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Wireless Broadband Access: Mobile WiMAX

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ABSTRACT: The Wi-MAX is an acronym for Worldwide Interoperability for Microwaves Access is an efficient and emerging wireless communication scheme that can offer broadband access with significant coverage. As a lucrative solution, multihop communication is becoming more and more important to WiMAX systems. The 4G Revolution has begun with various benefits in wireless technology. Mobile WiMAX is asserted to have the huge potential of all wireless access technologies already in the markets with regard to network capacity, range, and quality of service and mobility support. Mobile WiMAX has also accepted MIMO as a fundamental factor for enhancing capacity and data propagation consistency. This paper provides a brief overview of mobile WiMAX, its features and challenges on the wireless local and Metropolitan Area Network (MAN) standards IEEE 802.16 and IEEE 802.16e. With the development and advancement of Internet, the demand of Wideband High data rate communication services is increasing. This triggered the demand of WiMAX as it supports high data rate and high capacity in mobile Broadband wireless access (BWA). IEEE 802.16e (mobile WiMAX) is better than IEEE 802.16d (fixed WiMAX) as it gives full mobility at vehicular speeds and better performance.

KEYWORDS: WiMAX, Performance, throughput, MIMO, OFDM, MBS, IEEE 802.16e.

I. INTRODUCTION

Wireless technologies are bringing revolution in telecommunication industries. WiMAX networks provides high data rates, last mile wireless access, point to multipoint communication, large frequency range and quality of services for various type of applications. There are two types of WiMAX standards, IEEE 802.16d-2004 (Fixed WiMAX) and IEEE 802.16e-2005 (Mobile WiMAX). Fixed WiMAX supports fixed and nomadic applications while mobile WiMAX grants support to mobile, portable, fixed and nomadic applications. WiMAX is convergence of wireless with the internet.

To satisfy constantly ongoing demands for broadband wireless applications, WiMAX is the best solution. The bandwidth and range of WiMAX make it appropriate for following potential applications: (i) providing portable broadband connectivity across cities and countries through numerous devices, (ii) providing wireless substitute to cable and digital subscriber line (DSL) and (iii) providing data, telecommunication (VoIP) and IPTV services (triple play).

WiMAX operates both in 10GHz-66GHz (licensed frequency band) for Line of Sight (LOS) and 2 GHz-11 GHz (unlicensed frequency band) for Non-line of Sight operation.

The WiMAX Network technology is a progressive one as it uses Orthogonal Frequency Division Multiplexing which makes transmission resist fading and minimizes multipath effect. Additionally, a WiMAX network can work as a point-to-point backhaul trunk with a transmission rate of 72 Mbps at a transmission distance over 30 miles.

With its technological advantages of power, throughput, transmission range and versatility, WiMAX might be a strong competitor of other technologies, such as WiFi and 3G.

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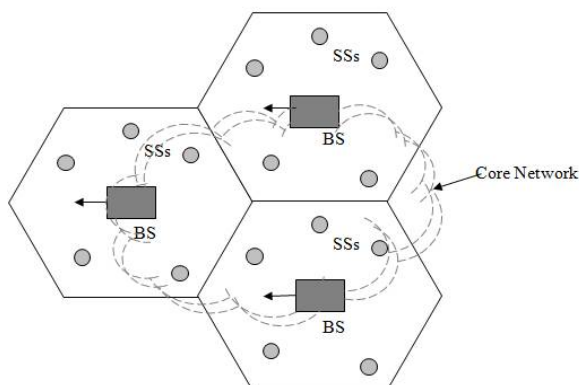


Fig. 1 Simplified network architecture of WiMAX

A WiMAX system consists mainly of two parts: base station and subscribers. The typical size of a WiMAX base station is usually between 7-10 kilometres. Though, radii can extend up to 50 kms with favourable circumstances and can be further extended with the help of Backhauls. Backhauls are merely WiMAX towers that work as repeaters for WIMAX base stations hence serving range extension. A WiMAX base station is normally connected to the Internet using a wired connection having high bandwidth. Consumer uses Customer Premise Equipment (CPE) to join to base station. CPE is basically an antenna that is oriented towards the WIMAX base station to receive optimum signal. Alternatively the receiver antenna could be built into laptops or other mobile devices.

II. HOW MOBILE WI -MAX WORKS

IEEE 802.16e standardizes networking between carrier's fixed base stations and mobile devices, instead of just between base stations and recipients that are both stationary. The technology delivers mobility by facilitating systems to exchange data broadcast from one base station to another as customers move between them. They carry out either *soft handoff*, in which a station makes a connection to the next one before the switch occurs, which lessens latency; or *hard handoffs*, which break connections with one station for up to 50 milliseconds before connecting to the next. Mobile WiMax works via modems powered by chipsets that can sit within a device or on an add-on card or motherboard.

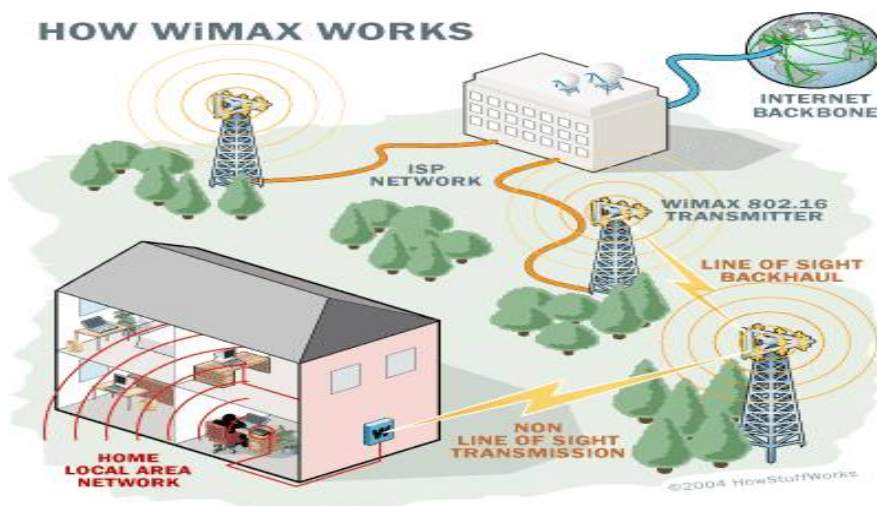


Fig.2 How WiMAX Works

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A) Added features

Unlike Wi-Fi, mobile WiMax delivers quality of service. It allocates each participating device its own access slot, which can expand or contract depending on network usage. As Wi-Fi doesn't use this approach, its access points can be crushed by excessive requests. According to the proposed IEEE 802.11n version of Wi-Fi, mobile WiMax works with multiple-input, multiple- output technology. MIMO uses multiple antennas as transmitters and receivers to minimize faults and enhances data rates by superior capturing the signals during transmission. Additionally mobile WiMax uses scalable OFDM, which enhances bandwidth by dividing a data-bearing radio signal into minor signal sets, modulating each onto different subcarriers spaced orthogonally to minimize interference, and assigning subsets of subcarriers to individual base stations.

B) Rate, range, and spectrum

Mobile WiMax can deliver a theoretical maximum data rate of 70 Mbps on a single channel, as Table 1 shows. However, that rate attenuates over distance. Thus, today's WiMax Forum-approved modems support a sustained bandwidth of only 6 Mbps at a range of about a mile. 3G cellular's maximum data rate is about 3 Mbps. Wi-Fi's is 54 Mbps for the currently adopted IEEE 802.11g version.

Table 1. Comparison of mobile wireless technologies

Type of wireless technology	Theoretical maximum data rate	Theoretical maximum transmission range
Mobile WiMax	70 Mbps	35 miles
3G cellular	3 Mbps	3 miles
Wi-Fi (802.11g)	54 Mbps	328 feet

III. FEATURES OF MOBILE WI-MAX

A. Smart antenna Technology

It typically implies complex vector or matrix operations on signals due to multiple antennas. OFDMA permits smart antenna functions to be executed on vector-flat sub-carriers. Complex equalizers are not required to compensate for frequency selective fading. OFDMA hence, is very compatible to support smart antenna technologies. In fact, MIMO-OFDM/OFDMA is imagined as the corner-stone for next generation broadband communication systems [1, 2]. Mobile WiMAX supports a full range of smart antenna technologies to enhance system performance. The smart antenna technologies supported include:

Beam forming- The system uses several antennas to transmit weighted signals to increase the coverage area and capacity of the system and reduce outage possibility [3].

Space-Time Code (STC) - Broadcast diversity is supported to offer spatial diversity and lessen fade margin.

Spatial Multiplexing (SM) - Spatial multiplexing [4, 5] is used to increase the throughput and to generate higher peak rates. With this, multiple streams are sent out over multiple antennas. To separate the different streams multiple receiver antennas are used to achieve higher throughput compared to single antenna systems.

B. Fractional frequency reuse

WiMAX carries frequency reuse in which all cells operate on the same frequency channel to maximize spectral efficiency. Though, heavy co-channel interference (CCI) in frequency reuse causes degradation in connection quality of the users at the cell edge. Customers can operate on sub-channels, which only engage a small portion of the whole channel bandwidth; the cell edge interference trouble can be easily tackled by properly configuring sub-channel usage without resorting to traditional frequency planning.

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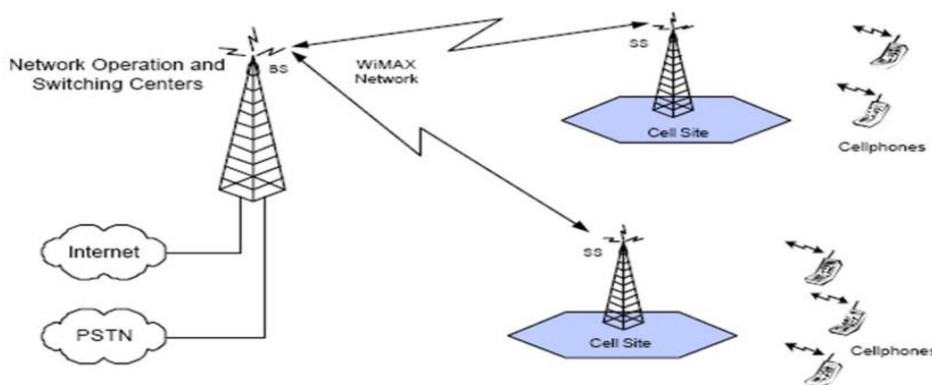


Fig3. WiMAX Frequency Distribution

C. Multicast and broadcast service (MBS)

Multicast and Broadcast Service (MBS) supported by WiMAX assure the following requirements:

- Flexible distribution of radio resources
- Low MS power consumption
- Support of data-casting in addition to audio and video streams
- Low channel switching time: Mobile WiMAX holds optimized handover schemes with latencies less than 50 milliseconds to ensure real-time requests without service degradation. Flexible key management schemes assure that security is retained during handover.
- **High Data Rates:** The addition of MIMO antenna techniques along with flexible sub-channelization schemes, advanced coding and modulation all enable the Mobile WiMAX technology to support peak DL data rates up to 63 Mbps per sector and peak UL data rates up to 28 Mbps per sector in a 10 MHz channel.
- **Quality of Service (QoS):** The elementary idea of the IEEE 802.16 MAC architecture is QoS. It defines Service Flows which can map to different server code points that facilitate end-to-end IP based QoS. Additionally, sub channelization and MAP-based signalling schemes offer a flexible mechanism for optimal scheduling of space, frequency and time resources.
- **Scalability:** Mobile WiMAX technology is designed to be capable to scale to work in diverse channelization from 1.25 to 20 MHz to meet the terms with diverse global requests as attempts carry on to accomplish spectrum synchronization in the longer term. This also permits diverse economies to apprehend the benefits of the Mobile WiMAX technology in multiple aspects for their explicit geographic necessitates such as providing reasonable internet access in rural settings versus enhancing the capacity of mobile broadband access in metro and suburban areas.
- **Security:** The qualities granted for Mobile WiMAX for safety point of view are best in class with EAP-based authentication, AES-CCM-based authenticated encryption, and CMAC and HMAC based control message protection schemes. Support for a varied set of user credentials exists including; SIM/USIM cards, Smart Cards, Digital Certificates, and Username/Password schemes based on the applicable EAP methods for the credential type.

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IV. COMPARISON BETWEEN FIXED WiMAX AND MOBILE WiMAX

Features	Fixed WiMAX	Mobile WiMAX
Network Architecture	Fixed, Nomadic, Portable	Fixed, nomadic, portable, mobile
PHY Technology	OFDM 256	OFDMA 128, 512, 1024, 2048
Duplexing Format	TDD, FDD, HD-FDD	TDD, FDD, HD-FDD
Channel size	1.25-20 MHz	1.25-14 MHz
Modulation	64QAM, 16QAM, QPSK and BPSK	64QAM, 16QAM, QPSK and BPSK
Spectrum Profiles	2.5GHz, 3.5GHz and 5.8GHz	2.3GHz, 2.5GHz, other TBD
QoS Features	Excellent effort, non real time polling service, unsolicited grant service	Similar to fixed WiMAX along with broaden real-time polling service

V. SECURITY

Mobile WiMAX supports best in class security features by implementing the best technologies present today. Support exists for mutual device/user authentication, flexible key management protocol, strong traffic encryption, control and management message protection and security protocol optimizations for fast handovers [6].

The usage aspects of the security features are:

- 1) **Key Management Protocol:** Privacy and Key Management Protocol Version 2 (PKMv2) is the basis of Mobile WiMAX security as defined in 802.16e. This set of rules manages the MAC security using PKM-REQ/RSP messages. PKM EAP authentication, Traffic Encryption Control, Handover Key Exchange and Multicast/Broadcast security messages all are based on this protocol.
- 2) **Device/User Authentication:** Mobile WiMAX supports Device and User Authentication using IETF EAP protocol by providing support for credentials that are SIM-based, USIM-based or Digital Certificate or User Name/Password-based.
- 3) **Traffic Encryption:** AES-CCM is the code used for protecting all the user data over the Mobile WiMAX MAC interface. The keys used for driving the cipher are generated from the EAP authentication. A Traffic Encryption State machine that has a periodic key (TEK) refresh mechanism enables sustained transition of keys to further improve protection.
- 4) **Control Message Protection:** Control data is protected using AES based CMAC, or MD5-based HMAC schemes.
- 5) **Fast Handover Support:** A 3-way Handshake scheme is supported by Mobile WiMAX to optimize the re-authentication mechanisms for supporting fast handovers. This mechanism is also useful to prevent any man-in-the-middle-attacks.

VI. ADVANTAGES

- **Excellent standard:** Mobility, roaming and meshing supported by WiMAX as an IEEE standard.
- **Long range:** compared to other existing technologies WiMAX is able to provide a significant range.
- **Economical:** reduced fixed broadband prices and the network expansion cost also reduced.
- **Quality of service (QoS) support:** the MAC protocol guarantees the service level and support QoS.
- **Non-line-sight support:** to become less susceptible to hindrances as it operates on 2 to 11GHz.
- **Offering portable mobile broadband connectivity:** across cities and countries through a variety of devices.

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- **Providing a wireless substitute to cable:** and digital subscriber line (DSL) for "last mile" broadband access.
- **Provide data, telecommunications (VoIP) and IPTV services (triple play).**
- **Providing a source of Internet connectivity:** as part of a business continuity plan.

VII. APPLICATION SCENARIOS

In this section we review the existing application and several potential scenarios of WiMAX.

Internet Access: Apparently, Internet access will still be the foremost demand in WiMAX networks, especially when they are recently installed. To support Internet access, a simple method is to provide a unicast connection between SSs (including RSs and MSs) and the BS, which has the link toward the Internet.

Group Communications: Since WiMAX networks can cover a wider area, it is natural to imagine that many group communications, such as video conferences, will be vital applications in WiMAX networks. To support such communication scenarios, multicast is the fundamental technology. Earlier, Internet multicast has not been flourishing because of its intricacy and, more important, because Internet multicast requires global consumption, which is practically unfeasible. In a WiMAX network, although, all nodes are located inside, realizing such group communication becomes possible.

Metropolitan Area Distributed Service: With the use of WiMAX networks, value-added services can be increasing in a metropolitan area. To support a large number of clients in a well organized manner, distributed services can be enabled [8]. In other words, a client can access the service from any of the servers in the network in which these servers are shared out to serve the entire metropolitan area. In this system the client doesn't need to state the precise address of a server in the network. Instead, it only needs to point out the service it wants to access. Additionally, in such a communication scenario, the client can communicate with a subset of all the servers in order to achieve better reliability and/or security. An example of many casts is shown in Fig. 4, in which the MS has chosen to access servers 1 and 4 simultaneously.

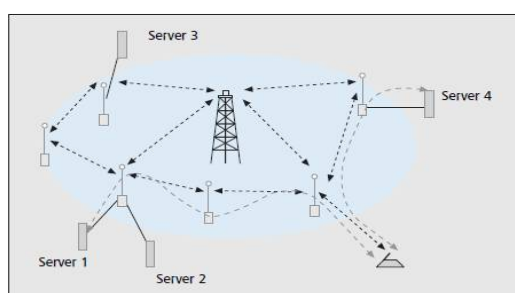


Fig4. An example of manycast in a WiMAX network

Content-Based Instant Messaging: The content based routing scheme is a service-oriented communication model [9]. In this scheme the sender of a message does not need to explicitly indicate its destination(s). The network layer will automatically convey the message to receivers that are concerned in the matter of the message.

Quality Guaranteed Applications: For numerous applications, it is desirable that the network layer can offer a satisfactory quality of service (QoS) assurance, usually in terms of bandwidth, data rate, delay, and delay jitter. However, wireless communications are as expected error-prone; hence, it is complex to grant such a guarantee in a wireless network. To deal with this issue, multipath routing has been used. Usually, multipath routing can provide better quality than single-path routing [10]. An exemplar is shown in Fig. 5, in which the MS accesses server 3 via two different paths.

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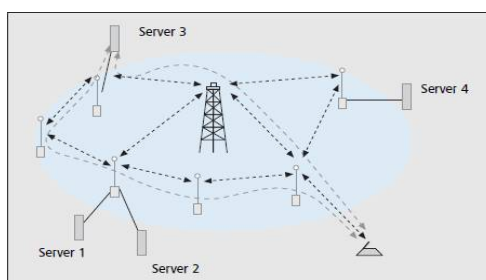


Fig. 5 An example of multipath routing in a WiMAX network

Multihoming Applications: Multihoming [11] is a technology that can provide services similar to those of multipath routing. The major variation between these two designs is that in multihoming, one station has two or more IP addresses and usually has the equal number of interfaces. In this way, the station can have multiple paths to access the same resources. In short, the application layer requirements must be addressed in the network layer design.

VIII. CONCLUSION

WiMAX's strong industry backing, standards-based approach, and mobility support brought a new horizon to wireless broadband. The excellent traits and brilliant performance capability of Mobile WiMAX makes it a compelling and promising technology for high performance, low-priced broadband wireless facilities. Mobile WiMAX is on a path to deal with universal market through a common wide area broadband radio access technology and flexible network architecture. In this paper we provided an overview of Mobile WiMAX and its attributes. We addressed that mobile WiMAX can provide 10mbps of capacity per channel from each base station with a baseline configuration. The performance will enable transparency of quality of service between Mobile WiMAX and broadband wired services such as Cable and DSL, an important requirement for the success of the targeted Mobile Internet application for Mobile WiMAX. The scalable architecture, high data throughput, efficient data multiplexing and low data latency enabled Mobile WiMAX a leading solution for wireless broadband services. Hundreds of companies have contributed to the advancement of the technology and several companies have proclaimed product plans for this technology. This addresses another significant requirement for the accomplishment of the technology, which is economical in subscription services for mobile internet. The broad industry participation will ensure economies of scale that will help drive down the costs of subscription and enable the deployment of mobile internet services globally, including emerging countries.

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