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Architectural Performance of WiMAX over WiFi with Reliable QoS over Wireless Communication

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----------**ABSTRACT**----------
Due to fast development of technology, future communication and transmission are totally depends upon wireless network. Wireless networks are generally less efficient and irregular compared to wired networks, which make quality of service (QoS) provision a bigger challenge for wireless communications. The wireless medium has limited bandwidth, higher packet error rate, and higher packet overheads that in total to limit the capacity of the network to offer guaranteed QoS. In response to the increasing QoS challenge in wireless networks, researchers have made significant modifications in Wireless Fidelity (WiFi) in the legacy IEEE 802.11 standards to make possible QoS to end users. The design constraints at several layers of the IEEE 802.11 restrict its capacity to deliver guaranteed QoS. Recently, the IEEE 802.16 standard, also known as worldwide interoperability for microwave access (WiMAX), has emerged as the strongest contender for broadband wireless technology with promises to give guaranteed QoS to wireless application end users over wifi wireless technology. This paper tries to explain the architectural performance issues of WiMax over WiFi wireless communication in the term of wireless network design and management which upgrading the upcoming wireless communication technology over a wide region.

Keyword: WiMAX, WiFi, WLAN, Wireless Networks, QoS.

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I. Introduction

Wireless access techniques are continuously expanding their transmission bandwidth, coverage, and Quality of Service (QoS) support in recent years. With the huge market success of Wireless Local Area Networks (WLANs) (IEEE 802.11), the new-generation wireless technique, WiMAX (IEEE 802.16) has now been standardized and deployed. WiMAX stands for Worldwide Interoperability for Microwave Access. WiMAX technology enables ever-present communication of wireless broadband service for fixed and/or mobile users, and became a truth in 2006 when Korea Telecom started the use of a 2.3 GHz version of mobile WiMAX service called WiBRO in the Seoul metropolitan area to offer high performance communication for data and video over wireless communication. The WiMAX Forum is an industry-led non-profit organization which has more than 570 member companies including service providers, equipment vendors, chip vendors and content providers. Its primary mission is to ensure interoperability among IEEE 802.16 based .The air interface of WiMAX technology is based on the IEEE 802.16 standards. In particular, the current Mobile WiMAX technology is mainly based on the IEEE 802.16e which specifies the Orthogonal Frequency Division Multiple Access (OFDMA) air interface and provides support for mobility [11].

The network specifications of mobile WiMAX devices are include the end-to-end networking specifications and network interoperability specifications.

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The Network Working Group (NWG) within the WiMAX Forum is responsible for these network specifications, some of which involve Access Service Network (ASN) control and data plane protocols, Connectivity Services Network (CSN), ASN profiles, mobility support, Authentication, Authorization and Accounting (AAA) interworking with other technologies, and various services such as Location-Based Service (LBS), Multicast and Broadcast Service (MCBCS) etc.

IEEE 802.11 WLAN, or WiFi, is possibly the most widely accepted broadband wireless networking technology, providing the highest transmission rate among standard wireless networking technologies. Today's WiFi devices, based on IEEE 802.11a and 802.11g, provide transmission rates up to 54 Mbps and new standard of IEEE 802.11n which supports up to 600Mbps transmission rates. The transmission range of a typical WiFi device is up to 100m but its exact transmission range varies. It depend upon the transmission power, surrounding environments, and others parameters. The 802.11 devices operate in unlicensed bands at 2.4 and 5 GHz, where the exact available operate bands is varies according to county[4].

II. Wireless Technology:

The theory of wireless access networks emerged in the late 1980s as invention of cellular wireless technology. *Wireless* means transmitting signals using radio waves as the medium instead of wires. There are some inbuilt qualities of wireless communications systems like mobility, reachability, simplicity, maintainability, roaming services, new smart Services etc. which make it attractive for users. There are three basic way to setup wireless network for the end user, which are Point-to-point bridge, Point-to-multipoint bridge and Mesh or ad hoc network. Wireless access techniques are constantly increasing their transmission bandwidth, coverage, and Quality of Service (QoS) support to future communication.

Wireless technologies can be classified in different ways depending on their range. Each wireless technology is designed to serve a specific usage sector. The requirements for each usage sector are based on a variety of needs like bandwidth, distance and power. Now, a wide variety of different wireless data technologies exist, some in direct competition with each other's and some designed for specific applications. Some well know wireless technologies are GSM, UTMS, HSPA, WiMax, WiFi, CDMA, GPRS, Bluetooth etc. In the future communication, competition will be new evolution of the major cellular standards called 4G which have high-bandwidth, low-latency and all-IP networks with voice services. Currently 2G and 3G network operators will migrate to a 4G network technology. Mobile WiMAX is likely to face competition from 3G and 4G technology enhancements. They include the code division multiple access (CDMA) variants CDMA2000 and wideband-CDMA(WCDMA) and their enhancements which are 1x evolution data optimized (1xEVDO) and HSDPA, respectively[7].

Wi-Fi allows the deployment of local area networks (LANs) without wires for client devices, typically reducing the costs of network deployment and expansion. Due to the complex nature of radio propagation at typical Wi-Fi frequencies Mobility over wider ranges is limited. High Speed Packet Access (HSPA) is another mobile telephony protocol that extends and improves the performance of existing WCDMA protocols. HSPA supports increased peak data rates of up to 14 Mbit/s in the downlink and 5.8 Mbit/s in the uplink. HSPA increases peak data rates and capacity. In Universal Mobile Telecommunications System (UMTS) is one of the third-generation (3G) mobile telecommunications technologies, which is also being developed into a 4G technology. UMTS, using 3GPP, supports maximum theoretical data transfer rates of 42 Mbits/s. GSM is a cellular network, which means that mobile phones connect to it by searching for cells in the immediate vicinity. GSM networks operate in a number of different carrier frequency ranges. with most 2G GSM networks operating in the 900 MHz or 1800 MHz bands[9]. Most 3G networks in Europe operate in the 2100 MHz frequency band. Figure 1 show the comparison between different wireless technologies like WiFi, WiMAX, HSPA, UTMS and GSM in the respect of the speed and mobility of nodes in their respective network.

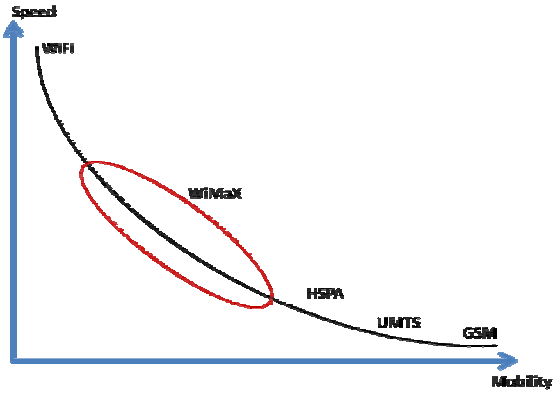

Fig 1: Comparison of different Wireless technologies

III. DESCRIPTION OF WiMAX / WiFi Technology Model

This section introducing the essential properties WiMAX/WiFi system and then provides a detailed

description of network performance and comparison between mobility and transmission speed.

a) WiMAX System:

WiMAX is a telecommunications protocol that provides fully and fixed mobile internet access. The current WiMAX revision provides up to 40 Mbit per second with the IEEE 802.16m update and expected to offer up to 1 Gbit/s fixed communication speeds. "WiMAX" name was first created by the WiMAX Forum, which was formed in June 2001 and to promote conventionality and interoperability of the IEEE standard. The IEEE 802.16 standard forms of basis 'WiMAX' and it is divided sometimes into Fixed WiMAX and Mobile WiMAX of IEEE 802.16d and IEEE 802.16e standard respectively.

WiMAX has several different physical radio transmission options which allow it to be deployed in areas with different regulatory and frequency availability requirements. Moreover, the system was designed with the ability to be used in licensed or unlicensed frequency bands using narrow or wide frequency channels. WiMAX systems have the potential to provide very high data transmission rates. Data throughput is the amount of data information that can be transferred through a communication channel or transfer through a point on a communication system. iMAX systems can be configured to offer services that have different types of quality of service (QoS) levels. QoS is one or more measurement of desired performance and priorities of a communications system. QoS measures may include service availability, maximum bit error rate (BER), minimum committed bit rate (CBR) and other measurements that are used to ensure quality communications service. The QoS capabilities of WiMAX systems permit system operators to provide priority services to high-value customers and best effort services to less demanding consumers[11].

The 802.16a standard for 2-11 GHz is a wireless metropolitan area network (MAN) technology that will provide broadband wireless connectivity to Fixed, Portable and Nomadic devices. WiMAX is expected to offer initially up to about 40 Mbps capacity per wireless channel for both fixed and portable applications, depending on the particular technical configuration. WiMAX is also intended to provide broadband connectivity to mobile devices. It would not be as fast as in these fixed applications, but expectations are for about 15 Mbps capacity in a 3 km cell coverage area. WiMAX could potentially be deployed in a variety of spectrum bands: 2.3GHz, 2.5GHz, 3.5GHz, and 5.8GHz. WiMAX, which is an IP-based wireless broadband technology, can be integrated into both wide-area third-generation (3G) mobile and wireless and wire line networks [4]. Figure 2 presents the different composition of the current mobile WiMAX technology, normally referred to as Release 1.0 profile. Its air interface specifications consist of four related IEEE 802.16 Broadband Wireless Access Standards, that is, IEEE Standard 802.16-2004, IEEE Standard 802.16-2004/Cor.1-2005, IEEE Standard 802.16e-2005 and the IEEE Draft Standard P802.16-2004/Cor.2.[4][2]. Figure 3 presents the growth of the 802.16 wireless broadband band service specifications over time.

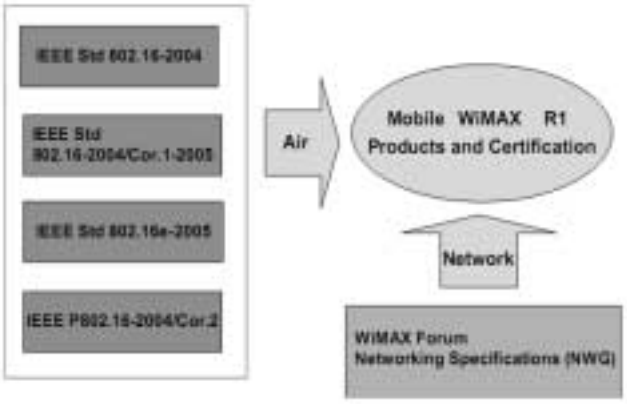

Fig. 2: Products and certification of Mobile WiMAX Release 1.0

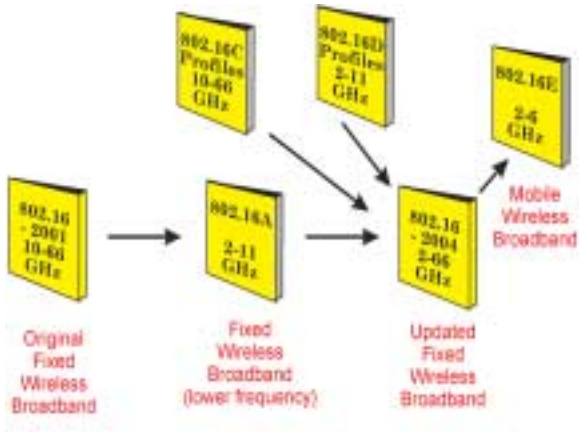

Fig. 3: Wireless Broadband (WiMAX) 802.16

b) WiFi System:

IEEE 802.11 WLAN, or WiFi, is probably the most widely accepted broadband wireless networking

technology, providing the highest transmission rate among standard-based wireless networking technologies. Today's WiFi devices, based on IEEE 802.11a and 802.11g , provide transmission rates up to 54 Mbps and, further, a new standard IEEE 802.11n, which supports up to 600Mbps, is being standardized. The transmission range of a typical WiFi device is up to 100m, where its exact range varies depending on the transmission power, the surrounding environments, and others. The 802.11 devices operate in unlicensed bands at 2.4 and 5 GHz, but the accurate available bands depend on each county.

IEEE 802.11 working group (WG) has generated a family of standards for WLAN. The IEEE 802.11 standard specifies the protocols for both the medium access control (MAC) sub-layer and the physical (PHY) layer. As illustrated in Figure 3a, existing higher-layer protocols, which were originally developed for wire-line networking such as TCP, UDP, IP, and IEEE 802.2 logical link control (LLC), can work on top of the 802.11 MAC since the 802.11 was developed basically to provide the services in a similar way that IEEE 802.3 Ethernet does.

There are several different versions of 802.11 WLAN systems .i.e. WiFi that have evolved over time. Figure 3b shows how WiFi 802.11 systems have evolved over time. This figure shows that the original 802.11 specification offered 1 or 2 Mbps data transmission rates and operated at 2.4 GHz. This standard evolved through new modulation to produce 802.11b that provides operated at 2.4 GHz and provided data transmission rates up to 11 Mbps. This figure also shows that a new 802.11a system was developed that provides data transmission rates up to 54 Mbps at 5.7 GHz. To help provide high-speed data transmission rates and provide backward compatibility to 802.11 and 802.11b systems, the 802.11g systems was developed that offers 54 Mbps data transmission in the 2.4 GHz range[4].

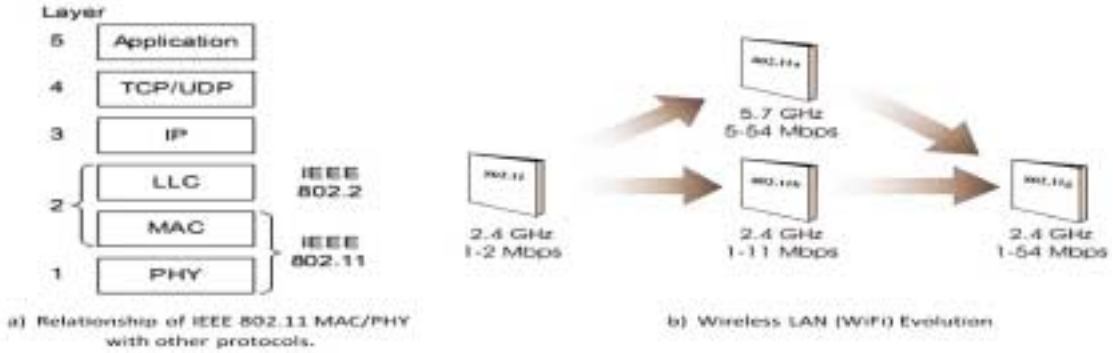

Fig. 3.1: WiFi system Layers and Evolution over time

IV. WiMAX Network Architecture:

The IEEE 802.16e-2005 standard provides the air interface for WiMAX technology but does not define the full end-to-end WiMAX network. The WiMAX Forum's Network Working Group (NWG), is responsible for developing the end-to-end network requirements, architecture, and protocols for WiMAX, using IEEE 802.16e-2005 as the air interface.

The WiMAX network reference model is unified network architecture for supporting fixed, roaming, and mobile deployments and is based on an IP service model. Figure 4 is simplified design of IP-based WiMAX network architecture. The overall network may be logically divided into three basic parts:

1. Mobile Stations (MS) used by the end user to access the network.
2. The access service network (ASN), which comprises one or more base stations and one or more ASN gateways that form the radio access network at the edge.
3. Connectivity service network (CSN), which provides IP connectivity and all the IP core network functions.

The below network reference model developed by the WiMAX Forum NWG defines a number of functional entities and interfaces between those entities. Below Figure 4 shows some of the more important functional entities[10], which are given as:

- **Base Station (BS):** The BS is responsible for providing the air interface to the MS. Additional functions that may be part of the BS are micro mobility management functions, such as handoff triggering and channel establishment, radio resource management, QoS policy enforcement, traffic classification, DHCP (Dynamic Host Control Protocol) proxy, key management, session management, and multicast group management.
- **Access Service Network Gateway (ASN-GW):** The ASN gateway typically acts as a layer 2 traffic aggregation point within an ASN. Additional functions that may be part of the ASN gateway include intra-ASN location management and paging,

radio resource management and admission control, caching of subscriber profiles and encryption keys, authentication authorization, and accounting (AAA) client functionality, establishment and management of mobility tunnel with base stations, QoS and policy enforcement, foreign agent functionality for mobile IP, and routing to the certain CSN.

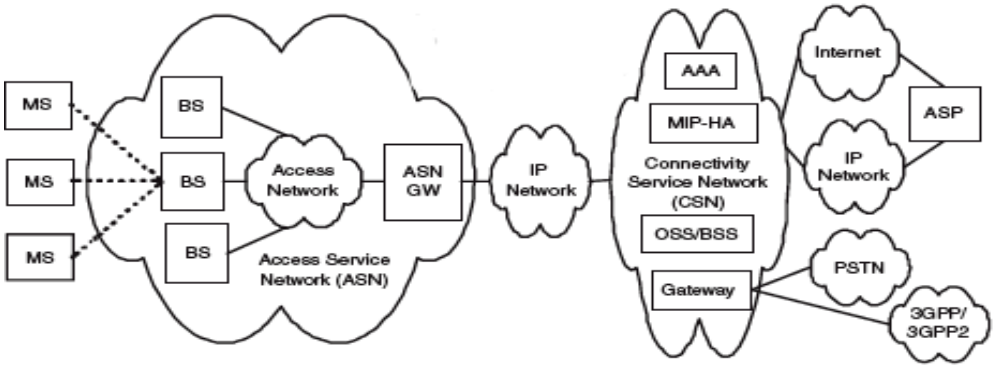

Fig. 4: IP Based WiMAX Network Architecture

- **Connectivity Service Network (CSN):**

  The CSN provides connectivity to the Internet, Access Service network (ASN), other public networks, and corporate networks. The CSN is owned by the Network Service Provider and includes AAA servers that support authentication for the devices, users, and specific services. The CSN also provides per user policy management of QoS and security. The CSN is also responsible for IP address management, support for roam between different NSPs, location managem between ASNs, and mobility and roaming betw ASNs.

The WiMAX architecture framework allows the flexible decomposition and/or combination functional entities like ASN may be decomposed into b station transceivers (BST), base station controllers (BS and an ASNGW similar to the GSM architecture of B BSC, and Serving GPRS Support Node (SGSN).

V. Integrated WiMAX / WiFi Network Architecture:

When constructing integrated WiMAX/WiFi networks, one of the most challenging issues facing network designers is that of designing efficient links and Medium Access Control (MAC) layer protocols to optimize the QoS between the WiMAX and the WiFi components of the architecture [3]. Several researchers have recently proposed QoS provisioning mechanisms for integrated WiMAX/WiFi systems. QoS framework for 802.16/802.11 internetworking applications designed to map the QoS requirements of an application originating in an IEEE 802.11e network to an IEEE 802.16 network. Similarly, a QoS control protocol was also presented to support an integrated QoS for converged networks comprising WiMAX and WiFi systems[6][8].

To meet QoS, Researcher evaluates proposed efficient and unified connection-oriented architecture for integrating WiMAX and WiFi technologies in broadband wireless networks [5]. In the proposed approach, a new wireless Access Point (AP) device, designated as WiMAX/WiFi AP (W2-AP), is developed to manage the WiMAX/WiFi interface.

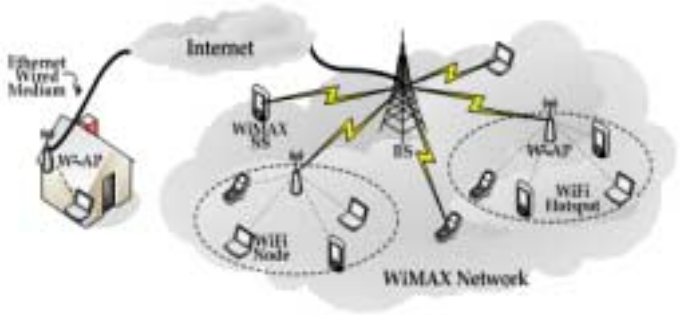

Fig. 5. Integrated WiMAX/WiFi Network structure.

Figure 5 presents a classical example of the integrated WiMAX/WiFi network architecture. As shown in figure, a single WiMAX Base station BS, operating in a licensed band, serves both multiple WiMAX Subscriber Stations (SSs) and multiple W2-APs within its coverage area. In other words, the WiMAX system provides broadband wireless access to multiple W2-AP devices in a point-to-multipoint (PMP) topology. Each WiFi network is connected to the WiMAX BS through a WiMAX/WiFi (W2)-AP. The connection between the BS and a SS is dedicated to a single user. However, the connection between the BS and each W2-AP is shared amongst all the nodes within the Wireless LAN served by the W2-AP. As a result, the WiMAX network guarantee secured

communications service for connecting multiple scattered WiFi nodes to the Internet.

VI. Performance Comparison of WiMAX with Computing Technologies:

WiMAX technology reflects the general trend in the communications industry toward unified packet-based voice and data networks. Fundamental benefits of this transition are reduced operation cost, improved network optimization, and better management of changes. The followings are some of the major benefits of WiMAX are,

- **Wireless**: By using a WiMAX system, no longer have to use expensive cables.
- **High bandwidth:** WiMAX can provide shared data rates of up to 70Mbps.
- **Long range**: WiMAX compared to existing wireless technologies is the range.WiMAX has a communication range of up to 40 km.
- **Flexible architecture:** WiMAX supports several systems architectures, including point-to-point,point-to-multipoint, and ubiquitous coverage.

a) Comparison of WiMAX with 802.11 Wi-Fi:

WiMAX is similar to the wireless standard known as Wi-Fi, but on a much larger scale and at faster speeds. 802.11 Wi-Fi is the IEEE standard for wireless network communication to provide wireless local area network (WLAN) services. It usually operates in the 2.4 GHz or 5.8 GHz spectrum and permits data transmission speeds from 1 Mbps to 54 Mbps. Wi-Fi typically provides local network access for around a few hundred feet (upto 100 meter) but WiMAX antenna is expected to have a range of up to 50 kms with speeds of 70 Mbps or more. WiMAX can bring the primary Internet connection needed to service local Wi-Fi networks[2].

WiMAX differs from Wi-Fi in various ways including frequency band channel, Band width, communication technology, radio technology, efficiency, service range, data transmission throughput, quality of service capability, security processes etc. The results of the comparison show that WiMAX has better performance with WiFi in all the areas listed in given below table 1 and shown in figures 6.

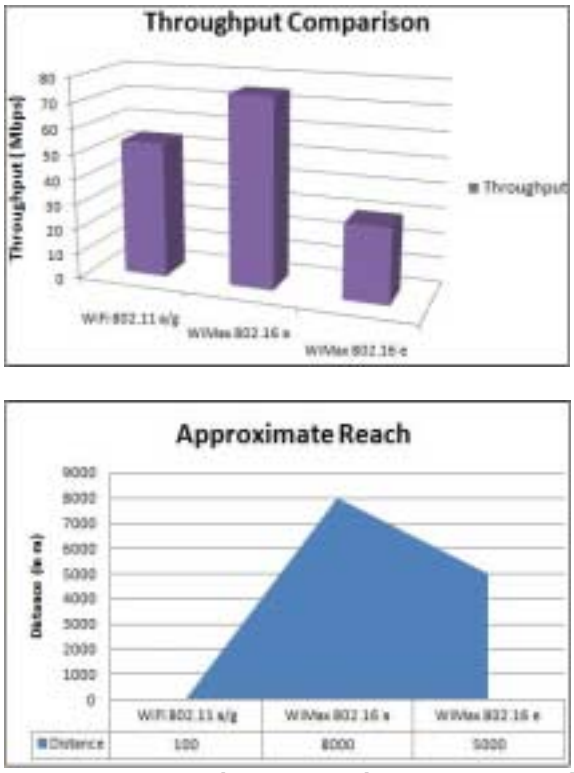

Figure: 6: Pictorial Comparison between WiMAX and WiFi on Throughput & Access range

Characteristics	WiMax (802.16a)	Wi-Fi (802.11b)	Wi-Fi (802.11a/g)
Primary Application	Broadband Wireless Access	Wireless LAN	Wireless LAN
Frequency Band	Licensed/Unlicensed 2 G to 11 GHz	2.4 GHz ISM	2.4 GHz ISM (g) 5 GHz U-NII (a)
Channel Bandwidth	Adjustable 1.25 M to 20 MHz	25 MHz	20 MHz
Half/Full Duplex	Full	Half	Half
Radio Technology	OFDM (256-channels)	Direct Sequence Spread Spectrum	OFDM (64-channels)
Bandwidth Efficiency	<=5 bps/Hz	<=0.44 bps/Hz	<=2.7 bps/Hz
Modulation	BPSK, QPSK, 16-, 64-, 256-QAM	QPSK	BPSK, QPSK, 16-, 64-QAM
Access Protocol	Request/Grant	CSMA/CA	CSMA/CA
Quality of Service(QoS)	Coordinated QoS control	Decentralized QoS control	

Tab.1: Performance comparison between WiMAX and WiFi on various standards

b) Comparison of Mobile WiMAX with 3G Enhancements:

At some point, Current 2G and 3G network operators will migrate to a 4G network technology. Mobile WiMAX is likely to face competition from 3G and 4G technology enhancements. They include the code division multiple access (CDMA) variants CDMA2000 and wideband-CDMA (WCDMA) and their enhancements which are 1x evolution data optimized (1xEVDO) and HSDPA, respectively.

Mobile WiMAX has been simulated against the 3G enhancements [9]. These simulations have shown that Mobile WiMAX peak data rates are up to 5x and spectral efficiency is 3x better than any 3G+ technology. The WCDMA specification was enhanced to create the high-speed downlink packet access (HSDPA) and then HSPA specifications. WiMAX requires new infrastructure while high-speed packet access (HSPA) rides on UMTS. 1xEVDO is a high-speed data specification only for 1.25MHz frequency division duplex (FDD) channels with a peak downlink (DL) data rate of 2.4Mbps. 1xEVDO is an enhanced version of CDMA2000-1x.

A quantitative evaluation of mobile WiMAX, 1xEVDO, and HSPA system performance was conducted based on the usually accepted 1xEVDV evaluation standard. Table 2 and figure 6 (a, b, c) illustrates a comparison of mobile WiMAX with 3G technologies enhancements [1].

Parameter		1xEVDO Rev. A	3xEVDO Rev. B	HSDPA	HSUPA	Mobile WiMAX
Duplex		FDD	FDD	FDD	FDD	TDD
Occupied spectrum (MHz)		2.5	10	10	10	10
Channel bandwidth (MHz)	DL	1.25	5	5	5	DL/UL = 3
	UL	1.25	5	5	5	
Spectral efficiency	DL	0.85	0.93	0.78	0.78	1.91
	UL	0.36	0.28	0.14	0.30	0.84
Net information throughput	DL	1.06	4.65	3.91	3.91	14.1
per channel/sector (Mbps)	UL	0.45	1.39	0.7	1.50	2.20

Table 2: Comparison of Mobile WiMAX with 3G Enhancements technologies

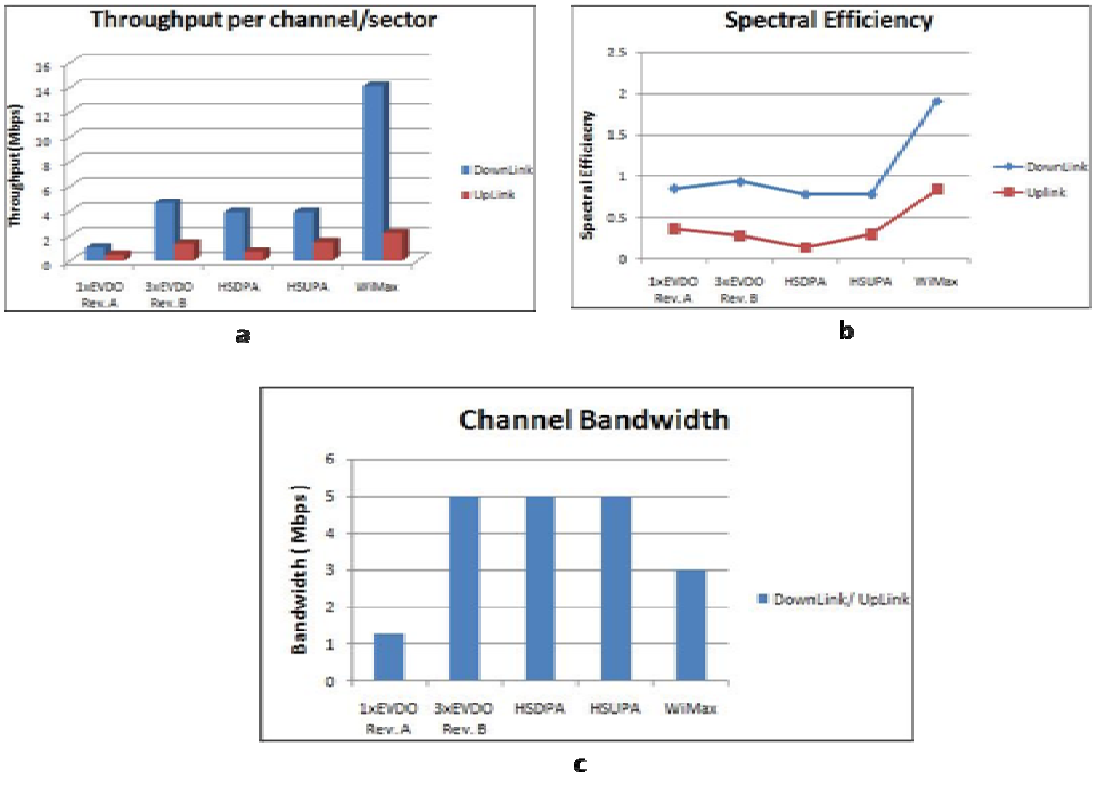

Fig 7 : Pictorial Comparison of moble WiMAX with 3G Enhancements technologies

Conclusion:

There are a number of differences between Mobile WiMAX and WiFi. First of all, Mobile WiMAX is developed for wireless metropolitan area network (WMAN), providing the transmission range of a few kilometers, while WiFi is for wireless local area network with the transmission range up to 100m. WiMAX is an excellent complement to other wireless technologies that are designed to work in the LAN (WiFi) or that offer wider exposure but with more limited capacity (GSM, CDMA, UMTS, EVDO). Mobile WiMAX (802.16e) provides the only standards-based OFDMA WAN technology. WiMAX and future wireless networks that aspire to offer 4G services will attempt to become unified communications systems that fit various markets and have very different sets of customers and requirements. WiMAXis expected to take importance in about three years (2013).The strengths of WiMAX lie in its ability to address the requirements of modern telecommunications networks and the commitment that has been shown to its development and wide acceptance by a number of leading equipment vendors and service providers. In future, Develop the proposed a unified connection-oriented architecture to support the integration of WiFi and WiMAX technologies in broadband wireless networks. This common architecture is supposed to result in an overall advance in technology and a reduction in costs.

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