Performance Analysis of WiMax

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Abstract: WiMax, a broadband wireless access technology, is based on World Interoperability for Microwave access. It provides the last-mile solutions for different applications up to the maximum distance as compared to the other wireless technologies with better coverage and data rates. Basically, it is an IEEE 802.16 standard termed as a wireless MAN and the subset of this standard is 802.16a called as WiMax. It is developed by ETSI (European Telecommunication Standard Institute) offering data rate up-to 100Mbps and its transmission range is up-to 51km. WiMax, wireless MAN (Metropolitan Area Network), uses directional antennae to maximize the transmission range and coverage in LOS (Line of Sight) and NLOS (Non line of Sight). It uses both licensed and unlicensed frequency bands having spectrum range from 2GHz-66GHz. This innovative technology is used to provide broadband access with high data-rate for residential as well as enterprise use with low cost infrastructure. Both continuous and bursty traffic can be accommodated through this wireless technology. The project aims to discuss its performance analysis on the basis of different parameters like QoS, modulation, data rate as compared to other wireless technologies such as 3G, GPRS etc. The work focuses on extensive background study of WiMax, its standards, technical issues, network consideration, Physical layer & MAC layer, its architecture and future enhancements in case of full mobility, coverage, high transfer rate in WiMax. Further investigation in this work will be used to explore different modulation schemes such as OFDM, OFDMA. Scalable Orthogonal Frequency Division Multiple Access (SOFDMA) which is used in mobile WiMax will be used as full mobility. In a nutshell, this cost effective broadband wireless having a throughput of 70Mbps technology is an alternative to DSL, fibre optics and cable modems. In future, WiMax will be a big threat to cellular technologies due to more capacity of voice, data, QoS, coverage, and cost etc.

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1. INTRODUCTION

WiMax, a broadband wireless access technology, is used to deliver a high data rate for residential and enterprise use in a line-of-sight as well as in non-line-of-sight [3]. WiMax provides wireless connectivity over a large distance as compared to other wireless technologies with the help different modulation techniques and different sorts of directional antennae. It provides a last mile solution to other receivers and with better coverage. WiMax protocols can be applied to different wireless point-to-point, mesh network and point-to-multipoint networks infrastructure. Legacy architecture is to be built through point-to-point connectivity and used in upper microwave radio regions. The point-to-multipoint architecture is to be utilized for low microwave frequency network and more and more subscribers can access the same network at the lower cost. This type of architecture limits the number of routers and switches having one Base station and other terminal stations. This approach is not very feasible for a large area network due to the high cost of the Base station. This deployment consists of directional antennae on each terminal station around the Base station. The most promising and costly architecture of WiMax is a 802.16a based Mesh network. Each node having multiple paths provides the most robust solution. As compared to other wireless or broadband technologies, WiMax is capable of communicating with devices at a much higher data rate by using a radio spectrum efficiently and transmits a signal over longer distances up to 50 kilometres in suitable conditions under line-of-sight and normally cell radii of up to 8 km under non line-of-sight. There are different applications deployed by WiMax in commercial as well as industrial sectors. It provides different services like video- and audio conferencing, Telemetry, remote area broadband connectivity and Storage Area Network for different frequencies [11][14]. In figure 1.0, a comparison of different wireless technologies is to be shown with respect to data rate. WiMax has the highest data rate of 70Mbps in LOS (Line of Sight). Its practical coverage in LOS (Line of Sight) is 5km and its coverage can be maximized with the help of modern antenna systems like AAS (Adaptive

Antenna System) and Smart Antennae. IEEE 802.11 or Wi-Fi is a wireless LAN (Local Area Network) technology and it provides data rate up to 54 Mbps. Wi-Fi can be used to provide wireless broadband connectivity to the hot-spots like airports, schools within a distance of 100m. There are other wireless PAN (Personal Area Network) technologies like UWB (Ultra Wide Broadband) and Bluetooth etc. having the data rate of 500 Mbps. It has the highest data rate as compared to other wireless technologies but its coverage is not more 10 metres limited to short range.

WiMax provides a cost effective fixed wireless solution alternative to wired DSL and cable. It also provides the lower cost broadband access solution in the areas without having DSL and cable [4]. In figure 2.0, different applications of WiMax are to be shown. The success of WiMax is to provide broadband connectivity up to certain extent with last mile solution and low cost infrastructure. It provides always broadband best connected facility to users and different applications. It is used to connect different hot-spots like schools, buildings, public community halls with the same data rate with high coverage. It is also used to provide a broadband facility to the areas where there is no accessibility via DSL cables, fibre optics to get Internet access. The WiMax Forum is an organization for providing interoperability among WiMax products through standardization and certification. Interoperability can be achieved through the sharing of the same PHY and MAC layers specification of HiperMAN (High Performance Radio Metropolitan Area Network) and 802.16 standards. As compared to other wireless technologies like Bluetooth & Wi-Fi, WiMax has the more data rate of 70Mbps. It can be used for fixed, nomadic as well as for mobility purposes in future. The future application of IEEE 802.16 is 802.16e which adds mobility factor to WiMax with the support of multiple access techniques such as OFDM, OFDMA and enhance coverage with the use of smart antennas and narrower channel width. The latest WiMax standard 802.16m will use to elevate the data speed up to 1Gbps for fixed applications and 100Mbps for mobile applications being backward compatible with all existing WiMax setup with the Advanced Air Interface [12]. The others upcoming and astonishing WiMax standards like 802.16h, 802.16i, 802.16j and 802.16k will revolutionize the wireless technology and will compete with the Next Generation Network.

2. GENERAL OVERVIEW

2.1 Line of Sight

WiMax provides wireless service similar to Wi-Fi but at high data rate and with more coverage for a higher number of users. Firstly, WiMax standard was designed to perform operations in the frequency range of 10-66GHz to provide Line-of-sight between transmitter and receiver. To provide a line-of-sight service, fixed dish antennae are to be used in Base stations. The line of sight connection between the transmitter and receiver provides high data rate with minimum error probability. At high frequency, signals travel in a straight line between transmitters and receivers with a high data rate. WiMax provides data up to the maximum range of 30 miles radius [7] [18].

2.2 Non Line of Sight

WiMax is also capable of providing data in non-line-of-sight with the help of small antennae in the frequency range of 5-11GHz because on low frequency signals can diffract/bend through different obstacles. As compared to line of sight, it requires less Base stations and provides a low cost infrastructure with licensed and unlicensed frequency bands. Signals having a low wavelength cannot be disturbed by physicals obstacles and they can move from here to there. WiMax's MAC layer is modified to handle all non-line-of-sight applications based on the Orthogonal Frequency Division Multiplexing technique [7]. Non-line-of-sight use unlicensed frequency as well as a licensed band. As compared to WiMax, Wi-Fi uses an unlicensed band and is very robust in this 2-11GHz band limit.

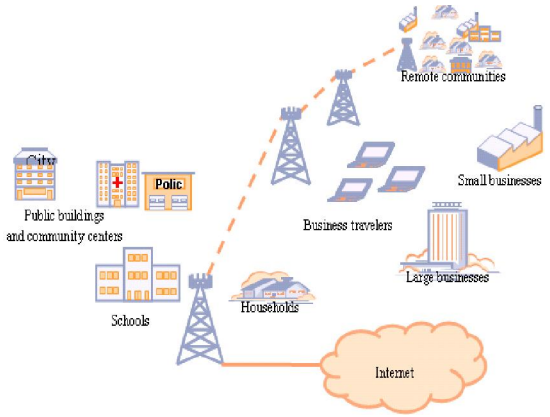


Figure 1. WiMax Architecture

3. TYPES OF WIMAX

3.1 Fixed WiMax

The initial version of WiMax applies 802.16 standards which are used to provide data in a line of sight manner. It provides fixed access with the help of certain types of antennae mounted on WiMax Base stations and Subscriber stations. It operates on high frequency in the range of 10-66GHz because at high frequency, signals coming from a transmitter follow a certain path in a straight line to the receivers. At a high frequency, signals do not bend or diffract

through obstacles. To get line of sight, base stations would need to be set out in a line and this will increase cost due to the availability of more stations. Fixed WiMax provides the bandwidth of 32-124 Mbps and a high frequency band is required to provide high bandwidth. It provides data in the range of 1-3 miles radius [9]. There are different adaptive modulations schemes like 64QAM, 16QAM or QPSK in fixed WiMax. The channel bandwidth may vary according to the requirement of data in the range of 20, 25 and 28 MHz and it depends on the principle of request and grant access.

3.2 Portable WiMax

After the fixed WiMax, another version came into market name as portable WiMax and it has fixed as well as portable data access in the non-line-of-sight and line-of-sight system. It operates at low frequency in the range of 2-11GHz due to its multi path property. At low frequency, signals can be easily diffracted or bend and cannot penetrate through physical obstacles or obstructions. In point to multipoint, it provides data bandwidth up to 70Mbit/s in the range of 4-7 miles radius. The range of radio frequency channel bandwidth lies between 1.5MHz & 20MHz [9]. It also follows the principle of request and grant access system.

3.3 Mobile WiMax

It is an IEEE 802.16e standard which is used to provide broadband access in the case of mobility or fixed WiMax. It is an enhancement of fixed WiMax. According to the Cisco Forum (2006), "It is based in a next-generation all IP-core network, that offers low latency, advanced security, QoS (Quality of Service), worldwide roaming capabilities".

From the above mentioned discussion, WiMax future applications like the mobile WiMax has the capability to compete in the next future generation wireless cellular network on the basis of high security features and advanced modulation techniques like Orthogonal Frequency Division Multiple Access to support full mobility and scalability.

OFDMA based Mobile WiMax is used to work under a non-line-of-sight environment giving high coverage and data throughput. It works under the frequency range of 2-11GHz to overcome NLOS with data bandwidth of 50Mbps. It is feasible with a request and grant access system. Different antennae systems like MIMO (Multiple Input Multiple Output), beam forming techniques based on mobile WiMax are also used to enhance throughput and coverage. Security enhancements are to be done with the help of high performance coding techniques like Turbo coding etc. To avoid strong multi- path interference, Fast Fourier transforms base algorithms are to be implemented as MAC (Media Access layer). Owing to the 802.16e standard in WiMax, anyone can access wireless broadband voice or data either in the home, office or when on the move [7].

4. WIMAX STANDARDS AND ITS ARCHITECTURE

Before you begin to format your paper, first write and save the content as a separate text file. Keep your text and graphic files separate until after the text has been formatted and styled. Do not use hard tabs, and limit use of hard returns to only one return at the end of a paragraph. Do not add any kind of pagination anywhere in the paper. Do not number text heads-the template will do that for you.

WiMax, IEEE 802.16 standard, is a globally certified and standardized wireless access technology that provides interoperability between WiMax products to provide lower cost infrastructure as compared to other wireless technologies. It provides different parameters like QoS establishment, security issues depending on its standards. The following are the main standards of WiMax [10] [7].

IEEE 802.16: The first version of WiMax standard developed by the IEEE is 802.16 to provide broadband wireless access in the frequency range of 10-66 GHz in LOS (Line of sight). At a high frequency, signals propagate strictly in a straight line and do bend or diffract through obstacles. This standard is further modified into different categories according to signal propagation, coverage, data rate and coverage issues.

IEEE 802.16a: This standard was designed to provide signals in line-of-sight as well as in non-line-of-sight having licensed as well as licensed exempt frequency. Particularly, this standard is useful for rural and developing countries in the presence of unlicensed spectrum. This standard uses a low frequency band in the range of 2-11GHz due to the signals' penetration or diffraction through obstacles and provides non-line-of-sight facilities.

IEEE 802.16c: The interoperability between WiMax products is to be maintained through this standard and it works under non-line-of-sight in 2-11GHz frequency range.

IEEE 802.16d: This is the enhancement of IEEE 802.16, 802.16a standards and it is also recognized as an 802.16-2004. Both FDD (frequency division duplex) and TDD (time division duplex) methods are to be used by this standard for a high data rate.

IEEE 802.16e: WiMax is to be modified by adding enhanced features like mobility, portability, adaptive antenna systems in it to improve performance and data rate etc. It provides high coverage, low cost infrastructure, scalability and a higher data rate than other cellular based technologies. To mitigate NLOS (Non-line-of-sight), mobile WiMax uses different methods like OFDM technology, sub-channelization,

directional antennae, receive and transmit diversity, adaptive modulation and error correction technique etc. Mobile WiMax based OFDMA is used to overcome non-line-of-sight in a multi path. SOFDMA (Scalable OFDMA) is used to provide channel bandwidth in the range of 1.25MHz to 20MHz [9]. Mobility is to be added at MAC and PHY. Mobile WiMax provides high degree of security on basis of EAP (Extensible Authentication Protocol) and AES (Advanced Encryption Standard).

IEEE 802.16f: This standard discusses coverage issues and enhances coverage using Mesh configuration (point-to-point) and it is still under consideration.

IEEE 802.16g: This incoming standard of IEEE 802.16 is based on either OFDM or OFDMA to control mobility between higher layers and backhaul rather than lower layers. It will make possible communication of users moving from one Base Station to other Base Station without dropping the signal level.

IEEE 802.16m: This standard is based on IEEE 802.16 wireless MAN-OFDMA specification with the support of advanced air interface. It will be used to provide improved performance with a high data rate of 1Gbps. It will be useful for next generation mobile applications having the high data rate, increased peak, system capacity and cell coverage while sustaining overall system capacity. The system will support different services like Streaming, Conversational, Interactive and Background with different delay, data rate according to the application requirements and specifications [17]. For security reason, it will be used to provide advanced air interface with a location privacy scheme, control information and device authentication scheme etc. This coming WiMax standard will be based on the most advanced antenna technique such as Multiple Input Multiple Output (MIMO) with an OFDM-based radio system. There are different applications of this standard such as web-browsing, voice, video, online gaming. The maximum data rate can be achieved through a 64-QAM modulation scheme [10] [20].

IEEE 802.16 h/i: These futures based on up and coming WiMax standards are at pre- draft stage. These standards will be used for progressed coexistence Mechanisms for License-Exempt Operation and for Mobile Management Information Base respectively [10].

4.1 WiMax MAC layer

WiMax, a broadband wireless technology, has the two important layers; MAC (Media Access Control) and PHY layer. MAC layer has built-in characteristics to give bandwidth on demand to different channels to overcome dilapidation of wireless services such as jitter, latency etc. It is built on intelligent algorithms for example the request/grant principle to overcome this problem.

To provide broadband wireless access in a point-to-multipoint way, the MAC layer is to be designed with the help of different algorithms [10]. It assigns the bandwidth to channels according to data rate from either uplink or downlink.

	802.16	802.16a/802.16d	802.16e
Spectrum	10-66GHz	<11GHz	<6GHz
Channel conditions	LOS	NLOS	NLOS
Modulation	QPSK, 16QAM	OFDM 256 sub carriers	Same as 802.16a
Mobility	Fixed	Fixed	Mobility
Channel bandwidth	20, 25 and 28 MHz	1.25&20MHz	Same as 802.16a
Bit rate	32-134Mbps	75 Mbps	15 Mbps

Table 1: WiMax's Standards [13]

Figure 2. WiMax Standards

WiMax MAC layer was designed to support for bursty traffic. It consists of different MAC protocol and sub layers which are to be used to carry traffic efficiently and robustly as compared to other transport media. In WiMax, there is a central Base Station having specified antennas system to handle multiple other subscriber stations. These subscriber stations receive the equal amount of data transmission from a central Base Station in a defined frequency or spectrum allocation in a line of sight as well as in non-line-of-sight. The MAC layer is associated with a CID (Connection identifiers) which is used to deliver bandwidth on demand and it acts on the Request/Grant principle. Different PDU (packet data units) residing in the MAC layers of the Base Station and Subscriber Station are to be exchanged for data transfer. Each SS subscriber station is to be identified through its standardized 48-bit MAC address and usually is called CID (Connection Identifier). For Quality of Service (QoS), each SS is to be allocated by three management levels in UP (Uplinks) and DL (Downlink) directions.

Basic Connection

This is also the type of connection management and this algorithm is feasible for short type, time critical MAC and radio link control [11].

Primary management connection

This connection management type is used to transfer long, bursty messages. Different protocols like DHCP, TFTP are to be used for secondary connection management purposes.

Transport connections

This type of connection can be used to transport UP (Uplink) and DL (Downlink) messages in one direction at a time. Base station acts upon the Request/Grant principle from subscriber station.

Service classes and Quality of Service

There are different transmissions protocols used in MAC layer to controls contention between different applications and provide the facility of required bandwidth and delay for them. To maintain QoS parameters between different applications, there are four categories of services.

4.1.1 MAC layer functions

Here are the different functions performed by the WiMax MAC (Media Access Control) layer as following;

- Transmission scheduling
- Admission control
- Link establishment
- Fragmentation
- Retransmission

4.2 WiMax Physical layer

WiMax is the unique wireless broadband technology providing data rate up to maximum throughput with maximum coverage and reliability. WiMax PHY layer is based on different modulation schemes like OFDM, TDD, FDD, QPSK (Quadrature Phase Shift Keying) to get maximum reliability, coverage, high throughput etc. The most efficient multiplexing technique is OFDM which is used to deliver wireless signals with minimum interference and loss. WiMax PHY layer is to be supported by two duple Xing techniques like TDD and FDD etc. The initial version of WiMax supports only line of sight and it worked in frequency range of 10-66GHz but after that more modifications are to be done on PHY layer. For NLOS, PHY layer is further divided into three more layers which are used to provide end to end reliability with the help of the MAC layer [12].

Wireless MAN-Single carrier

The initial version to provide NLOS (Non-line-of-sight) is based on single carrier of modulation. It is used in point to point in the frequency range of 2-11GH.

Wireless MAN-OFDM

To get NLOS applications, 256-carrier OFDM modulation technique is used for this purpose. It also works on low frequency in the range of 2-11GHz to provide data in point to multipoint. TDMA scheme is used to access different subscriber stations via the Base station.

Wireless MAN-OFDMA

Another modified technique used to get data in non-line-of-sight is based on 2048-carrier OFDM scheme. Both FDD and TDD are to be supported by OFDMA. Advanced techniques like Adaptive Antenna System and Multiple Input Multiple Output are to be used for increased data capacity and channel coverage.

V. WIMAX STRENGTHS AND WEAKNESSES

The innovative broadband Wireless enabled technology; WiMax has tremendous advantages and few disadvantages. It provides latest standards giving full opportunities in public as well as in private sectors. Instead of other broadband wireless technologies, there are many other positive issues like high coverage, more data throughput, scalability, portability for its popularity. WiMax provides data rate with high speed in line of sight as well as in NLOS (non-line-of-sight) with equal transmission rate [7]. There are different drawbacks of WiMax which are still under consideration.

5.1 Advantages of WiMax

There are different distinct features in WiMax on the basis of which it is more desired wireless broadband technology.

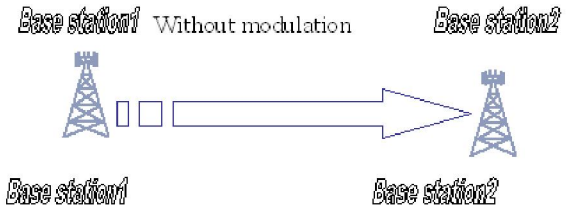
5.1.1 Quality of Service

WiMax, an innovative wireless technology, provides the different mechanisms to ensure better QoS with the help of advanced algorithm based on MAC and PHY layers. WiMax technology was designed to fulfil the requirements of users in case of multimedia, real time and non real time applications like video, voice over IP, online gaming etc. QoS means to minimise latency and jitter in multimedia applications and overcome on packet loss. As compared to TCP/IP applications, multimedia services need more bandwidth reservation and bounded delay are required to ensure and guarantee of QoS [15].

As compared to wired media, it is difficult to support QoS in wireless networks due to its unpredictability and variability characteristics. In wireless media, MAC (Media Access Control) layer is used to fulfil the requirement of users and to ensure QoS. MAC layer in WiMax use different QoS mechanisms for different applications according to their requirements such as bandwidth, data rates etc. For instance, voice and video in multimedia applications require less latency as compared to other data applications. Bandwidth (frame by frame) is applied on demand for fulfil the requirement of data application to reduce latency and enhance the QoS.

In WiMax, adaptive modulation is to be used to balance different data rate in different applications and link quality. MAC is dynamically enabled to support bandwidth allocation over the distance between BS and the subscriber station to ensure QoS parameters. It supports both TDD (Time division

duple Xing) and FDD (Frequency division duple Xing) and bandwidth can be allocated on the basis of traffic requirements. Generally, WiMax measures QoS through different modulation schemes like 64-QAM, 16-QAM, and QPSK etc. With respect to distance, WiMax uses different mechanisms. If a link fails due to much distance between subscriber station and base station then the modulation order is reduced to minimise throughput and to increase range [10][9].



With modulation, Throughput vs. distance, 12 Mpbs to miles/5Mbps to 3 miles

In the above figure 3, the effect of modulation is shown. With the help of modulation data throughput can be maximized from 5 Mbps to 12 Mbps in the range of 3 miles. Different modulation schemes are to be used by WiMax but QPSK is more favourable in the noisy conditions.

5.1.2 Improved User Connectivity

WiMax provides adaptive modulation and provides bandwidth to the subscriber stations on demand. As compared to other wireless standards like 802.11, the 802.16-2004, it uses a narrower channel and provides a low data rate to subscribers without wasting the bandwidth. When the signal strength becomes weak in noisy conditions or in other interference conditions, the adaptive modulation keeps them connected with the Base station. Its MAC layer works on the principle of Request/Grant [10].

5.1.3 Efficient Spectrum Usage and Standardization

The big advantage of WiMax is to ensure globally interoperability and compatibility between WiMax products to provide broadband MAN (Metropolitan Area Network). According to Fujitsu (2004), " The standards define and suggest key profiles for the Media Access Control (MAC) layer, which packs and unpacks raw data based on standard protocols to accommodate data, voice and video, and for the physical layer (PHY), which handles the air interface and modulation schemes based on subscriber needs and radio frequency link quality. "

On the basis of this statement, interoperability and compatibility among wireless products will lead to accelerate deployment of broadband networks and it will provide low cost infrastructure. Standardization maintains and defines the MAC layer and PHY layer profile and is globally recognised in case of products and it results in customer satisfactions and needs [19].

5.1.4 Low Cost Infrastructure

Due to standardization and certification of WiMax products, WiMax networks provide the broadband access in the areas where there is no availability of DSL cables and fibre-optics etc low cost infrastructure as compared to other wireless technologies. Due to wireless enabled technology, installation of plug and play is much easier for Wi.Max. WiMax uses licensed as well as unlicensed frequency spectrum. Unlicensed frequency bands are to be used by many broadband service providers in order to minimise cost for network deployment in the range of 10-66GHz.

5.1.5 Secure Exchange of Data

WiMax is fully capable of providing security to the subscriber through different encryption algorithm between Base stations and Subscriber stations. Firstly, data is encrypted through a specified encapsulation protocol (X.509) and then PKM protocol is used to distribute secured data between BS and SS.

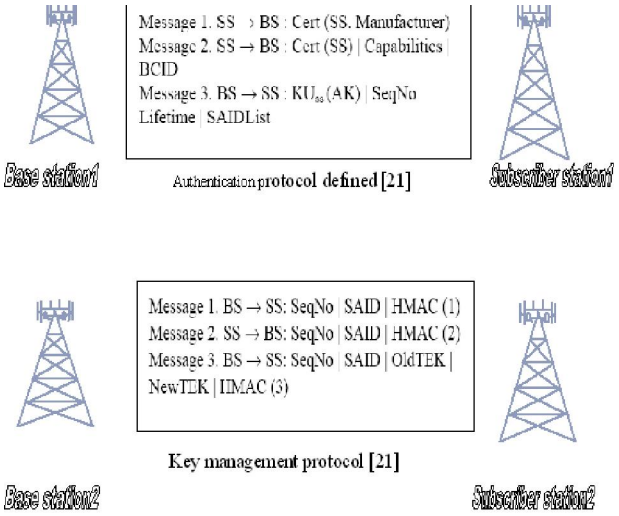


Figure 4. Security Implementation

In the above figure 4, the secure exchange of date between two stations is to be shown with the help of certain secure protocol. In the 1st case, two messages are sent from SS to BS and one message is sent from BS to SS authentication. In the 2nd case, two messages are sent from BS to SS and one message is sent from SS to BS for key management protocol.

5.1.6 Flexible Architecture

The WiMax based network can be configured on the basis of different system structure. Its MAC layer can be modified based on different algorithms and access techniques for each subscriber station. A Base station can be configured on the basis of MAC layer and use narrower beam antennae for maximum coverage.

5.1.7 Quick Deployment

WiMax is a wireless technology and it provides the easy solution of its deployment as compared to wireless network. More DSL cables, fibre optics cables are required to deploy a wired network to get broadband access. In the case of WiMax, it provides broadband wireless in the areas where there is no accessibility for wires such as remote areas or mountaineering areas etc. It takes less time to deploy WiMax network as compared to other solutions.

5.1.8 Interoperability

WiMax, IEEE 802.16 standard, is a wireless broadband access technology and its products are fully standardized and certified all over the world. Due to its standardization, service providers can adopt the WiMax products with satisfaction and due to this factor the cost of WiMax hardware may be driven down.

5.1.9 Mobility

After the initial version of WiMax, there are many more changes deployed to enhance its mobility and portability. To get mobility, major changes are to be carried out on its physical layer. OFDM and OFDMA are access techniques used to provide mobility to the mobile users. The SOFDMA (Scaleable OFDMA), MIMO are the advanced techniques used to provide full mobility and scalability at a speed of 160km/h [7]. IEEE 802.16e is working on both MAC and PHY layers of WiMax to provide full mobility by using advanced multiplexing techniques.

5.2 Disadvantages of WiMax

With its many advantages, there are some weaknesses in this broadband wireless technology. IEEE is trying to overcome this deficiency. In future, more and more hybrid wireless technologies will come into being with 100% results. Here are some main disadvantages in WiMax.

5.2.1 Limitation of Frequency Spectrum

It is a big disadvantage for WiMax not having much frequency spectrum in a high capacity area. High bandwidth is required to fulfil the needs of high density area network which results in high costs. The WiMax standard is to be regulated through licensed frequency spectrum and huge amount is to be given for licensed frequency spectrum to establish its network [11].

5.2.2 No Terminal Mobility

WiMax structure is not fully spread all over the world so that is why big companies feel some hesitation in deploying WiMax Base Station and also till yet it has not achieved full mobility.

6. APPLICATION OF WIMAX

WiMax, a wireless Metropolitan Area Network, is used to provide broadband internet access in the areas where there is no accessibility of fibre optics, DSL cables and cable modems etc, for example, rural or developing countries. It provides connectivity in line-of-sight as well as in non-line-of-sight with a data rate of 70Mbps. WiMax can be used as a backbone for wireless LAN or 802.11 hotspots for Internet connection due to its large transmission range and rate. Mobile WiMax provides broadband connectivity to mobile users with the range of 5-6 miles as compared to wireless hotspots.

In the below diagrams, there are different applications of WiMax and its applicability shows its efficient usage in different areas. It provides connectivity as a last mile to hot spots, public buildings, schools and to remote areas etc with low cost infrastructure. Its initial version of WiMax, IEEE 802.16 standard, is used in line-of-sight by using frequency spectrum in the range of 10-66 GHz but its later versions can also be used in non-line-of-sight in the range of below 10 GHz. As compared to other wireless technologies, WiMax can be used to provide signal transmission in multi-paths to a large extent. On a high frequency of 10-66GHz, it is impossible for signals to propagate in multi-path in the presence of obstacles. To maintain line-of-sight on a high frequency, transmitter and receivers are directly opposite to each other to overcome any obstacles. For multi-path propagation, WiMax works on a low frequency in the range of 2-11GHz due to its diffraction through obstacles [5].

It has many types of applications supporting broadband wireless connection and other miscellaneous applications as well. WiMax can be used for both public as well as private networks.

6.1 Metropolitan Area Network

Being an open standard, WiMax provides advantages to network operators, users and different types of service providers. IEEE 802.16 provides the solution of last-mile, hot zones and wireless coverage for remote areas where wired infrastructure is not established in metropolitan area network. Wireless Internet Service Providers give the Internet a facility

to rural areas where there is a lack of wired networks. WiMax provides broadband facility to users with extra ordinary facilities such as no ongoing charges, service to rural areas, low cost and robust deployment [6].

6.2 Educational Networks

WiMax, wireless broadband technology, provides the wireless service in public as well as in private networks. In private networks such as the education sector, WiMax is used to connect different schools with high bandwidth in a point to point or point to multipoint system. WiMax based broadband wireless enabled school systems are fully compatible to provide full QoS, intranet and internet facility and multimedia messages etc. It also provides a feasible broadband solution in the rural education system where there is no accessibility to a wired broadband network.

6.3 Campus connectivity

WiMax provides wireless access and is used to connect different hotspots, schools, buildings, large enterprises having main Base station. Connection is established through main Base Station with other subscriber stations providing much QoS, high security, high coverage and high data capacity. The WiMax based system provides low cost infrastructure due to its standardized products.

6.4 Wireless Service Provider Backhaul

Another application of WiMax is in private networks to provide wireless accessibility from its Base station as a core network. Traffic is to be transported from the main Base station to different access networks based on either Wi-Fi, WiMax etc. The Wi-Fi based network hotspot and traffic is to be transported on the basis of the requirements of access networks. Wireless Service Provider provides the facilities like voice, data and video to different access networks depending on the basis of requirements. WiMax provides the facility of wireless broadband and it is a cost effective infrastructure. As compared to a wired network built on DSL cables, fiber optics and other leased lines, a WiMax based network can handle the more traffic and data capacity.

6.5 Rural Connectivity

A WiMax based network provides broadband access in public as well as in private sector. It is also very useful for a service provider to use WiMax in rural as well as urban areas. It provides a cost effective solution as compared to wired network. Rural areas as compared to urban areas need much telephony and internet services. According to WiMax Forum (2005), "WiMax solution can be deployed quickly, providing communication links to these underserved areas, providing a more secure environment, and helping to improve their local economies".

On the basis of the above discussion of the Cisco Forum, WiMax provides the low cost infrastructure with better communication links by providing broadband facility developing areas.

6.6 Residential and SOHO

IEEE 802.16 certified and standardized wireless broadband access technology is suitable to provide services in those areas where accessibility of Internet is too difficult due to lack of resources. Under non suitable demographic region or in residential areas, it provides best solution of broadband wireless access as compared to DSL and leased line services. It provides equal bandwidth to individual customers according to their needs and requirements [8].

6.7 Cellular backhaul

With the advancements in cellular networks, competition among service providers is increasing. More and more customers are opting for cellular technology but cost is a major factor for emerging cellular technologies. WiMax is a solution for this problem and provides better coverage at a longer distance of data rate. In point to point, WiMax provides data at a distance of 30 miles radius. WiMax based Base stations support different subscribers' stations and send traffic to network operation and switching centres. WiMax based networks do not operate with the same data rate due to the difference of spectrum availability globally. WiMax based network is highly suitable for cellular networks due to built-in solution of high QoS, security and better coverage etc [9].

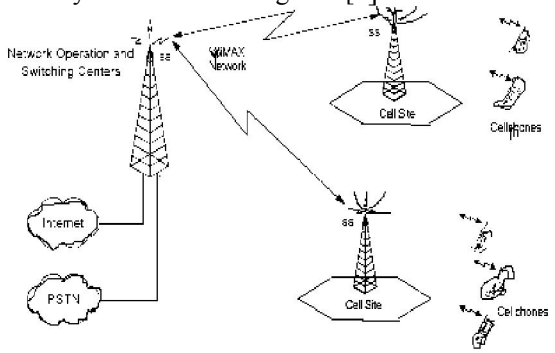


Figure 5. WiMax Cellular Network

In figure 6, WiMax also provides application in the cellular network. WiMax main Base stations are to be connected through different Subscriber stations and other networks to provide bandwidth on demand and QoS etc.

VII. CHALLENGES FACED BY WIMAX TECHNOLOGY

WiMax is a revolutionizing wireless technology having high data rate provides broadband connectivity in LOS (line-of-sight) as well as in NLOS (non-line-of-sight). There are some challenges faced by WiMax which are as follows:

7.1 Full Mobility

According to Vijay Dube (2006), "Mobility covers different levels of services including nomadicity (using services in different locations), portability (basic mobility without soft hand-off) and full mobility (high vehicular speed and seamless hand-off between cells)"

WiMax is a wireless Metropolitan Area Network, used to provide broadband data access at longer distances with a high data rate. Now, more advanced access techniques like OFDM, OFDMA, SOFDMA (Scalable Orthogonal Frequency Division Multiple Access) are to be used to provide full mobility and signal strengths cannot change while changing from one Base station to another.

7.2 Multi path/Interference Challenge

In wireless communication, signals transmitting from transmitter to receiver travel in line of sight as well as in non-line-of-sight. Multi path distortion/fading occurs due to traveling of signals along different paths and that is why, fade margin is used to overcome this effect [8].

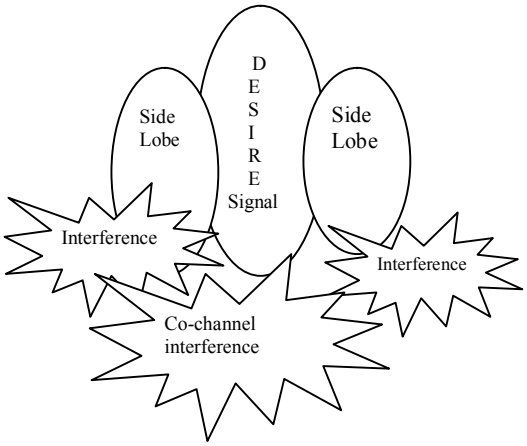


Figure 6. Types of Interference

WiMax, wireless Metropolitan Area Network OFDM based technology, used to overcome ISI (inter symbol interference). OFDM use guard interval between each symbol to avoid interference or multipath distortion. OFDM uses narrow sub carriers having high data rate.

In figure 7 and 8, different interferences are shown. Signals coming from transmitter in multi path results in the deterioration of the signals and follow Inter Symbol Interference. WiMax technology mitigates NLOS or the multi path problem through different techniques like OFDM, sub-channelisation, directional antennae etc.

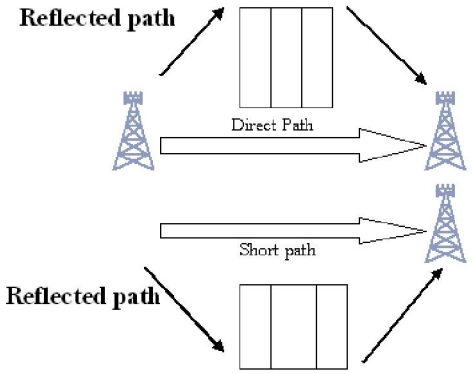


Figure 7. Inter Symbol Interference

7.3 Voice over WiMax

It is a big challenge for WiMax to transport the voice over its network properly. The different objections relating to voice over WiMax are, for example, voice quality, security issues which are are under consideration.

8. CONCLUSION

In a nutshell, the broadband wireless technology WiMax, plays a pivotal role in public as well as in the private sector and provides internet connectivity to rural and urban areas with key roles like high data rate, more coverage, high QoS etc. Nowadays, WiMax is getting more and more advanced features such as mobility, scalability with specialized modulation techniques and antennae system usage. At present, WiMax is working on its latest innovative standard 802.16m with an expected data rate of 1Gbps with the support of 64QAM modulation technique. In future, WiMax will be a considerable threat to cellular technologies having the latest features like QoS, more capacity of voice and data etc. The latest standard of WiMax 802.16m will be capable of having multimedia services like IPTV streaming video, robust audio and video downloading etc. Keeping in mind the need to fulfil the requirements of 4G cellular technology, it is compulsory to give all priorities to this upcoming standard and it is a big challenge for IEEE. According to the source, Rysavy Research (2007), "Both 3G Cellular Technologies Evolution and

Broadband Wireless Technology Evolution are converging to 4th G OFDMA based wireless technology having Interoperability with each other".
From the above said discussion in the paragraph, the 3G cellular technologies like W-CDMA, EDGE, CDMA 2000 1X EV, WLAN, and Bluetooth having data rate of 384kbps-2Mbps are trying to update themselves using different modulation schemes and converging into 4th G networks with 100Mbps. WiMax and WiBro having the capability of higher data rate with the help of more efficient modulation techniques may compete with the 3G cellular network.

As a result of this research paper, we have good understanding of the basic WiMax network, its standards, its applications and architecture. In future, we will proceed with this work to further investigation in its new standards, mobile WiMax networks, network considerations, coverage issues with OFDMA and SOFDMA (Scalable OFDMA). It is the up gradation IEEE 802.16 standard of fixed OFDM256 and provides more efficiency, scalability etc. Full mobility in case of mobile applications in WiMax can be achieved through SOFDMA with the help of sub- channelization and advanced modulation and coding schemes. OFDMA has the high system gain performance as compared to OFDM and is an appropriate solution for full mobile applications with a better frequency reuse factor. OFDM is similar to FDM (Frequency Division Modulation) with more spectral efficiency through the closeness of sub-channels and these channels do not interfere due to Orthogonality. OFDM is also useful in case of multi-path effect and overcomes on interference, frequency selective fading through parallel and slower bandwidth nature. In the case of Scalable OFDMA, it improves efficiency and performance for lower-bandwidth channels through smaller FFT (Fast Fourier Transform). The FFT size will be reduced from 2048 to 128 to handle channel bandwidth in the range of 1.25 to 20 MHz and it reduces complexity in case of wide channels with the help of larger FFT for higher performance. In a nutshell, WiMax based on OFDM's tremendous spectral efficiency and high resistance to multi-path effect, it will converge to 4th Generation Future Network.

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