WiMAX Basics from Deployments to PHY Improvments

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Abstract—**WiMAX (Worldwide Interoperability for Microwave Access) is an emerging broadband wireless technology for providing Last mile solutions for supporting higher bandwidth and multiple service classes with various quality of service requirement. The unique architecture of the WiMAX MAC and PHY layers that uses OFDMA to allocate multiple channels with different modulation schema and multiple time slots for each channel allows better adaptation of heterogeneous user's requirements. The main architecture in WiMAX uses PMP (Point to Multipoint), Mesh mode or the new MMR (Mobile Multi hop Mode) deployments where scheduling and multicasting have different approaches. In PMP SS (Subscriber Station) connects directly to BS (Base Station) in a single hop route so channel conditions adaptations and supporting QoS for classes of services is the key points in scheduling, admission control or multicasting, while in Mesh networks SS connects to other SS Stations or to the BS in a multi hop routes, the MMR mode extends the PMP mode in which the SS connects to either a relay station (RS) or to Bs. Both MMR and Mesh uses centralized or distributed scheduling with multicasting schemas based on scheduling trees for routing. In this paper a broad study is conducted About WiMAX technology PMP and Mesh deployments from main physical layers features with differentiation of MAC layer features to scheduling and multicasting approaches in both modes of operations.**

Keywords - WiMAX, PMP, Mesh, Scheduling WiMAX, Multicasting WiMAX

I. INTRODUCTION

The past few months have seen a storm of debate about the economics and return on investment of Wi-Fi hotspots. What almost all the arguments entirely ignore is the standard lurking on the horizon, which will turn current assumptions on their head. This is the 802.16x wireless metropolitan area network (WMAN) specification, which is being developed and promoted by the WiMAX industry group, whose most powerful members are Intel and Nokia. [2] As with Wi-Fi, the WiMAX label has now become widely acceptable as a name for the standard itself. Intel has called 802.16 "the most important thing since the Internet itself", and even allowing for a dose of self-serving, it is not talking entirely in hyperbole.

In July [7] WiMAX showed off its first system profiles and interoperability tests at the WCA annual conference in Washington DC, in a significant step towards making the 802.16a standard, ratified by the IEEE in March, a commercial technology. While a fully mobile version of WiMAX is in the wings, this first release will cover fixed wireless, and its supporters are focusing in particular on broadband last mile in unwired areas, and on backhaul for hotspots.

The WiMAX (Worldwide Interoperability for Microwave Access) group was actually set up two years ago by Nokia, Ensemble and the OFDM Forum, but gained a new lease of life in April when it was revived by Nokia in collaboration with Intel and added five new members, with nine more joining in May [11]. The non-profit group takes a similar role to the Wi-Fi Alliance in WLANs, backing development of wireless Man products based on 802.16 and working on standards certification and interoperability testing. The initial version of the standard operates in the 10-66GHz frequency band and requires line of sight towers, but the 802.16a extension, ratified in March, uses the lower frequency of 2-11GHz, easing regulatory issues, and does not require line of sight. It boasts a 31 mile range compared to Wi-Fi's 200-300 yards, and 70Mbps data transfer rates.

WiMAX president Margaret Labrecque says that collaborating on mass market products will achieve similar economies of scale to those seen in Wi-Fi WLAN devices. She says base stations will cost under $20,000 and support 60 enterprise customers with T1-class connections. Systems based on the mobile version of the standard, which should ship towards the end of next year, about six months after fixed wireless products, will be able to achieve long distance wireless networking and will have far greater potential than

Wi-Fi hotspots to provide ubiquitous coverage to rival that of the cellular network.

WiMAX stands for Worldwide Interoperability for Microwave Access and is a wireless communication technology that delivers high speed Internet access to wide geographical areas. Additionally, this is used as the trade name in reference to IEEE 802.16 global standard [3]. Also it is an established standard on Broadband Wireless Access under fixed and mobile network.

The purpose of WiMAX is to offer an access network that can supply a bigger coverage area with higher bandwidth than any currently available using the current wireless technologies like Wi-Fi and 3G. Regarding coverage, it has been developed, too, so as to provide a long range system that can cover a space of many miles. WiMAX has a service range of up to twenty or thirty miles, with fixed station broadband wireless access for as much as thirty miles and mobile station access for between three and ten miles.

II. WiMAX – Not just another standard

Broadband wireless access provides more capacity at lower cost than DSL or cable for extending the fiber networks and supporting multimedia and fast internet applications in the enterprise or home. But it has been held back by the lack of a standard, so that solutions have been based on proprietary, single-vendor efforts. Standardization through the IEEE 802.16 [4] specification raises the potential to:

- Stall wired broadband and makes wireless the key platform of the future

- Extend the range of Wi-Fi so that the myth of ubiquitous wireless can become a reality

- Provide an alternative or complement to 3G

- Provide an economically viable communications infrastructure for developing countries and mobile black spot regions in developed nations Markets for WiMAX

The greatest media excitement about WiMAX has Centered on its potential mobility and its role as a backhaul or even replacement for public Wi-Fi. However, its initial raison d'etre and still its primary focus is on broadband fixed wireless access for homes and businesses. This sector is populated by a horde of mainly American niche players with expensive equipment using various versions of smart antennas, OFDM and sometimes meshes to provide often effective alternatives to wired communications [7][8]. ArrayComm, Alvarion, IP Wireless, Navini and Beamreach are high profile names, though the majority of these specialists will refocus their products around WiMAX .

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Business users only 5 percent of commercial structures worldwide are served by fiber networks, the main method for the largest enterprises to access broadband, multimedia data services. In the wired world, these networks are extended to the business or residence via cable or DSL, both expensive options because of the infrastructure changes required. DSL typically operates at 128Kbps to 1.5Mbps and slower on the upstream. Enterprises can use WiMAX instead of T1 for about 10 percent of the cost, while SMEs can be offered fractional T1 services. Base stations will cost under $20,000 and support 60 enterprise customers with T1-class connections. Last mile to the home A low cost alternative could end the wars between the cable and ADSL operators and really make the broadband home revolution happen

A. Hotspots

Wi-Fi hotspot operators may be able to build a spot for a few thousand dollars' worth of equipment, but then they need to anchor it to the public network, and this is normally done with expensive T1 or DSL. WiMAX backhaul could significantly reduce hotspot costs, although there is also the potential for Wi-Fi to be bypassed altogether by WiMAX 'hot zones' [9]. Remote regions The most lucrative market for the proprietary BWA vendors has been remote regions, especially in developing countries but also in rural areas of the US, where there is no wired or cellular infrastructure nor the will or cash to invest in building it. The main alternative to BWA in this market is satellite. Still early in its lifecycle – and potentially a powerful technology to integrate with WiMAX – satellite has severe limitations of upstream bandwidth, spectrum availability and also suffers from high latency.

III. WiMAX Standards

In the last several years, the IEEE 802.16 working group has come up with many standards for WiMAX. The initial standard was introduced in 2001, endeavoring to establish communications in the 10–66 GHz frequency band along with line of sight requirements. Then IEEE 802.16a came out in 2003 to set forth more physical layer specifications for the 2–11 GHz frequency band with non line of sight when (OFDM) Orthogonal division Multiplexing and mesh mode were inserted into the WiMAX. Those two standards were revised some more in 2004 (IEEE 802.16-2004) [4]. The IEEE 802.16e standard has recently gained acceptance as the official mobile application standard as well.

A. PHY LAYER

WiMAX's physical layer is based on OFDM (orthogonal frequency division multiplexing) which is the transmission method of choice to operate high-speed data, video, and multimedia communications and it is employed by an assortment of valuable broadband systems, such as DSL, Wi-Fi, Digital Video Broadcast-Handheld (DVB-H), and Media FLO. OFDM offers an exquisite and professional approach to high data rate transmission in a non-line-of-sight or multipath radio setting[9][10].

OFDM, or orthogonal frequency-division multiplexing, is a way digital data can be encoded using more than one frequency for transmission. OFDM is well suited for wideband digital communication, either wireless or over copper wires, and is employed in applications like digital television and audio broadcasting, DSL broadband internet access, wireless networks, as well as 4G mobile communications[15].

Basically the same as coded OFDM (COFDM) and discrete multi-tone modulation (DMT), OFDM is a frequency-division multiplexing (FDM) mechanism employed as a digital multi-carrier modulation technique. For carrying data, many orthogonal sub carrier signals are closely spaced. The data is partitioned into a number of parallel data streams or channels, one for every sub-carrier. Every sub-carrier is modulated with a traditional modulation mechanism (like quadrature amplitude modulation or phase-shift keying) at a low symbol rate, keeping total data rates very much like traditional single-carrier modulation mechanisms in the same bandwidth[13].

There are three PHY alternatives for 802.16a: 1) an OFDM with 256 sub-carriers which is the only choice allowed by the ETSI in Europe, where the competing Hagerman standard will probably be subsumed by WiMAX; 2) OFDMA, with 2048 sub-carriers; and 3) a single carrier choice for vendors who believe they can solve multipath issues in this mode.

It is nearly a certainty that OFDM is poised for preeminence in cellular and all other wireless technology, with the OFDM Forum, its voice in the industry, counted also among the WiMAX Forum's founding members[2].

B. MAC layer

The MAC layer's main purpose is to offer the interface between the physical layer and the upper transport layers. In addition, the MAC layer IEEE 802.16 has been created for broadband wireless access applications that are point-to-multipoint. There's only one competition for the permission to enter the network, and for that WiMAX MAC utilizes a scheduling algorithm that requires a subscriber station. Once entry to the network is approved, the base station gives the subscriber station an access slot[12][13]. Its time slot might get bigger or smaller but it always still belongs to the particular subscriber station and others can't use it. Besides maintaining stability in overload and over-subscription conditions, the scheduling algorithm has the capability for improved bandwidth efficiency. In addition, the scheduling algorithm lets the base station control Quality of Service (QoS) variables by balancing the time-slot assignments among the application requirements of the subscriber station[6].

C. Quality of Service (QoS)

QoS is the basic core of the IEEE 802.16e media access control (MAC) architecture. Operators can get optimal network performance with mobile WiMAX QoS features, depending upon what the service level of the user is and what kind of service, such as voice, video, or gaming, is being provided. Service flows are specified by the standard to represent fine, granular IP sessions or coarsely differentiated services code points to allow end-to-end IP based QoS [15]. Moreover, sub-channelization and media access protocol (MAP) based signaling methods offer a flexible means on optimal scheduling of broadcast and uncast traffic on a frame-by-frame principle.

IV. WiMAX Deployments

Mesh and standard PMP, as per the IEEE 802.16, are the two operating modes of WiMAX. The WiMAX PMP is a network whose purpose is to offer last mile accessibility to an ISP (broadband service provider) [8]. In 2001 PMP was the standard network for WiMAX. Fig.1a shows an instance of network topology in which the WiMAX network contains one BS and many SSs.

A. Mesh mode

The implication of mesh mode is that there must be networking such as multi hop ad hoc via SSs. An instance of a WiMAX mesh network is shown in Fig.1b. It is supposed that BS is capable of supporting access to the Internet; a relay station (RS) is a special kind of SS which can forward traffic flows to BSs or other RSs; and a mobile station (MS) is an SS which can go around the network. While mesh mode gained excessive interest from researchers, it failed to deploy in the real world as it supports only OFDM and does not work well with PMP with different frame structure as well as network entry procedure [11].

B. PMP mode

In contrast [6][7] to PMP mode, mesh mode can be quickly employed to set up infrastructure plus it is more flexible. Actually, a more common term for mesh mode, wireless mesh network has drawn considerable attention in the last several years. Right now various standard groups for the IEEE are trying to see how to provide wireless mesh support to personal area and local area networks, among others .

Mesh [13][15] Mesh Mode is an alternative topology for subscriber-to-subscriber communication under non-line of sight 802.16a. In addition, it is added to the standards to permit overlapping, ad hoc networks in the unlicensed bands and widen the edges of the WMAN's range at little cost. Mesh support has lately been broadened into the licensed bands as well Mesh is a nice substitute for the more common NLOS,

even though it's topology and messaging are quite complex, because it is good at scaling and also addresses interference that comes from those who are license exempt. It lets a geographical area be densely seeded very affordably with WiMAX connections, allowing for strong communication possibilities because of the multiple paths that traffic can take (diagram following).
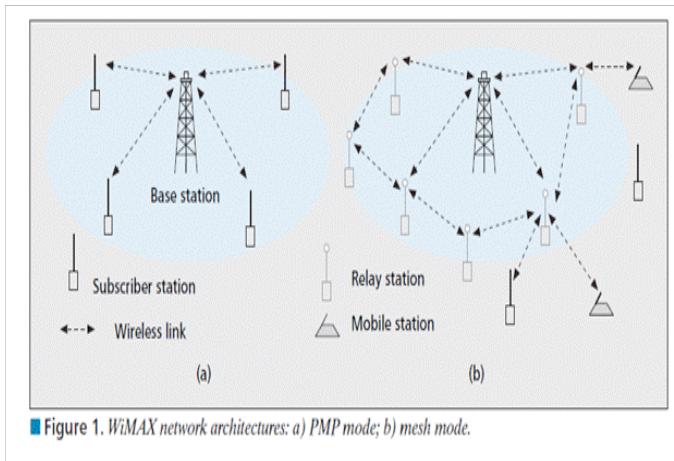

Figure 1. *WiMAX network architectures: a) PMP mode; b) mesh mode.*

Figure 1, showing the wimax deployment or the heterogeneous network [2]

- For a WiMAX network to be deployed effectively, two important issues need to be addressed regarding network layer design, and these are security as well as support of present and future applications [2].

C. Security

802.16 also contain sections on privacy and encryption: authentication with x.509 certificates and data encryption employing DES in CBC (cipher block chaining) mode with hooks specified for firmer algorithms such as AES.

Since April when the WiMAX Forum was created, there has been increasing momentum gathering behind 802.16a and its standard has been progressing with amazing speed. Ensuring that WiMAX will be quickly adopted, continually improved, and will distinguish itself from the other mobile standards that have become politically charged will require forceful leadership. Thus far significant names have been absent from WiMAX [11] its earliest focus on last mile is shown by the preference of the group on fixed wireless, OFDM specialists (the 802.16 specification is found on an implementation of OFDM from Wi-Lan of Canada), instead of enterprise focused providers or mobile carriers.

Some big vendors will roll the dice as always attempting to erect such market presence for their proprietary solutions as to bypass the industry standard – one example would be Motorola with its Canopy broadband fixed wireless platform. But those firms will join – Cisco being an important target – and meanwhile, the really remarkable feature of WiMAX has

been its clear aim and unity of purpose. Thus far, probably due to its somewhat small numbers, with the majority of them being little firms, it has stayed away from the complex politics and hidden agendas of most industry associations – albeit it comes at the cost of a direction which is greatly dominated by Intel and Nokia.

D. Mobility

Mobile WiMAX technology provides optimized handover mechanisms with latencies under 50 ms to help make certain real-time applications like Voice over Internet Protocol (VoIP) are efficiently supported without a decline in service quality. Good security measures are maintained during handover because of flexible key management schemes that are in place[8].

Spectral efficiency is necessary to provide support to complex user environments where there are hundreds of users per channel utilizing high bandwidths and a blend of continuous as well as burst traffic.

IPv4, IPv6, Ethernet, and ATM, among others, can be transported by WiMAX, which can support with high quality many services at once.

Bandwidth on demand (frame by frame) Quality of Service:

802.16's 'b' extension has to do with quality of service (QoS), which allows NLOS operation without excessive distortion of the signal due to buildings, weather and vehicles. In addition, traffic is prioritized smartly, by how urgent it is. Mechanisms in the Wireless MAN -- MAC offer differentiated QoS to take care of the different requirements of different applications. For example, low latency is required by voice and video although there is some error rate tolerated, although a lot of other data applications need to be free of errors although they can make allowances for latency [12]. The standard takes care of those various transmissions by employing suitable attributes in the MAC layer, which is more efficient than using layers of control above the MAC.

E. Scalability

Scalable OFDMA (SOFDMA) is employed by mobile WiMAX technology which, as shown by the first Mobile WiMAX system profiles, can work in channel sizes of 5, 7, 8.75, and 10 MHz to conform with assorted spectrum allocations throughout the globe.

Security [11] the latest state-of-the-art IEEE 802 wireless access system security features are adopted by mobile WiMAX technology. They encompass authentication based on Extensible Authentication Protocol

(EAP), authenticated encryption established on Advanced Encryption Standard (AES), Cipher-based Message Authentication Code (CMAC), as well as control message protection methods found on Hashed Message Authentication Code (HMAC).

The preferred spelling of the word "acknowledgment" in America is without an "e" after the "g". Avoid the stilted expression "one of us (R. B. G.) thanks ...". Instead, try "R. B. G. thanks..." [9].

V. PHY IMPROVEMENTS FOR 802.16E

At the PHY level, the important technologies of 802.16e are OFDMA plus an enhanced version known as Scalable OFDMA (SOFDMA). A multicarrier modulation is employed by OFDMA with the carriers partitioned between the users to produce sub channels. The coding and modulation are adjusted individually for every sub channel, enabling channel optimization on a finer scale (instead of using the same parameters for the entire channel). This approach optimizes spectrum resource usage and improves indoor coverage by allocating a vigorous scheme (yet, with low rates) to weak links[5][6].

In 802.16 OFDMA is an option for fixed access but isn't necessary to get its products certified. Still, OFDMA is needed in 802.16e instruments and a must for certification. An expansion of OFDMA is provided by SOFDMA, which feeds a number of subcarriers into a channel that has possible values of 128, 512, 1,024, and 2,048.

Fixed broadband services are benefited by OFDMA and SOFDMA, too, since they allow carriers to more effectively allocate spectrum so that interference is reduced.

Conversely, OFDMA [5] and SOFDMA, in comparison to OFDM, require a more complex installation and operation. As time goes on, there may be providers who deploy 802.16e networks in order to offer services to both fixed and mobile users. Moreover, a number of vendors have declared that their first 802.16 base stations can be upgraded to 802.16e via software.

Manufacturers as well as those who set the standards have largely given the seal of approval to SOFDMA. Looking at the SOFDMA based Korean standard WiBro (Wireless Broadband) made a believer of the IEEE on SOFDMA's strengths. Wi Bro has operated together with 802.16e, and the devices of the two technologies will be interoperable. Plus, Intel has just reported that the chosen layer of PHY for both inside and mobile equipment will be SOFDMA [6].

VI. CONCLUSION

In this report we did some research on WiMax. We began by investigating a broad definition of WiMAX, then delineating the Standards of WiMAX and its architecture as sort forth by the IEEE 802.16 standard's work group. In addition, communication in the 10-66 GHZ frequency band was augmented by line of sight requirements.

Following this, in the year 2003, IEEE 802.16 came out and provided more physical layer specifications for use by the 2-11 GHz frequency band in conjunction with non-line-of-sight. Simultaneously, use of the (OFDM) Orthogonal division Multiplexing and the Mesh mode were introduced to the WiMAX. In the year 2004 we mulled over the notion of the Physical layer based on (OFDM).

This is the chosen transmission scheme that enables high-speed data, video, and multimedia communications. This scheme is used by multiplicity of beneficial broadband system. Additionally, we considered the MAC layer which serves the purpose of providing an interface between the physical layer and the higher transport layers. Nevertheless, created for point-to-multipoint broadband wireless access applications, the IEEE 802.16 MAC layer attempts just one time to connect for the first time to the network. WiMAX MAC employs a scheduling algorithm for which the subscriber station requires.

We looked at Quality of Services (QOS) as well, which is the basic foundation of the IEEE 802e media access control (MAC) architecture. In addition, we provide a short summary of the WiMAX Deployments and PMP as well as Mech mode. PMP network strives to handle last mile access to a broadband internet service provider ISP. Subscriber-to-subscriber communication is enabled by the non-line of sight 802.16a, which is an optional topology of mech mode. This research may be quite a good reference point for comprehending WiMAX technology so it was worthwhile mentioning its deployment and its challenges.

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