WHITEPAPER

WiMAX Goes the Last Mile

This whitepaper is an extract from:

Fixed WiMAX
Opportunities for 'Last Mile' Broadband Access 2008-2013

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Introduction

The Last Mile is referred to as the final stage of delivery for a communications service such as cable TV, voice telephony, broadband Internet, to the end user or subscriber. This leg is usually connected by a wired connection and is relatively expensive to lay, especially in the case of fibre optic cables. This becomes very crucial in developing economies where there are constraints on the cost of deployment of communications networks. With the advent of WiMAX, the costs and time consuming aspects of wired network construction are negated, but there is still a need to study whether WiMAX could actually be considered as a replacement or complement to the traditional last mile technologies.

This white paper is focused on WiMAX 802.16e as a fixed broadband "last mile" technology to deliver broadband to subscribers who either cannot receive wired DSL or who are not receiving high speed of DSL connection via a wireless local loop. The white paper explains the various alternative broadband technologies and highlights technical differences as well as performance parameters. This white paper also investigates market status and forecasts.

Last Mile Technologies

WiMAX Standard

WiMAX is defined as Worldwide Interoperability for Microwave Access, which allows for broadband wireless access of information in the form of packet data. It was introduced in October 2001 and is also known as the IEEE 802.16 standard. The standard defines the air interface, also known as the PHY (Physical) layer as well as the MAC (Media Access Control) layer. These are the bottom two layers, which define the OSI 7 layer model that define a network technology. The protocols defined in these two layers allow it to control how packet data is handled at the air interface and at the first point of entry and exit of a system. The MAC layer is designed in such a way that it controls various PHY specifications. The original specification allowed it to operate in the 10 to 66 GHz range. There were subsequent changes made to the standard, which curtailed it to the 2-11 GHz range. This was primarily done to improve its range. The standard is meant to operate in both licensed and unlicensed frequencies.

OFDM

WiMAX is based on the OFDM (Orthogonal Frequency Division Multiplexing) protocol where the information packet is broken down into closely spaced carriers, which are sent on individual frequencies. The data on each individual or orthogonal carrier is independently modulated using Quadrature Amplitude Modulation (QAM) or Phase Shift Keying (PSK) techniques. The orthogonality allows for signals to be perpendicular to each other in mathematical terms, which means that they are able to overlap without interfering with each other. The OFDM signal is the sum of the individual orthogonal carriers.

The advantages of OFDM include high resistance to noise and high spectral efficiency. This means that operators achieve higher utilisation of their costly spectrum. OFDM is normally combined with error correcting codes leading to coded OFDM or COFDM. This gives it the property of coping with multipath fading which is the phenomenon due to which multiple copies of the signal are received at various time intervals. Sub-channelisation is another method that is used in conjunction with OFDM to where a sub-set of carriers in COFDM are used to carry upstream traffic. This is advantageous to the end client as it increases his power and range. This is being used in the Fixed WiMAX standard.

802.16d WiMAX

The 802.16d 2004 standard was released in October 2004 and was set as the fixed version of the WiMAX standard. This version allows for NLOS (Non line of sight) connections and sets OFDM as the transmission protocol. The end user can use Fixed WiMAX from a fixed location or can move as a nomadic user. The nomadic user usually moves at pedestrian speeds. The Fixed WiMAX standard is suitable for last mile connections and for backhaul connections to cellular networks and Wi-Fi hotspots. Fixed WiMAX could be compared to technologies like DSL and Wi-Fi as a last mile option. In the case of backhaul connections it could be compared to traditional wired backhaul solutions like leased line and to wireless backhaul solutions like satellite and microwave backhaul.

Fixed WiMAX 802.16 2004 has however been superseded by the new 802.16e – 2005 standard also known as Mobile WiMAX.

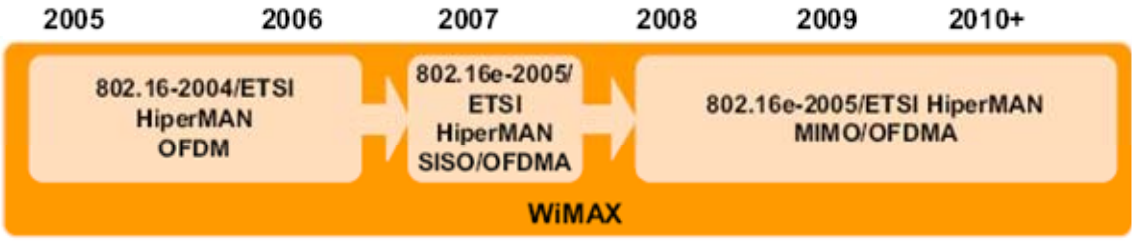
802.16e-2005 WiMAX

The 802.16e WiMAX standard has been established to provide specifications for mobile broadband wireless access systems. The IEEE Working group ratified the standard in December 2005. Though the fixed version of WiMAX focuses on the point to multipoint broadband access and the last mile solution, the mobile version of WiMAX will focus on mobility for broadband. The strength lies in the fact that as well as mobility it will also support fixed and nomadic access. In fact, most 802.16e based networks will begin operation as fixed networks and evolve into portable and then later mobile access.

The peak throughput rates are expected to be 75 Mbps, but the typical throughput will be less than that. The throughput depends on the bandwidth in which the system operates. 802.16e is supposed to operate in the channel bandwidth of 10 MHz, which gives the 'best possible' throughput at 37 Mbps (Source: The Promise of WiMAX, Motorola).

The aim of the WiMAX standard is to ensure that interoperability is maintained among devices. The WiMAX Forum members include prominent industry vendors like Intel, Fujitsu, Samsung, AT&T, Nokia, Cisco, Motorola, Nortel and operators like Sprint, BT, ZTE, and Korea Telecom. In August 2007, the WiMAX Forum announced that Vodafone had become a principal member. Vodafone is seeking to evaluate the full capabilities and potential of WiMAX. The WiMAX Forum has defined a timeline (see Figure 1) which shows how WiMAX standards will evolve to a full mobility solution 802.16e.

Figure 1: WiMAX Timeline



Source: WiMAX Forum March 2007

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In January 2007 the IEEE outlined a proposed work plan for a new version of the 802.16 standard that could increase speeds up to 1 Gbps while maintaining backwards compatibility with existing WiMAX products. The new version has been called 802.16m, and the IEEE aims to complete the standard by September 2008 for approval by December 2008. The IEEE wants to develop a "competitive" and "significantly improved" radio access technology that is "compliant with the ITU R/IMT advanced requirements for 4G" while keeping interoperability with mobile WiMAX. Potential new radio interfaces will need to support up to 100Mbps for high mobility such as mobile access and up to 1Gbps for low mobility such as nomadic/local wireless access, by around 2010. A step-change speed increase of this magnitude will enable service providers to offer a range of content-rich multimedia services such as TV, fast music downloads and streamed video as well as greatly improved VoIP performance and capacity.

In October 2007, the ITU approved WiMAX mobile broadband technology as a global 3G communications standard.

HSPA (High Speed Packet Access)

HSPA is the UMTS Forum's generic term for improvements in the UMTS Radio Interface in Releases 5 and 6 of the 3rd Generation Partnership Project (3GPP) standards, and represents the packet data service for the Wideband CDMA (WCDMA) standard. This means both improvements in the downlink allowing operators to increase throughput, often referred to as HSDPA (High Speed Downlink Packet Access), and in the uplink, often called High Speed Uplink Packet Access (HSUPA) but also called Enhanced Dedicated Channel (E-DCH).

3GPP Release 5 (announced in 2003 and initially rolled out in 2005) introduced HSDPA. With HSDPA, WCDMA has been extended with additional transport and control channels, such as the high-speed downlink shared channel (HS-DSCH), which provides improved support for interactive, background and, to some extent, streaming services. HSDPA enables speeds of up to a maximum of 14.4Mbit/s, subject to network conditions. HSDPA is a software upgrade that doubles the air interface capacity of WCDMA networks and provides a 5-10 fold increase in downlink speeds of standard 3GSM/W-CDMA networks. It enables users to access the Internet on mobile phones and PC notebooks, at speeds previously reserved for DSL. Release 5 also introduced the IP Multimedia Subsystem (IMS) architecture to enhance integrated multimedia applications and offer mobile operators a more efficient way of offering these services. Release 5 also introduced the IP UTRAN concept to realise transport network efficiencies and reduce transport network costs.

3GPP Release 6 provides for High Speed Uplink Packet Access (HSUPA) with increased speed up to 5.8Mbps via a dedicated uplink channel, the second phase of IP Multimedia Subsystem (IMS), inter-working with Wireless Local Area Networks (WLAN), Multimedia Broadcast Multicast Service (MBMS), and

Enablers for Push to talk (PoC). Release 6 was completed in March 2005, and 2006 and 2007 have seen a number of trials and demonstrations of its features such as HSUPA.

The next phase of HSDPA is 3GPP Release 7. Its main priority is improved support and performance for conversational and interactive services such as Push-to-talk, picture and video sharing, and Voice and Video over IP. For users, all these developments translate into improved network performance, faster application performance, a wider range of applications that function well, and increased productivity

Beyond Release 7, 3GPP currently has a study item referred to as "HSPA Evolution" or "HSPA+" not yet in a formal specification development stage. The intent is to create a highly optimised version of HSPA that uses both Release 7 features and other features such as interference cancellation and optimisations to reduce latency. Peak data rates could approach 42 Mbit/s in the downlink, depending on configuration. These improvements are designed to enable HSPA to remain competitive until at least 2010.

There is also a 3GPP vision of Long Term Evolution (LTE), although it is not yet at the stage of being specified as part of any Release 8. The overall aim is to improve the capacity to cope with ever-increasing volumes of data traffic in the longer term, and peak data rates will be up to 50Mbit/s in the uplink and 100Mbit/s in the downlink.

In the very long term, operators could deploy Fourth Generation (4G) networks using LTE. There are no official standards yet for 4G, but research is focusing on technologies capable of delivering peak rates of 1 Gbps, fully IP based, and with full network agility for handovers between different types of networks.

CDMA 1X EVDO & UMB

The CDMA EVDO (Evolution Data-Only) standard is a part of the family of 3G CDMA standards. It officially belongs to the cdma2000 family and is being backed by Qualcomm. It supports only data and no voice. In case it is deployed with a voice network it needs to support an extra 1.25 MHz channel. There are three versions of 1x EVDO, which include 1x EVDO Rev 0, Rev A and Rev B. The initial revision of the standard, Rev 0, is an improvement over the 1xRTT data standard. Rev 0 was approved by the ITU in 2000 and has been in use worldwide. The Rev A standard offers improvements in latencies and data rates. Rev A can now support low latency applications like VoIP along with Internet services. The data rates for Rev A are 3 Mbps for the downlink and 1.8 Mbps for the uplink. The next revision, EV-DO Rev. B, allows operators to combine Rev. A channels for increased performance and capacity. This first implementation of Rev. B is available as a software upgrade. Rev. B supports peak data rates of up to 14.7 Mbps.

At the CTIA Wireless show Qualcomm announced the addition of an end-to-end solution for Ultra Mobile Broadband (UMB) or EVDO Rev. C to its roadmap. UMB technology incorporates the benefits of OFDMA, CDMA and other air interface techniques with MIMO and advanced antenna technologies to offer features such as support for broadband speeds, greater capacity and coverage, and an enhanced user experience for future mobile services.

ADSL

Asymmetric Digital Subscriber Line (ADSL) is a technology that allows for users to transmit information mainly over traditional copper lines. ADSL allows for data to flow in an asymmetric or single direction at higher speeds. ADSL provides speeds up to 8Mbps downstream (to the user) and up to 1 Mbps upstream, depending upon line length and loop and line conditions. Some service providers offer speeds up to 24 Mbps and upstream speeds are typically much slower – in the 256kbps range. Home users normally prefer high download speeds and do not run servers, which require a high upload return path. DSL is also available in a number of more "flavours" including SHDSL, VDSL and VDSL2 which provide different line speeds; for example VDSL2 offers 100Mbps symmetrical for very intensive applications such as multi-channel HDTV.

The problem with ADSL is that its quality is very much dependent on the quality of the copper phone line, which is likely to have been first installed many years previously. The quality is also dependent on the

distance from the telephone exchange, and the contention ratio with other users which varies according to time of day. Thus rural or remote areas, as well as some metropolitan areas could suffer with quality and speed issues. Deploying fibre optic cables or even copper wires to such remote areas is a costly (and as a result often unfeasible) alternative. There is no guarantee of service/speed, up to 2 weeks' leadtime for deployment to the user, no portability outside of the immediate home area, and certainly no mobility. These problems are negated with WiMAX. It is being seen as a viable alternative and complement to ADSL networks.

Wi-Fi and Mesh Networking

Wireless Fidelity or Wi-Fi is a set of standards that allow devices such as desktops, laptop computers, PDAs (Personal Digital Assistants) and mobile phones to connect to the Internet or a LAN (local area network) using a Wireless connection. The set of standards in the IEEE 802.11 specification come under Wi-Fi. It is also known as a Wireless LAN (WLAN). Depending on the standard, the range of coverage also differs from 45m indoors to around 90m outdoors. The Wi-Fi standard consists primarily of 5 standards, which have bit rates in the range of 2 Mbps to 100 Mbps.

Table 1: List of Wi-Fi Standards

Standard	Maximum Bit Rate	Channels Provided	Frequency Band	Radio Technique
802.11	2 Mbps	3	2.4 GHz	FHSS or DSSS
802.11b	11 Mbps	3	2.4 GHz	DSSS
802.11a	54 Mbps	12	5 GHz	OFDM
802.11g	54 Mbps	3	2.4 GHz	OFDM
802.11n	100+ Mbps	2	2.4 GHz, 5GHz or dual band	OFDM

Source: Intel; Juniper Research

802.11n is the first wireless networking technology with the bandwidth and feature set to replace standard wired Ethernet. In February 2006, the IEEE task group responsible for developing the 802.11n standard accepted a joint proposal to amend the IEEE 802.11 wireless local area network (WLAN) standard by adding specifications for new technologies that will raise WLAN connection speeds to as much as 600 Mbps. 802.11n adds MIMO, enabling the transmission of multiple data streams through multiple antennas. The 802.11n standard promises to achieve as much as 5x the throughput and up to double the range over legacy 802.11a/b/g technology. The 802.11n draft 2.0 readies Wi-Fi for connected home applications such as home theatre, audio, gaming, and computing systems. The Wi-Fi Alliance began testing of products based on the new IEEE 802.11n draft 2.0 in June 2007. In the first three months over 95 such products were certified. The 802.11n standard has been delayed and is still in draft; it may not be issued finally until 2009. There are further versions of 802.11 such as 802.11y that are planned as improvements to the existing standard.

Wi-Fi is being used commercially to provide coverage at 'hotspots' as well as convert homes and offices into wireless Internet ready locations. Wi-Fi operates in a fixed bandwidth while WiMAX operates using flexible bandwidth. The flexible bandwidth capability in WiMAX makes it more spectrum efficient than Wi-Fi. The majority of Wi-Fi services are data oriented at the moment and do not provide voice services. The spectrum on which Wi-Fi operates is unlicensed in most of the countries in which it operates. This is one reason why it is not considered a very secure standard. It uses WEP (Wireless Encryption Protocol), which provides minimal security, but the later Wi-Fi standards of 802.11g and 802.11i provide improved security and use the WPA (Wi-Fi Protected Access) encryption protocol. Although there have been improvements in security, the Wi-Fi standard is still considered to be a LAN standard and is limited in its range and speed capabilities.

Wi-Fi is also being used in mesh networks, where a series of Wi-Fi nodes are connected to each other in order to enhance the coverage of a LAN to a MAN (Metropolitan area Network). The 802.11s standard will standardise Wi-Fi Mesh Networking topology. The standard is still at the draft stage, with the IEEE continuing to work on resolving comments and improving the Draft.

i. QoS (Quality of Service) in Wi-Fi

Although the successive standards of Wi-Fi such as 802.11n are trying to match WiMAX in range and security, it is doubtful if they would be able to offer similar QoS levels. QoS is an important feature that is becoming important with the advent of VoIP. This concept when extended to Wi-Fi networks takes the shape of VoWi-Fi (Voice over Wi-Fi). With services such as audio, video and voice being offered over wireless, it becomes important to have QoS. The Wi-Fi standard that is promoting QoS in Wi-Fi is 802.11e - also known as WMM (Wireless Multimedia). It supports the 802.11a, 802.11b and 802.11g set of standards. 802.11n is expected to support multimedia applications in the home, with the ability to transport multiple HD video streams, whilst accommodating VoIP and data transfers for multiple users with high QoS and latest generation security protections.

ii. Differences between WiMAX 802.16e and Wi-Fi

Technically there are many differences in WiMAX and Wi-Fi such as the capability of the MAC layer in WiMAX to be more bandwidth efficient as well as support scheduling. In Wi-Fi the end points compete with each other depending on the distance from the access point. This is because Wi-Fi operates in half-duplex configuration. The ability of WiMAX to have a flexible MAC layer, which operates by assigning a time slot to the end points, enables it to provide QoS to the various nodes in its network. Wi-Fi does not have this flexible capability in the MAC layer, which restricts its QoS features. The enhanced QoS features in WiMAX allow it be a superior standard to Wi-Fi especially for enterprise services where there is a need for service level guarantees.

iii. Wi-Fi Mesh and Mobile WiMAX

The optimal solution for Wireless Service Providers is to employ a solution, which contains both a wireless mesh architecture and WiMAX. Wi-Fi has already been deployed in laptops, PDAs and now in mobile phones, which gives it market presence advantage over WiMAX. The release of the 802.16e WiMAX Mobile standard brings superior security: WiMAX usually operates in licensed spectrum whereas this is not the case for Wi-Fi. WiMAX has been created with the view of solving the last mile problem and improving connectivity. WiMAX used in conjunction with Wi-Fi could provide enhanced solutions both in terms of costs and performance, taking advantage of the large number of Wi-Fi supported devices and using WiMAX as a backhaul for the mesh.

Satellite

Satellite is another last mile technology, which mainly provides television services and is now also being used for broadband Internet services. Although itself expensive compared to other technologies, satellite technology is useful in remote and rural areas where the deploying copper or fibre is difficult. There are a few proprietary satellite technologies like Dish Network, DirecTV and Direct to Home (DTH) that are providing these services. The major disadvantage of Satellite based last mile technology is that the upload speed is about one-tenth of the download speed, which is around 500 kbps. This is much slower than ADSL, Cable and even Wi-Fi.

Future Developments

In January 2007 the IEEE outlined a proposed work plan for a new version of the 802.16 standard that could increase speeds up to 1 Gbps while maintaining backwards compatibility with existing WiMAX products. The new version has been called 802.16m, and the IEEE aims to complete the standard by September 2008 for approval by December 2008.

Technology Summary

Clearly there are several more technologies that can deliver mobile broadband services now and in the future such as HSPA for example. Many detailed technical papers have been authored that compare the technical merits of the various solutions, and it is not the intention of this white paper to replicate these. However it is safe to conclude that the ultimate technology choice for network operators depends on a mix of factors, according to their relative importance given the business objective of the operator.

802.16e WiMAX: Market Status

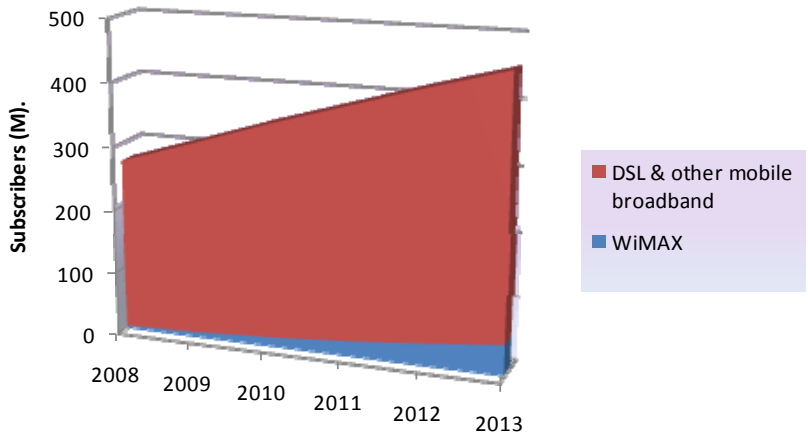
There are over 250 trial 802.16e WiMAX networks globally, and a small but growing number of commercial networks in service. It is also indisputable however, that Mobile WiMAX has become over the last year a market threat to HSPA technologies, whereas it has previously been just a technical threat. There has been a swathe of trial and network contract announcements over the last 12 to 15 months.

Juniper Research has analysed the primary target market focus of each of 55 service providers. The stand-out market focus is offering an alternative to DSL in both underserved (usually rural) areas and in metro areas where WiMAX is often positioned as a head-on competitor to DSL. Service providers in a number of underdeveloped countries are also targeting rural areas which have no wired networks at all, to provide basic telephony as well as more advanced services.

Fixed WiMAX Subscriber Forecasts

WiMAX is forecast to substitute for 12% of DSL and other mobile broadband subscriber deployments globally by 2013, representing 47 million subscribers. The following chart shows the rate of DSL substitution globally by WiMAX:

Figure 3: DSL Replacement by Fixed 802.16e WiMAX Subscriber Base (m) Global Forecast 2008 – 2013



Source: Juniper Research

The top WiMAX regions for DSL substitution will be the Far East and North America, followed by Western Europe and Africa/Middle East.

Order the Full Report

Fixed WiMAX: Opportunities for 'Last Mile' Broadband Access, 2008 - 2013

This whitepaper is taken from Juniper Research's report entitled "The Last Mile: Opportunities for WiMAX 2008 - 2013".

In the full report, Juniper Research forecasts the market potential for 802.16e Fixed WiMAX as a broadband wireless local loop technology, as an alternative to DSL in unserved and underserved areas. Juniper Research assesses the current and future status of 802.16e WiMAX based on interviews with senior executives of some of the leading vendors and operators in the growing WiMAX market. The report includes regional forecasts, and case studies describing how a number of operators are deploying 802.16e WiMAX in their networks, and their development plans for the future.

As well as extensive qualitative analysis, this report provides five-year forecasts, across eight regions of the world. Forecasts are broken down into Fixed 802.16e WiMAX subscriber numbers, service revenues and devices.

For more details on this report visit the website www.juniperresearch.com or phone +44 (0)1256 830002.

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Juniper Research specialises in providing high quality analytical research reports and consultancy services to the telecoms industry. We have particular expertise in the mobile, wireless, broadband and IP-convergence sectors. Juniper is independent, unbiased, and able to draw from experienced senior managers with proven track records.

About the Author

Howard Wilcox is a Senior Analyst with Juniper Research. He has over twenty five years' experience in the Telecommunications sector. Howard has extensive experience of analysing markets, vendors and service providers in the telecoms networks marketplace. He was previously Director of Industry Intelligence at Marconi, where he has spent most of his career in a variety of analytical and management roles. Howard began his career at Ferranti where he established a win/loss system. From 1997 to 2004 he represented UK Telecoms Industry body Intellect as a Member of European IT Observatory (EITO) Task Force. Howard has a BA in Business Administration with French from Loughborough University.

Publication Details

Publication date: April 2008

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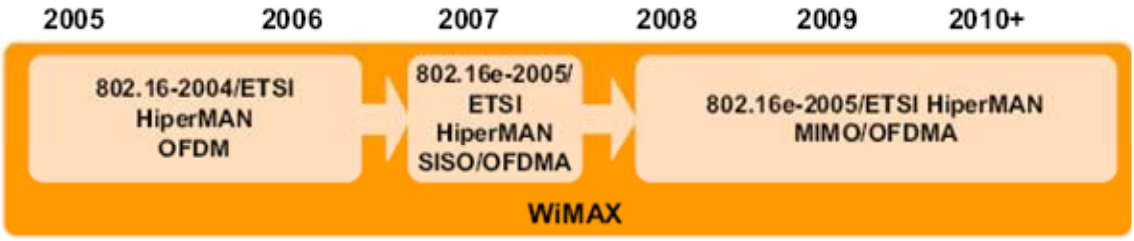

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HSPA is the UMTS Forum's generic term for improvements in the UMTS Radio Interface in Releases 5 and 6 of the 3rd Generation Partnership Project (3GPP) standards, and represents the packet data service for the Wideband CDMA (WCDMA) standard. This means both improvements in the downlink allowing operators to increase throughput, often referred to as HSDPA (High Speed Downlink Packet Access), and in the uplink, often called High Speed Uplink Packet Access (HSUPA) but also called Enhanced Dedicated Channel (E-DCH).

3GPP Release 5 (announced in 2003 and initially rolled out in 2005) introduced HSDPA. With HSDPA, WCDMA has been extended with additional transport and control channels, such as the high-speed downlink shared channel (HS-DSCH), which provides improved support for interactive, background and, to some extent, streaming services. HSDPA enables speeds of up to a maximum of 14.4Mbit/s, subject to network conditions. HSDPA is a software upgrade that doubles the air interface capacity of WCDMA networks and provides a 5-10 fold increase in downlink speeds of standard 3GSM/W-CDMA networks. It enables users to access the Internet on mobile phones and PC notebooks, at speeds previously reserved for DSL. Release 5 also introduced the IP Multimedia Subsystem (IMS) architecture to enhance integrated multimedia applications and offer mobile operators a more efficient way of offering these services. Release 5 also introduced the IP UTRAN concept to realise transport network efficiencies and reduce transport network costs.

3GPP Release 6 provides for High Speed Uplink Packet Access (HSUPA) with increased speed up to 5.8Mbps via a dedicated uplink channel, the second phase of IP Multimedia Subsystem (IMS), inter-working with Wireless Local Area Networks (WLAN), Multimedia Broadcast Multicast Service (MBMS), and

Enablers for Push to talk (PoC). Release 6 was completed in March 2005, and 2006 and 2007 have seen a number of trials and demonstrations of its features such as HSUPA.

The next phase of HSDPA is 3GPP Release 7. Its main priority is improved support and performance for conversational and interactive services such as Push-to-talk, picture and video sharing, and Voice and Video over IP. For users, all these developments translate into improved network performance, faster application performance, a wider range of applications that function well, and increased productivity

Beyond Release 7, 3GPP currently has a study item referred to as "HSPA Evolution" or "HSPA+" not yet in a formal specification development stage. The intent is to create a highly optimised version of HSPA that uses both Release 7 features and other features such as interference cancellation and optimisations to reduce latency. Peak data rates could approach 42 Mbit/s in the downlink, depending on configuration. These improvements are designed to enable HSPA to remain competitive until at least 2010.

There is also a 3GPP vision of Long Term Evolution (LTE), although it is not yet at the stage of being specified as part of any Release 8. The overall aim is to improve the capacity to cope with ever-increasing volumes of data traffic in the longer term, and peak data rates will be up to 50Mbit/s in the uplink and 100Mbit/s in the downlink.

In the very long term, operators could deploy Fourth Generation (4G) networks using LTE. There are no official standards yet for 4G, but research is focusing on technologies capable of delivering peak rates of 1 Gbps, fully IP based, and with full network agility for handovers between different types of networks.

CDMA 1X EVDO & UMB

The CDMA EVDO (Evolution Data-Only) standard is a part of the family of 3G CDMA standards. It officially belongs to the cdma2000 family and is being backed by Qualcomm. It supports only data and no voice. In case it is deployed with a voice network it needs to support an extra 1.25 MHz channel. There are three versions of 1x EVDO, which include 1x EVDO Rev 0, Rev A and Rev B. The initial revision of the standard, Rev 0, is an improvement over the 1xRTT data standard. Rev 0 was approved by the ITU in 2000 and has been in use worldwide. The Rev A standard offers improvements in latencies and data rates. Rev A can now support low latency applications like VoIP along with Internet services. The data rates for Rev A are 3 Mbps for the downlink and 1.8 Mbps for the uplink. The next revision, EV-DO Rev. B, allows operators to combine Rev. A channels for increased performance and capacity. This first implementation of Rev. B is available as a software upgrade. Rev. B supports peak data rates of up to 14.7 Mbps.

At the CTIA Wireless show Qualcomm announced the addition of an end-to-end solution for Ultra Mobile Broadband (UMB) or EVDO Rev. C to its roadmap. UMB technology incorporates the benefits of OFDMA, CDMA and other air interface techniques with MIMO and advanced antenna technologies to offer features such as support for broadband speeds, greater capacity and coverage, and an enhanced user experience for future mobile services.

ADSL

Asymmetric Digital Subscriber Line (ADSL) is a technology that allows for users to transmit information mainly over traditional copper lines. ADSL allows for data to flow in an asymmetric or single direction at higher speeds. ADSL provides speeds up to 8Mbps downstream (to the user) and up to 1 Mbps upstream, depending upon line length and loop and line conditions. Some service providers offer speeds up to 24 Mbps and upstream speeds are typically much slower – in the 256kbps range. Home users normally prefer high download speeds and do not run servers, which require a high upload return path. DSL is also available in a number of more "flavours" including SHDSL, VDSL and VDSL2 which provide different line speeds; for example VDSL2 offers 100Mbps symmetrical for very intensive applications such as multi-channel HDTV.

The problem with ADSL is that its quality is very much dependent on the quality of the copper phone line, which is likely to have been first installed many years previously. The quality is also dependent on the

distance from the telephone exchange, and the contention ratio with other users which varies according to time of day. Thus rural or remote areas, as well as some metropolitan areas could suffer with quality and speed issues. Deploying fibre optic cables or even copper wires to such remote areas is a costly (and as a result often unfeasible) alternative. There is no guarantee of service/speed, up to 2 weeks' leadtime for deployment to the user, no portability outside of the immediate home area, and certainly no mobility. These problems are negated with WiMAX. It is being seen as a viable alternative and complement to ADSL networks.

Wi-Fi and Mesh Networking

Wireless Fidelity or Wi-Fi is a set of standards that allow devices such as desktops, laptop computers, PDAs (Personal Digital Assistants) and mobile phones to connect to the Internet or a LAN (local area network) using a Wireless connection. The set of standards in the IEEE 802.11 specification come under Wi-Fi. It is also known as a Wireless LAN (WLAN). Depending on the standard, the range of coverage also differs from 45m indoors to around 90m outdoors. The Wi-Fi standard consists primarily of 5 standards, which have bit rates in the range of 2 Mbps to 100 Mbps.

Table 1: List of Wi-Fi Standards

Standard	Maximum Bit Rate	Channels Provided	Frequency Band	Radio Technique
802.11	2 Mbps	3	2.4 GHz	FHSS or DSSS
802.11b	11 Mbps	3	2.4 GHz	DSSS
802.11a	54 Mbps	12	5 GHz	OFDM
802.11g	54 Mbps	3	2.4 GHz	OFDM
802.11n	100+ Mbps	2	2.4 GHz, 5GHz or dual band	OFDM

Source: Intel; Juniper Research

802.11n is the first wireless networking technology with the bandwidth and feature set to replace standard wired Ethernet. In February 2006, the IEEE task group responsible for developing the 802.11n standard accepted a joint proposal to amend the IEEE 802.11 wireless local area network (WLAN) standard by adding specifications for new technologies that will raise WLAN connection speeds to as much as 600 Mbps. 802.11n adds MIMO, enabling the transmission of multiple data streams through multiple antennas. The 802.11n standard promises to achieve as much as 5x the throughput and up to double the range over legacy 802.11a/b/g technology. The 802.11n draft 2.0 readies Wi-Fi for connected home applications such as home theatre, audio, gaming, and computing systems. The Wi-Fi Alliance began testing of products based on the new IEEE 802.11n draft 2.0 in June 2007. In the first three months over 95 such products were certified. The 802.11n standard has been delayed and is still in draft; it may not be issued finally until 2009. There are further versions of 802.11 such as 802.11y that are planned as improvements to the existing standard.

Wi-Fi is being used commercially to provide coverage at 'hotspots' as well as convert homes and offices into wireless Internet ready locations. Wi-Fi operates in a fixed bandwidth while WiMAX operates using flexible bandwidth. The flexible bandwidth capability in WiMAX makes it more spectrum efficient than Wi-Fi. The majority of Wi-Fi services are data oriented at the moment and do not provide voice services. The spectrum on which Wi-Fi operates is unlicensed in most of the countries in which it operates. This is one reason why it is not considered a very secure standard. It uses WEP (Wireless Encryption Protocol), which provides minimal security, but the later Wi-Fi standards of 802.11g and 802.11i provide improved security and use the WPA (Wi-Fi Protected Access) encryption protocol. Although there have been improvements in security, the Wi-Fi standard is still considered to be a LAN standard and is limited in its range and speed capabilities.

Wi-Fi is also being used in mesh networks, where a series of Wi-Fi nodes are connected to each other in order to enhance the coverage of a LAN to a MAN (Metropolitan area Network). The 802.11s standard will standardise Wi-Fi Mesh Networking topology. The standard is still at the draft stage, with the IEEE continuing to work on resolving comments and improving the Draft.

i. QoS (Quality of Service) in Wi-Fi

Although the successive standards of Wi-Fi such as 802.11n are trying to match WiMAX in range and security, it is doubtful if they would be able to offer similar QoS levels. QoS is an important feature that is becoming important with the advent of VoIP. This concept when extended to Wi-Fi networks takes the shape of VoWi-Fi (Voice over Wi-Fi). With services such as audio, video and voice being offered over wireless, it becomes important to have QoS. The Wi-Fi standard that is promoting QoS in Wi-Fi is 802.11e - also known as WMM (Wireless Multimedia). It supports the 802.11a, 802.11b and 802.11g set of standards. 802.11n is expected to support multimedia applications in the home, with the ability to transport multiple HD video streams, whilst accommodating VoIP and data transfers for multiple users with high QoS and latest generation security protections.

ii. Differences between WiMAX 802.16e and Wi-Fi

Technically there are many differences in WiMAX and Wi-Fi such as the capability of the MAC layer in WiMAX to be more bandwidth efficient as well as support scheduling. In Wi-Fi the end points compete with each other depending on the distance from the access point. This is because Wi-Fi operates in half-duplex configuration. The ability of WiMAX to have a flexible MAC layer, which operates by assigning a time slot to the end points, enables it to provide QoS to the various nodes in its network. Wi-Fi does not have this flexible capability in the MAC layer, which restricts its QoS features. The enhanced QoS features in WiMAX allow it be a superior standard to Wi-Fi especially for enterprise services where there is a need for service level guarantees.

iii. Wi-Fi Mesh and Mobile WiMAX

The optimal solution for Wireless Service Providers is to employ a solution, which contains both a wireless mesh architecture and WiMAX. Wi-Fi has already been deployed in laptops, PDAs and now in mobile phones, which gives it market presence advantage over WiMAX. The release of the 802.16e WiMAX Mobile standard brings superior security: WiMAX usually operates in licensed spectrum whereas this is not the case for Wi-Fi. WiMAX has been created with the view of solving the last mile problem and improving connectivity. WiMAX used in conjunction with Wi-Fi could provide enhanced solutions both in terms of costs and performance, taking advantage of the large number of Wi-Fi supported devices and using WiMAX as a backhaul for the mesh.

Satellite

Satellite is another last mile technology, which mainly provides television services and is now also being used for broadband Internet services. Although itself expensive compared to other technologies, satellite technology is useful in remote and rural areas where the deploying copper or fibre is difficult. There are a few proprietary satellite technologies like Dish Network, DirecTV and Direct to Home (DTH) that are providing these services. The major disadvantage of Satellite based last mile technology is that the upload speed is about one-tenth of the download speed, which is around 500 kbps. This is much slower than ADSL, Cable and even Wi-Fi.

Future Developments

In January 2007 the IEEE outlined a proposed work plan for a new version of the 802.16 standard that could increase speeds up to 1 Gbps while maintaining backwards compatibility with existing WiMAX products. The new version has been called 802.16m, and the IEEE aims to complete the standard by September 2008 for approval by December 2008.

Technology Summary

Clearly there are several more technologies that can deliver mobile broadband services now and in the future such as HSPA for example. Many detailed technical papers have been authored that compare the technical merits of the various solutions, and it is not the intention of this white paper to replicate these. However it is safe to conclude that the ultimate technology choice for network operators depends on a mix of factors, according to their relative importance given the business objective of the operator.

802.16e WiMAX: Market Status

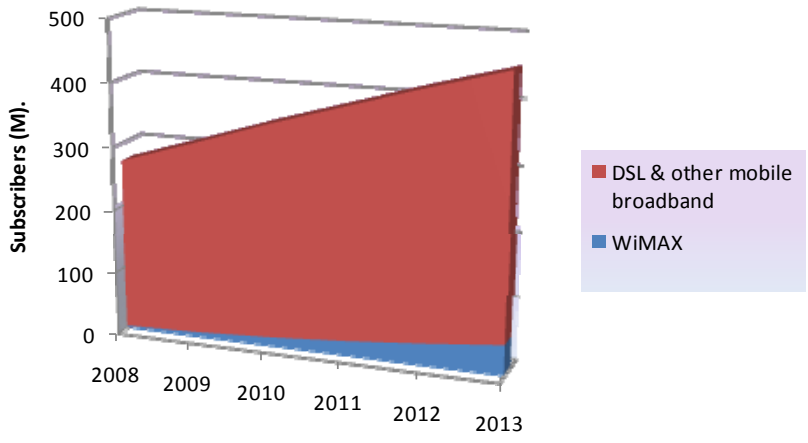
There are over 250 trial 802.16e WiMAX networks globally, and a small but growing number of commercial networks in service. It is also indisputable however, that Mobile WiMAX has become over the last year a market threat to HSPA technologies, whereas it has previously been just a technical threat. There has been a swathe of trial and network contract announcements over the last 12 to 15 months.

Juniper Research has analysed the primary target market focus of each of 55 service providers. The stand-out market focus is offering an alternative to DSL in both underserved (usually rural) areas and in metro areas where WiMAX is often positioned as a head-on competitor to DSL. Service providers in a number of underdeveloped countries are also targeting rural areas which have no wired networks at all, to provide basic telephony as well as more advanced services.

Fixed WiMAX Subscriber Forecasts

WiMAX is forecast to substitute for 12% of DSL and other mobile broadband subscriber deployments globally by 2013, representing 47 million subscribers. The following chart shows the rate of DSL substitution globally by WiMAX:

Figure 3: DSL Replacement by Fixed 802.16e WiMAX Subscriber Base (m) Global Forecast 2008 – 2013



Source: Juniper Research

The top WiMAX regions for DSL substitution will be the Far East and North America, followed by Western Europe and Africa/Middle East.

Order the Full Report

Fixed WiMAX: Opportunities for 'Last Mile' Broadband Access, 2008 - 2013

This whitepaper is taken from Juniper Research's report entitled "Fixed WiMAX: Opportunities for 'Last Mile' Broadband Access, 2008 – 2013".

In the full report, Juniper Research forecasts the market potential for 802.16e Fixed WiMAX as a broadband wireless local loop technology, as an alternative to DSL in unserved and underserved areas. Juniper Research assesses the current and future status of 802.16e WiMAX based on interviews with senior executives of some of the leading vendors and operators in the growing WiMAX market. The report includes regional forecasts, and case studies describing how a number of operators are deploying 802.16e WiMAX in their networks, and their development plans for the future.

As well as extensive qualitative analysis, this report provides five-year forecasts, across eight regions of the world. Forecasts are broken down into Fixed 802.16e WiMAX subscriber numbers, service revenues and devices.

For more details on this report visit the website www.juniperresearch.com or phone +44 (0)1256 830002.

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Publication Details

Publication date: April 2008

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