMAX operators now need a technology roadmap for WiMAX 802.16e technology that allows them to compete effectively in their domestic markets and also guarantees them a supply of reasonably priced CPE and access devices over the next five years. The WiMAX Forum is now uniquely positioned to open its operator community to a broader ecosystem of radio access technologies and devices beyond WiMAX Release 1.0 and 2.0. Heavy Reading believes the WiMAX Forum should take the necessary steps to support the development of WiMAX Advanced which will allow operators the flexibility to leverage their all-IP broadband data network capabilities and support multiple broadband wireless access technologies including TD-LTE devices. We believe WiMAX Advanced will allow operators to more easily coexist and accommodate harmonization within a heterogeneous WiMAX Advanced network environment. WiMAX Advanced will be viewed as a positive development that should be welcomed by operators, infrastructure, device and chipset vendors worldwide.

WiMAX Operator Market Segmentation

As indicated in Figure 2, the WiMAX operator market continues to be split between developed countries and emerging or rural markets with the lowest broadband penetration rates. WiMAX operators in mature markets tend to use spectrum in the 2.3 or 2.5 GHz bands with 802.16e WiMAX technology to offer mobile broadband service embedded in many advanced smartphones and tablet computers. Mobile WiMAX operators have developed a unique business case for all IP mobile broadband in relation to 3G, and many have sparked 4G wars in mature markets well before HSPA+ and LTE were available. Without Mobile WiMAX, 4G mobile broadband networks would have been deployed more slowly in mature markets. WiMAX operators have operated in the 2.3, 2.5 and 3.5 GHz spectrum bands using un-paired time division (TDD) rather than paired frequency division (FDD) modulation. This allowed WiMAX operators to enjoy a time to market advantage over existing cellular operators and develop in a protected niche using spectrum that was viewed as unusable or undesirable.

Figure 2: WiMAX Operator Market Segmentation
Source: Heavy Reading

Markets/ Regions	WiMAX in 3.5/3.6 GHz LTE Bands 42 and 43	WiMAX in 2.3/2.5 GHz LTE Bands 38, 40 and 41
Mature and Developed	Fixed/Nomadic Wireless Broadband with Smartphones and Tablets	Mobile Broadband with Advanced Smartphones and Tablets
Emerging and Rural	Fixed/Nomadic Wireless Broadband with Low Cost Outdoor and Indoor CPE or Dongles	Mobile Broadband with Low Cost MiFi and Dongles, simple Smartphones and Tablets

We estimate that roughly 70% of WiMAX deployments are in emerging market countries, led by the Africa and Middle East (AME) regions with more than a quarter of global deployments. SafariCom (Kenya) operates the largest WiMAX network in the AME region. In Malaysia, WiMAX has been deployed by PacketOne Networks which has grown to serve more than 400,000 fixed/nomadic WiMAX subscribers, and its competitor YTL Communications has now netted over 600,000 subscribers since it launched WiMAX services in November of 2010. In Pakistan, four WiMAX operators now serve 460,000 broadband wireless subscribers, including Wateen, WiTribe, Augere Qubee and Mobilink. Other significant WiMAX operators in Asia Pacific emerging markets include Globe Telecom supports 250,000 WiMAX subscribers in the Philippines, BSNL in India, as well as Vee Time, Tautang, Global Mobile and Far Eastone Telecom in Taiwan.

In Eastern Europe, WiMAX networks are being operated by Max Telecom (Bulgaria), Neotel (Macedonia) and LRTC MEZON (Lithuania). In Mexico, AxTel has deployed a WiMAX network using 2.6 GHz spectrum supporting some

500,000 subscribers. Digicel has deployed WiMAX networks in Jamaica and throughout the Caribbean, while IBW is developing WiMAX networks throughout Central America. WiMAX networks have been deployed in Latin America by such operators as Telmex in Chile, Movilmax in Venezuela, Ertech/Telmex in Argentina and Embratel in Brazil.

Many WiMAX network deployments in emerging markets still use 3.5 GHz spectrum to offer essential fixed or nomadic wireless broadband service and 802.16d technology, an older standard that leading vendors no longer ship. The first available WiMAX devices were PC cards and USB dongles, followed by laptops with embedded modems, leaving operators no choice but to focus on offering broadband competition in many rural areas or developing emerging countries worldwide. Going forward, we expect all WiMAX operators to use 802.16e equipment even if regulatory bodies restrict them from offering mobility.

4G Roadmaps to IMT Advanced

The first releases of mobile WiMAX, HSPA+ and LTE are all considered by the International Telecommunication Union (ITU) to be pre-4G technologies. The OFDMA architecture of both WiMAX and LTE will pave the way toward true 4G IMT-Advanced networks, which as defined by the ITU-R achieve 1 Gbps or more. In October 2010, the ITU announced that the following two technologies have successfully met all of the established criteria to be officially designated as IMT-Advanced, qualifying them as true 4G mobile broadband technologies:

- Mobile WiMAX 2 or IEEE 802.16m - also known as Wireless-MAN-Advanced
- 3GPP LTE Advanced - LTE Release 10 supporting both paired Frequency Division Duplex (FDD) and unpaired Time Division Duplex (TDD) spectrum

Each of these technologies requires further development before they can be commercially deployed. ITU has also recognized that the term “4G”, may also be applied to the forerunners of these technologies, LTE and WiMAX, and to other evolved 3G technologies such as HSPA+ “providing a substantial level of improvement in performance and capabilities with respect to the initial third generation systems now deployed.”

In October 2010 the ITU officially designated IEEE 802.16m as an IMT-Advanced (4G) technology. A few larger operators have already begun planning the evolution of their networks from Mobile WiMAX 802.16e to IEEE802.16m or WiMAX Release 2.0. UQ Communications has been conducting the world’s first WiMAX 2.0 field trial in Tokyo in cooperation with Samsung Electronics. The pilot uses 20MHz of spectrum in the 2.6GHz band. And achieved downlink transmission speeds of over 100Mbps. WiMAX 2.0 is based on the IEEE802.16m standard approved by the WiMAX Forum in May 2011. The ITU has approved IEEE802.16m as an IMT-Advanced technology. In a separate, but related, announcement UQ Communications has revealed that it has signed a memorandum of understanding (MoU) with YTL Communications to increase collaboration. Under the MoU, UQ and YTL plan to work together on business and technical aspects with the aim of creating a stronger WiMAX ecosystem.

The WiMAX standard has gained enough backing and volume to serve as an alternative for the provisioning of mobile broadband access. It has inspired a new wireless broadband operator business model based on its flexible, open, flat, all-IP network architecture which well suited to providing wireless Internet access services. The WiMAX ecosystem has always been focused on remaining open and flexible to adapt to the needs of its operators, applications and end customers. Without the constraints of any legacy mobile technologies and with the support of the vendor community, the WiMAX Forum has also developed new modes for addressing certain specific vertical industry market opportunities. The WiMAX Forum's roadmap already includes WiGRID, a new wide-area networking technology based on IEEE 802.16e and complementary to cellular M2M, for energy utilities and smart grid industrial applications. The WiMAX Forum has a similar AeroMACS initiative based on WiMAX technology to support the aviation industry, as airports around the globe update their communications infrastructure.

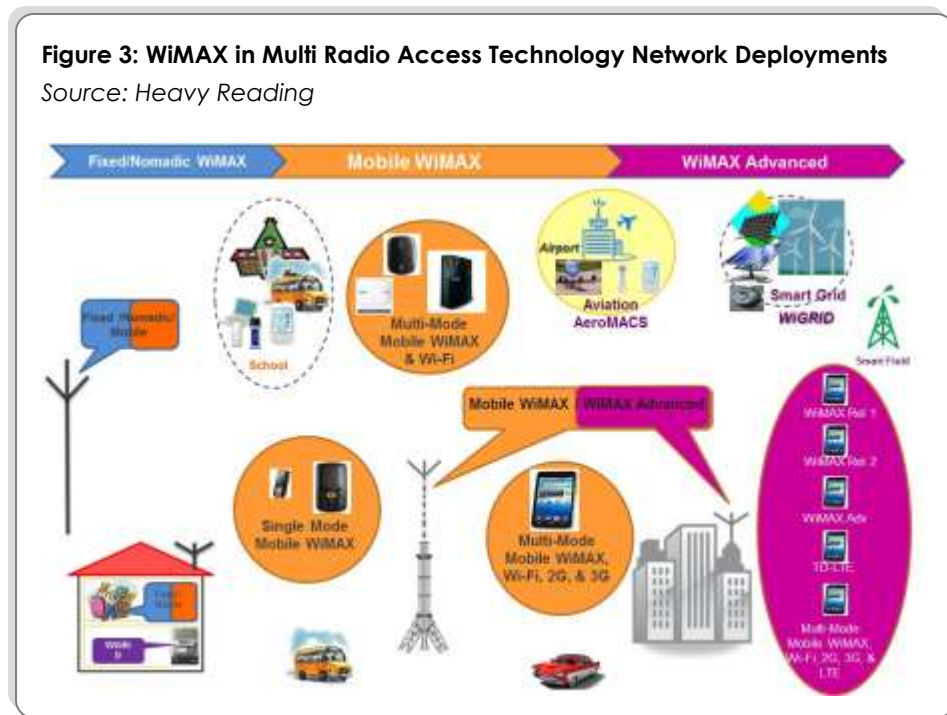
Technology Roadmap for Current WiMAX Operators

Many of the over 500 existing WiMAX operators in emerging and/or rural markets now need a technology roadmap for WiMAX 802.16e technology that allows them to compete effectively in their domestic markets and also guarantees them a supply of reasonably priced CPE and access devices over the next five years. Many of most advanced WiMAX network operators need a deterministic way to run their business, with a clear plan and schedule from Mobile WiMAX 802.16e to deploy WiMAX 2.0, or other next generation technologies that can provide an interim step to IMT Advanced. WiMAX Operators must define a clear strategy and roadmap to next generation technologies, even if this path is not executed for a number of years. Having a technology roadmap will enable them to satisfy their customer base, gain the investment they need, and continue to run their businesses successfully. With a clear technology road-map, these operators will find it easier to raise capital, satisfy investors, retain subscribers and sustain their businesses.

The WiMAX Forum has been the guiding force defining this technology roadmap, and must now step forward with a new framework for WiMAX network evolution on the path to IMT-Advanced. WiMAX Forum has partnered with key operators and their suppliers to demonstrate operators how they can future-proof their radio access and backhaul networks, core networks and CPE to provide continuity of service and continuity of business for their current customers and investors. The key is that by leveraging the unique models of UQ and YTL, the WiMAX Forum has recently approved the WiMAX Advanced that will be published in December as a network evolution road map. These roadmaps will establish a recommended timeline and outline the architecture changes necessary for a smooth transition path with a plan to ultimately converging as IMT-Advanced.

Many WiMAX operators also need near-term plan to access to a broader ecosystem of devices and operate more easily within a heterogeneous network environment. Just as 3GPP has defined interim steps toward Release 10 or LTE-Advanced, the WiMAX Forum should adopt *WiMAX Advanced* as an extension to its technical roadmap. WiMAX Advanced should offer WiMAX operators the flexibility to leverage their all-IP broadband data networks and more easily support of multiple radio access technologies in a heterogeneous

network environment through the harmonization of WiMAX with 3GPP LTE technologies and standards under IMT Advanced. The following is the first network architecture diagram developed by WiMAX Forum as an important next step on the WiMAX Roadmap positioned as WiMAX Advanced.



Dual Mode Device Strategy

One of the key issues facing current WiMAX operators is the continued supply of customer devices. The WiMAX Forum has been working with chipset and CPE vendors and selected operators to help ensure access to an on-going supply of low cost CPEs. An additional key piece of the forward looking strategy for the operators is how to implement a *WiMAX Advanced* device strategy that allows WiMAX operators to support WiMAX Release 1.0 (based on IEEE 802.16e), WiMAX Release 2.0 (based on IEEE 802.16m) and other radio access technologies on the same network as part of their technology roadmap.

The vendor community has taken a leadership role in this initiative, as chip set and CPE manufacturers working on dual mode devices, such as Sequans, GCT, HiSilicon, Huawei, Samsung, ZTE and GreenPacket. Here are some examples:

- GCT® Semiconductor and YTL Communications announced the launch of a new WiMAX + HSPA 4G smartphone, Eclipse, enabled by GCT's WiMAX single-chip solution, GDM7205. YTL's converged 4G smartphone Eclipse is making its debut on YTL's Yes 4G network.

- Sequans Communications has announced the first dual-mode, single die, WiMAX/LTE baseband chip at the heart of its second generation LTE platform, Andromeda, highly optimized for multi-mode 4G mobile devices. Andromeda includes baseband and RF chipsets and reference designs, and leverages three years of Sequans' LTE IOT, field trial, and commercial deployment experience.
- Sequans Communications and Clearwire have announced an agreement to collaborate on multi-band, multi-mode TD-LTE and FDD-LTE solutions for the purpose of accelerating the availability of LTE devices for Clearwire's planned TD-LTE network and to optimize the user experience for Clearwire's customers.
- Sequans is now working with Greenpacket and Packet One Networks to develop LTE solutions, including dual-mode 4G WiMAX/LTE TDD solutions for Greenpacket's global operator customers, including P1 in Malaysia. Greenpacket is testing Sequans technology to develop LTE and dual-mode WiMAX/LTE reference designs as part of its strategy to launch a complete ecosystem of 4G networking solutions and devices.
- The Taiwanese WiMAX device ecosystem is also supporting the development of dual-mode WiMAX/LTE devices to serve new markets in advanced applications for WiMAX in vertical markets such as smart grid, high speed rail and public safety."

Dual mode devices are a critical part of the operator's technology strategy and can be implemented during the evolution period by an operator. This would limit the number of devices that would have to be replaced by the operator that implements coexistence and customers can continue with uninterrupted service.

Radio Access Networks

WiMAX operators must also have a smooth and cost effective way to support multiple radio access technologies on the same network. Most existing WiMAX operators have an operational network, supporting existing customers at a high performance level with proven, reliable technology. Any roll off of performance, or degradation of service can jeopardize the successful business that these operators have created. Yet some operators may take the strategic decision to eventually evolve to a WiMAX 2 or other radio access technologies either for compatibility with other providers, an eventual greater selection of devices and the potential for lower costs eventually. If an operator makes the decision for coexistence, they must have a plan to ensure a smooth transition for their network and their subscribers.

Some vendors have made network equipment available which is software upgradeable using the same WiMAX hardware. Many of the existing BBUs are built in such a way that they are capable of accepting multiple channel cards supporting different access technologies. Some existing WiMAX remote radio heads (RRHs) support WiMAX only. However, there are advanced RRHs available in the marketplace that are capable of being upgraded via software to

support other TDD technologies. As a result, a single BBU could easily be shared by both the WiMAX 1.0, 2.0 or other radio access technologies. Depending upon the specific vendor or product, a wideband RRH can support multiple technologies in different bands simultaneously and antennas can also be shared between the technologies.

As an example, a successful test of Alvarion's 4Motion® WiMAX software-defined RAN infrastructure solution supporting a seamless TD-LTE option was announced by Xplornet Communications in late 2011. Airspan also offers a suite of 4G hybrid multi-platform RAN base stations capable of running a combination of WiMAX, TD-LTE, GSM and WiFi to support a Heterogeneous Network (HetNet). NewNet Communications is a US based technology firm that recently acquired the NSN-Motorola portfolio of dual mode TD-LTE/WiMAX base stations, access points, and ASN gateways.

Huawei has released one of the industry's first commercially available WiMAX and LTE TDD SingleRAN end-to-end network solutions which enables operators to simultaneously support WiMAX 1.0, 2.0 and TD-LTE devices. This SingleRAN WiMAX/LTE TDD network solution is being used by Clearwire in the US, Mobily and Saudi Telecom Company, and the first 3.5GHz commercial TD-LTE network operated by UK Broadband. Samsung also has a similar WiMAX and TD-LTE RAN solution being used by Clearwire that could also be used by YTL in Malaysia. ZTE provides a similar UniRAN multi-mode network solution for P1 in Malaysia, and Huawei and ZTE are also supplying the RAN infrastructure for Wireless City Planning (WCP) led by SOFTBANK for its TD-LTE compatible AXGP Mobile Broadband network in Japan.

With the technology options available, operators should develop plans for supporting multi-mode and multi-standard networks. Depending upon a mix of variables including spectrum availability, market rollout plans, and many other factors, operators may choose to deploy WiMAX 1.0, 2.0 and other all IP radio access network technologies together in one of several different scenarios.

- 100% overlay across the entire existing WiMAX network,
- partial overlay with WiMAX in a market, and
- no overlap between WiMAX and other all-IP network deployments

Core Network Plan

In addition to developing a strategy for supporting multiple radio access technologies, an operator must also plan to evolve its core network to support multiple standards and maintain session continuity. The evolution of the WiMAX core network to support technologies can be largely, if not completely, handled by software upgrades of WiMAX core components. This implementation allows a rapid development of an integrated architecture, and would ensure minimal disruption for existing subscribers. WiMAX operators need to work with their current core network provider to understand whether this type of software upgrade is possible for the WiMAX core equipment that has been deployed.

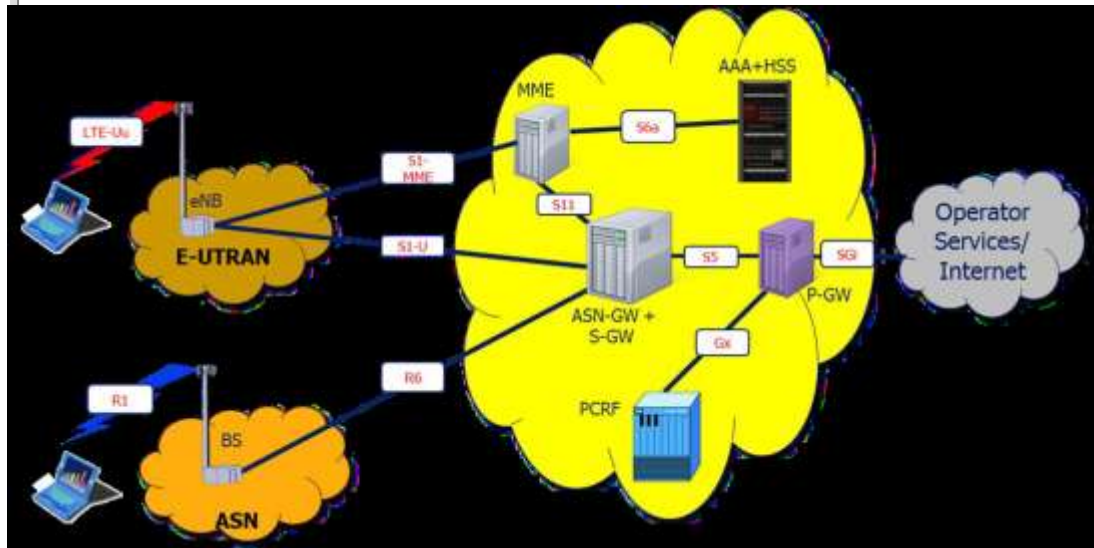
Figure 4 demonstrates a common WiMAX core architecture in which some of the components can be software upgraded. One example of the evolution to the common core network is as follows: the Serving Gateway (S-GW) function is added as a software upgrade or a hardware upgrade to the ASN-GW, the PDN Gateway (P-GW) function is added as a software upgrade or a hardware upgrade to the HA, the Mobility Management Entity (MME) function can be added as a new hardware component or as a software upgrade to ASN-GW, the Home Subscriber Server (HSS) function can be added as a software upgrade or a hardware upgrade to the WiMAX AAA, and the Policy and Charging Rules Function (PCRF) can be added via a new hardware component for serving both networks. For the operators not looking at session continuity between WiMAX and other radio access technologies, a Simple IP deployment scenario may make sense with combined ASN-GW, S-GW, and P-GW.

Backhaul Network Considerations

An operator must also plan the evolution of their backhaul network in addition to the RAN and Core. As the size and topology of the network grows and the traffic requirements of the network expand, the backhaul architecture and capacity must scale as well. WiMAX backhaul networks can implement with either wireless microwave solutions or wired fiber solutions, or a combination of wireless and wired solutions. As a network evolves, an operator must consider the effect of the overall backhaul requirements, and ensure that backhaul capacity does not become a bottleneck for the network.

Figure 4: Common Core Network to Support IMT-Advanced

Source: Heavy Reading



Conclusion

WiMAX operators need a technology roadmap to ensure continued investment in their broadband wireless access business. The WiMAX Forum should work with existing WiMAX Operators and their vendors to develop a technology roadmap to support future releases of WiMAX, and to harmonize them with other radio access technologies under IMT-Advanced. The WiMAX Forum should identify the key phases and best practices, and establish a timeline for a successful network evolution to accommodate coexistence and harmonization across multiple broadband wireless access technologies and CPE within a WiMAX Advanced network. The WiMAX Forum should specifically outline the network architecture changes necessary to allow operators to support TD-LTE devices within a WiMAX Advanced network. This will provide WiMAX operators the flexibility to leverage their all-IP broadband data network capabilities and more easily operate within a heterogeneous network environment.

Operators also need modeling tools and assistance in developing a transitional business case from Mobile WiMAX to WiMAX 2, WiMAX Advanced or other 4G radio access technologies. Figure 5 provides a screen shot image of the Wireless 20/20 WiROI 4G business planning tool that is designed to develop these transitional business cases. The WiMAX Forum could work with operators to develop the unique scenarios and assumptions that make it effective in their network evolution planning toward WiMAX Advanced.

