

EMERGING BROADBAND WIRELESS TECHNOLOGIES: WIFI AND WIMAX

Rama K. Raju¹ and A. Damodaram²

¹ Department of ECE, Medak College of Engineering & Technology
svs_raju63@yahoo.com

² Department of CSE, Jawaharlal Nehru Technological University
damodarama@rediffmail.com

ABSTRACT

Now-a-days there is high demand for broadband mobile services. Traditional high-speed broadband solutions depend on wired technologies namely digital subscriber line (DSL). Wifi and Wimax are useful in providing any type of connectivity such as the fixed or portable or nomadic connectivity without the requirement of LoS (Line of Sight) of the base station. Mobile Broadband Wireless Network (MBWN) is a flexible and economical solution for remote areas where wired technology and also terminal mobility cannot be provided. The IEEE Wi-Fi and Wi-Max/802.16 are the most promising technologies for broadband wireless metropolitan area networks (WMANs) and these are capable of providing high throughput even on long distances with varied QoS. These technologies ensure a wireless network that enables high speed Internet access to residential, small and medium business customers, as well as Internet access for WiFi hot spots and cellular base stations. These offer support to both point-to-multipoint (P2MP) and multipoint-to-multipoint (mesh) nodes and offers high speed data (voice, video) service to the customers. In this paper, we study the issues related to, benefits and deployment of these technologies.

KEYWORDS

Digital subscriber line (DSL), LoS (Line of Sight), Wireless metropolitan area networks (WMANs), Wireless Network, point-to-multipoint (P2MP).

1. INTRODUCTION

This WiMAX has become a popular and an excellent technology for the deployment of infrastructures which are difficult to be connected using cable or DSL technologies. WiMAX will serve the developing countries and metropolitan areas. It can be deployed for enterprise campus and Wifi hot-spots. Also WiMAX can be a rival of Third Generation cellular systems as high speed mobile data applications can be achieved with the 802.16e specification. The original WiMAX standard can provide fixed and Nomadic services but under the specification IEEE 802.16e full mobility is guaranteed [1]. Wimax offers high speed data (voice, video) service to its customers.

Benefits of Broadband Technologies

- Cost effective.
- Offers high data rates.

- Used in fixed, nomadic and mobile modes.
- Easily deployed due to use of flexible network infrastructure.
- Interoperable with other networks
- Anticipated as popular global wireless broadband network

Consider the following figure for the hierarchy of technologies.

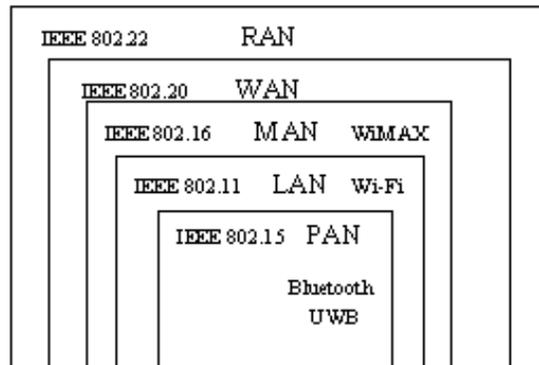


Figure 1. Hierarchy of Technologies

The WiMax broadband technology corresponds to the wireless metropolitan-area network that enables connectivity within fixed, portable and nomadic networks of users by providing interoperable ISPs have been aspirant for wireless technologies that make wireless broadband access possible. Wireless coverage uses IEEE 802.11 standard having gain-based antennas, the hot spots modified IEEE 802.11 equipment for the deployment. The open standard radio technologies (802.11, 802.16 and future standards) are offering advantages to Wireless Internet Service Providers [2] and also to users. Wireless Fidelity (Wi-Fi) revolutionized the trends in wireless technologies for unlicensed clients in variety of applications. In 2005, Worldwide Interoperability for Microwave Access (WiMAX) of IEEE 802.16 was launched whereas in 2006, the portable operation of IEEE 802.16e was standardized. This standard allows the users to overcome the cost and limited flexibility of wired internet over the wireless access. The Wireless ISPs have accepted the WiMAX as a solution to limited wired internet access. The wired solutions are very expensive for establishing the wireless access and there being no standard for deploying IEEE 802.11, the WISPs individually implements IEEE 802.11 as the long-distance solute wireless broadband up to 50- kms within the service area without the need of direct LoS with respect to the base station with access data rates of nearly 75 Mbps, a range of bandwidth that supports hundreds of people involved in various businesses and also at homes with the help of only a base station. This paper, discusses the issues related to the wireless metro-access broadband technologies: Wi-Fi and WiMAX. Section 2 discusses the issues and challenges, wireless usage associated with these technologies, deployment activities and benefits in the future.

2. ISSUES AND CHALLENGES

Directional antennas or a mesh-network topology is used by IEEE 802.11 network topologies for fixed-access and hot-zone coverage. The Wi-Fi implementations of Point-to-Point and Access Point to service providers are proprietary. Thus, the metro-access applications have no interoperability and thus face the following challenges:

- Non-standard wireless inter-AP communication.
- Providing quality of service (QoS) [3].
- Expensive
- Limited services
- Wireless metro-access solutions
- WISPs can offer broadband services to geographically challenged areas (such as rural towns).
- Local governments can provide free access for businesses or emergency services [11] (such as police and fire fighters).
- Educational institutions can broaden learning through online collaboration between students and faculty on and off campus.
- Enterprises and large private networks can communicate and monitor supply-chain activities in near real time.

2.1 Span of Wireless Technology Segments

Some of the wireless technologies are listed below:

- Personal area networks (PANs)
- Local area networks (LANs)
- Metropolitan area networks (MANs)
- Wide area networks (WANs)

The requirements criteria include variety of variables: Bandwidth requirements, distance requirements, Power, User location, Services offered and Network ownership. The interoperable standards of IEEE and ETSI are based on packet-based networking in wireless environment whereas the 3GPP standard is based on cellular and 3G mobile systems [4].

Wi-Fi using directional antennas (WDAs):

Wireless ISPs offer a substitute to DSL such as Data over Cable Interface Specification (DOCSIS). Still the distant-range restrictions exist, when multi-path interference [5] exists. The scalability is reduced due to QoS, proprietary tools and gadgets. Thus WiMAX is anticipated to tender QoS and to support backhaul communication.

Wi-Fi using a mesh-network topology (WMN):

Wireless ISPs cover huge areas to extend the reach of the LAN for both (indoor/outdoor) applications. This topology offers a more scalable solution than WDA implementation. To get rid of wire and increase vast client coverage, more number of nodes is deployed in dense cluster form. The problem of QoS and proprietary gadgets is still a matter of consideration.

WiMAX (802.16-2004): This new technology offers a great deal of potential. WPAN whose network coverage in the PAN is about ten meters, there is variation in its performance. The Bluetooth (IEEE 802.15.1) standard is rated up with performance data rates of upto 1 Mbps [12].

The next standard in given segment is ultra-wide band (IEEE 802.15.3) standard which is designed for offering multimedia services and supports data rates higher than 400 Mbps. The Wireless Local Area Networks (WLANs) as shown in the figure offers: (1) Better service, more users and applications than PANs. (2) They cover a larger area than PANs (approximately 100 meters). The WLANs are based on IEEE 802.11 standard and there are three major revisions to the physical layer since its release that is given as:

IEEE Standard	Bandwidth speeds (Mbps)
802.11a	54
802.11b	11
802.11g	54

Table 1. WLANs Revisions with supporting speeds

Based on the range, 802.11 standards are divided into two segments as shown in Figure 1.

1. LAN Local Area Networks
2. MAN Metropolitan Area Networks
3. WAN Wide Area Networks

Other parameters on which these segments depend are number of users and the distance between Access Points. The LANs are aggregated to form wireless MAN covering area up to 50 kms long. The next segment shown in Figure 1 is WAN that are formed by a collection of MANs covering over 50 km. WAN uses fiber optic links as communication media [6] for exchange of large amounts of traffic among the MANs. This network forms a high-bandwidth interconnection with very high-speed called core network. WAN can take over different traffic on the network such as voice only or voice, video, data and offers up to 10Gbps performance.

3. WI-FI WITH METRO-ACCESS-DEPLOYMENT (MAD) OPTION

The Wi-Fi provides certified interoperable connectivity support and is based on IEEE 802.11 standard. MAD for Wi-Fi products is an option through which an external modification to the standard is allowed with the help of hardware and software such as Fixed-access (last-mile usage) 802.11 with high gain antennas and portable-access (hot-zone usage) 802.11 mesh networks.

Wi-Fi products (with metro-access deployment) use the radio frequencies as specified in the table below:

Wi-Fi (MAD)	Frequency (GHz)	Radio Modulation	Bandwidth Speed
802.11a	5	OFDM	54 Mbps
802.11b	2.4	DSSS	11 Mbps.
802.11g	2.4	OFDM	54 Mbps

Table 2. WiFi Standards

Different frequency bands are used by these standards but the devices present on these bands cannot communicate (802.11a radio and 802.11b radio cannot talk to each other).

OFDM

The interference of OFDM is low and it is more adaptable to environment, so it is the most commonly used radio modulation technology for MAD solutions. This technology is based on

sub-carrier optimization by which it assigns small radio frequency sub-carriers to users. The carrier is divided with various frequencies and if these are selected such that the highest frequency coincides with the null of the adjacent frequency, then they are said to be Orthogonal. The data sequence is transformed from serial to parallel and each of this parallel data sequence is mapped onto a modulation block. An inverse fast Fourier transform (IFFT) block [8] is applied on the data for processing that transforms the discrete frequencies into a time domain. The resultant frequency drives the RF amplifier (radio frequency). The frequency obtained by this method offers extreme benefit to OFDM networks [7], thus providing high-speed data connections in both implementations (fixed and mobile solutions).

The 802.11a and 802.11g uses OFDM technology and are more flexible than the 802.11b that is prone to multipath interference. These factors were considered to develop the standard - 802.16-2004.

Network-Contention Protocol

The 802.11 standard uses CSMA/CA meaning carrier-sense, multiple access/ collision-avoidance protocol. It is a network-contention protocol. It functions by listening to the channel to avoid collisions of transmission on the network thus controlling the network traffic. While transmitting the data across the network, it broadcasts a signal on the network to listen for collision and informs other devices to stop broadcast. Using Intelligent Access points to monitor traffic the hidden-node problems can also be handled.

WiMAX uses a scheduling protocol. To improve reliability, this scheduling is performed by the base-station, but the increase in users on network, decreases the efficiency of the network due to additional subscribers. 802.11g network enjoys over 30 Mbps of throughput for a single user and the throughput decreases with increase in number of users.

Directional Antennas

Using Directional Antennas can also increase the range of 802.11. Omni-directional antennas (ODA) offer LoS communication by propagating Radio frequency (RF) signals in all directions equally on a horizontal plane for the mobile stations in its area. ODAs are used in traditional WLAN and mesh networks. On the other hand, a directional antenna transmits and receives RF rays in only one direction and the produced radiated light resembles spotlight. High-gain antennas provide coverage of a long distance within narrow areas and supports point-to-point communication in between buildings. A directional antenna minimizes the number of Access Points needed sometimes. Therefore usage of 802.11 with high-gain antenna can improve the long-distance communication but at the cost of more power.

4. WI-FI MESH NETWORKING (WMN)

A Wi-Fi mesh-networking infrastructure is a wireless network in which a collection of 802.11a (b or g-based) nodes are interconnected and share the communication protocols. This topology extends the range of LANs and WLANs. WMN repeatedly maintain dynamic path and configurations by learning on its own by creating a path for exchanging data with each other. Present proprietary-based backend implementations of WMN support VoIP and QoS with enhancement in coverage range (100-meter limit for standard Wi-Fi) of over 10 km and performance enhancement (from 54-Mbps limit for Wi-Fi's) of over 100 Mbps. But these implementations have limited scalability and are non-interoperable [9, 10]. The approval of 802.11s is likely to bring up WMN topology. WMN is sometimes referred to as “multi-hop” networking and they offer a flexible architecture to efficiently move data between nodes. In

WMN, nodes are installed throughout the neighbourhood area (within a school/college campus) where the small nodes serve as simple routers. Every node transmits a signal to neighbouring nodes, which in turn transmits signal to the next node and so on. This process is repeated until the data reaches its destination. In WMN, blocked subscribers can indirectly access the base station through other nodes. Nodes can change location in this architecture and can also be added or removed. These networks are applicable where the devices need to be more mobile and wireless such as in future business so that self-configuration is easy. The advantages of WMN include balanced traffic, robustness, resilience, low initial costs, availability, mobility and spatial reuse. Comparatively WMN can dynamically adapt to interference unlike the single-hop networks that are overburdened with nodes.

Benefits of using Wi-Fi for fixed-access solutions:

- Availability of Off-the-shelf 802.11 products
- Small deployments need less investment initially
- More flexible over wired installations

Limitations to mesh networks are as follows:

- Coverage of larger areas is possible with large subscriber base
- Usage of Shared bandwidth
- Increased Latency
- Proprietary product development

5. WIMAX WITH METRO-ACCESS-DEPLOYMENT (MAD)

WiMAX provides worldwide certified interoperability for products based on IEEE 802.16 standards. Two usage models of IEEE 802.16 standard with revisions such as fixed and portable are discussed below. The IEEE 802.16-2004 standard replaces IEEE 802.16a and 802.16REVd and is known as “fixed wireless” because a mounted antenna is used by the subscriber which is mounted to a roof just like a dish for satellite television. This standard provides an interoperable wireless option for fixed broadband Internet access with carrier-class solution. It operates in the licensed bands of 2.5-GHz, 3.5-GHz. Finally it provides a wireless solution to the Cable Modem, xDSL, Transmit/Exchange (Tx/Ex) and Optical Carrier level (OC-x) Circuits.

The IEEE 802.16e (802.16- 2004 amendment) offers portability and the clients having IEEE 802.16e adapters are allowed to directly connect to the WiMAX network. It uses Orthogonal Frequency Division Multiple Access (OFDMA), which is similar to OFDM in which the carrier is divided into multiple subcarriers and further multiple subcarriers are grouped into sub-channels. A single client may transmit through any number of sub-channels within the space or multiple clients may use a part of the available sub-channels concurrently. It also improves fixed-access delivery due to the key aspects such as multi-path interference, delay spread and robustness.

The factors such as delay spread and multi-path interference enhances the performance in situations where there is no direct LoS between the base station and client/subscriber station. WiMAX operating in exempted frequency bands will use TDD, otherwise TDD or FDD. The systems with emerging IEEE 802.16-2004 standards use OFDM based, wireless metropolitan area networks (WMAN). The signal is separated into 256 carriers.

The physical layer for 802.16-2004 can tolerate 10 microseconds delay spread which is 1000 times more than 802.11 standard.

The 802.16-2004 uses a grant-request access protocol in place of CSMA/CA protocol used under 802.11. This protocol does not allow data collisions utilizing the existing bandwidth efficiently. No collisions mean no loss of bandwidth due to data retransmission. All communication is

coordinated by the base station. The characteristics of the 802.16 standard in summary are enhanced user connectivity, high QoS, maximum support for WMAN and robust operation.

Smart Antenna Support

To maximize the spectral density (measure of total bits transmitted over a channel) and to increase the signal-to-noise ratio, the smart antennas are in use in both Wi-Fi and WiMAX. The 802.16 standard supports smart antenna.

Receive antenna- To operate effectively, the antennas are required to be kept half wavelength apart. The wavelength is the inverse of the frequency. Therefore for a 2.5-GHz signal carrier the wavelength would be 0.13 meters. Similarly for 5.8- GHz, wavelength would be 0.05m. The antennas can be made to be disjoint by maintaining minimum distance such that there will be different impact of signals obtained from multiple paths. Simple diversity antennas (SDA) — the more incoherent the antennas means, the higher the strong signal. Beam-steering antennas— to obtain higher gains, the antennas are prepared in an array pattern to get better signal direction but reject interference. Beam-forming antennas—these antennas divides the area into sectors near the base station and this pattern allows for reuse of frequency within sectors (few to a maximum of 24 sectors are allowed).

6. CONCLUSIONS

Broadband communication networks such as Wi-Fi and WiMAX are in demand due to the escalating explosion of wireless access. These are gainful solutions with more rapid performance. Mesh-network topologies and hotspots are formed using WiMAX and Wi-Fi networks to increase the performance and area of coverage (range) so that more users can receive the services i.e. to make them highly scalable. Every wireless solution has its benefits and limitations. The Wi-Fi and WiMAX offer mobile and long-distance fixed-access solution. To get maximum performance, these two can be combined and offer variety of models based on usage, geographic location, time of deployment and network application (data-only or VoIP or video). WISPs offer the mobile users with connectivity over large areas and extend the topology to reach WLANs. WiMAX, wireless broadband connectivity is used in areas which are beyond the reach of wired broadband namely xDSL, DOCSIS cable and T1. Wi-Fi has also become popular. Wi-Fi radios are found in laptops, PDAs, parking meters, mobile phones, security cameras and home entertainment equipment. As a result, both the broadband technologies are evolving in a very fast pace making communication more and more economical and cost effective.

ACKNOWLEDGEMENTS

I am thankful to Ms. Kahkashan Tabassum, Assistant Professor, Computer Science and Information Technology Department, Maulana Azad National Urdu University for her cooperation and guidance in this research work.

REFERENCES

- [1] IEEE Standard 802.16-2004, IEEE Standard for Local and Metropolitan Area Networks(MAN) - Part16: Air Interface for Fixed Wireless Access Systems.
- [2] Revision of IEEE Std. 802.16-2004 and consolidates material from IEEE Std. 802.16e-2005, IEEE Std 802.16-2004/Cor1-2005, IEEE Std 802.16f-2005 and IEEE Std. 802.16g- 2007.Gizem, Aksahya & Ayese, Ozcan (2009) Coomunications & Networks, Network Books, ABC Publishers.
- [3] IEEE Standard 802.16e-2005, Amendment to IEEE Standard for Local and Metropolitan Area Networks (MAN)– part 16: Air Interface for Fixed Broadband Wireless Access Systems-Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands.
- [4] Intel Corp., IEEE 802.16* and WiMAX: Broadband Wireless Access for Everyone, 2003, www.intel.com/ebusiness/pdf/wireless/intel/80216_wimax.pdf WiMAX Forum, WiMAX's Technical Advantage for Coverage in LOS and NLOS Conditions, Aug. 2004, [www.wimaxforum.org/news/downloads/ WiMAXNLOSgeneral-versionaug04.pdf](http://www.wimaxforum.org/news/downloads/WiMAXNLOSgeneral-versionaug04.pdf).
- [5] WiMAX Forum: (www.wimaxforum.org).
- [6] WiMAX technology overview: (www.intel.com/netcomms/technologies/wimax).
- [7] WiMAX World Conference & Exposition(www.wimaxworld.com)
- [8] Tropos Networks: (www.tropos.com)
- [9] “Who Pays for Wireless Cities?” In MIT Technology Review Asbrand, Debra. September 2004.
- [10] “Smart fabrics make for enhanced living,” In New Scientist, Bieber, Celeste. October 23, 2004.
- [11] “Vo-WLAN: The Wireless Voice Future is Here ... Almost” In Wi-Fi Planet. Cohen, Beth. June 14, 2004.
- [12] “Wireless MANs, Giving WMANs a Little Muscle.” In Network Computing. Bulk, Frank. Mar 18, 2004.