WiMAX OR WI-FI: THE NEXT GENERATION TECHNOLOGY FOR WIRELESS NETWORKING INFRASTRUCTURE

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ABSTRACT

Today on one hand wireless is emerging as the technology that is giving shape to more convenient and cost effective world on the other hand it demands wireless technology to expand from single home to whole world. This paper presents a comparison of the existing wireless technology Wi-Fi (IEEE 802.11) and WiMAX (IEEE 802.16e/m), with respect to technology which provides a better solution to build a wireless access infrastructure. On based of different parameters the technology is measured. Conclusion of the paper is to state which technology is best suited and cost effective solution to end users.

KEYWORDS: *Wireless Technology, WiFi,WiMax*

I. INTRODUCTION

With the help of many expert communication engineers IEEE has developed various wireless standards in a hierarchical fashion. Some of the deployed wireless standards are: 802.15 (Bluetooth), 802.11 (Wi-Fi), and 802.16 (WiMAX). With the latest development of 802.16m the world is shifting towards the Wi-Fi max networks. Mobile WiMAX is an enhanced version of IEEE 802.16 standard with mobility support. It offers scalability and supports flexible network architecture. Amendments support scalable channel bandwidths from 1.25 to 20 M Hz. Mobile WiMAX IEEE 802.16e supports mobility and is also capable to provide fixed access.

New standard, 802.20 for WANs has been proposed, the goals of 802.20 and 802.16e, the so-called "mobile WiMAX".

Each of these IEEE standards has been deployed to fulfill certain criteria and they complement each other. Wi-Fi standard IEEE 802.11 has had a lot of commercial success, for this reason, now the focus of wireless networking is shifting to the wide area market. For home and office use Wi-Fi was a huge success but the wide area network it still needs to grab the larger market.

So short for Worldwide Interoperability for Microwave Access, appeared to be the as solution for outdoor and long-range last-mile solutions. Many service providers had adopted this technology as a quick and cheap option to provide connectivity between access points or base stations and their backbone network. The main goal of WiMAX is to provide cheap and fast connectivity of both voice and data communication to remote and difficult terrain locations. With the increasing market demand for WiMAX, it is now regularly compared with Wi-Fi. Both technologies have tremendous similarities, however the approach is completely different towards the wireless space. The purpose of this paper is to provide a technical, commercial and market comparison of Wi-Fi and WiMAX technologies in order to highlight as to which technology will be better to build a wireless access infrastructure.

For both the technologies it has been tested for health regarding issues by WHO and all the devices are well tested for the radio waves. These evaluations are done in accordance with the various regulations and guidelines adopted or recommended by regulatory agencies around the world [10].

Thus far, I have discussed the motivation of the presented work and the brief overview of the both technology, WiFi and WiMax. The rest of the paper is organized as follows. Section II gives an overview of the WiFi and WiMAX. In Section III focus on the Key factors of wireless technology. Section IV presents the evaluation of both technology based on key factors. Section V presents the results obtained by these researchers and section VI concludes the paper.

The first part of the paper examines both of these wireless technology in order to understand them and their underlying concepts. After that, we have discussed some key characteristics to compare both of these technologies. The last part concludes and presents a conclusions which will be best technology to build a wireless access infrastructure.

II. OVERVIEW OF THE TECHNOLOGIES

2.1 Wi-Fi

The dream to network PCs and other devices without the cost and complexity of cable infrastructures has driven the rapid growth in the wireless market over the last few years. Wi-Fi technology can play a key role in making it more productive, convenient and fun. Wi-Fi is one of the wireless technology which appeared early in the wireless market which is based on the IEEE 802.11 wireless local area network (WLAN) specification. Actually it was designed to be used indoors at close range for example home user and office environment. Wi-Fi uses radio waves - just like other devices such as cellular phones, TV and radio - to create a reliable high-speed connections between computers, printers, gaming devices, cameras phones and home entertainment systems [11]. A user with a mobile computing device such as a laptop, cell phone, or PDA which is Wi-Fi enabled can connect to the global Internet when it is within in range of an access point. The region which is covered by one or more access points is called a hotspot. Hotspots can range from a single room to thousands of square feet's of overlapping hotspots. Wi-Fi can also be used to create a mesh network. Wi-Fi also allows connectivity in peer-to-peer (wireless ad-hoc network) mode, which enables devices to connect directly with each other. This connectivity mode is useful in consumer electronics and gaming applications [1].

Wi-Fi products can use different radio frequencies [2]:

- The 802.11a standard uses 5 GHz in an AP-to-AP interlink.
- The 802.11b and 802.11g standards use 2.4 GHz.

Figure 1: Wi-Fi Network

Different frequency bands are used by the 802.11a, 802.11b and 802.11g standards; Different devices using these different frequency bands do not interfere with one another. However, portable devices using different bands cannot communicate with each other, for example an 802.11a radio cannot

communicate with an 802.11b radio. The most commonly used standard in the Wireless LAN are the 802.11b and 802.11g standards because of their interoperability and the greater range option that they can achieve in the 2.4-GHz band. Each standard also uses different types of radio-modulation technology, which is as follows [2]:

- The 802.11b standard uses direct-sequence spread spectrum (DSSS) and supports bandwidth speeds up to 11 Mbps.
- The 802.11a and 802.11g standards use orthogonal frequency division multiplexing (OFDM) and support speeds up to 54 Mbps. Because OFDM is more suitable to outdoor environments and interference, that's why it is commonly used for Wireless LAN infrastructure.

2.2 WiMAX:

IEEE standard 802.16, also known as WiMAX [1], is a technology for last-mile wireless broadband as an alternative to cable and DSL(where the cost is high). New standard IEEE 802.16m-2010 is introduced with backward compatibility and ready to take over the world with 4G enabled devices. It's intended to deliver high speed data communication, and it also has the ability to maintain dedicated links and VoIP services at a reliable quality and high speed. WiMax 2 allows higher data rates, lower latency and higher efficiency.

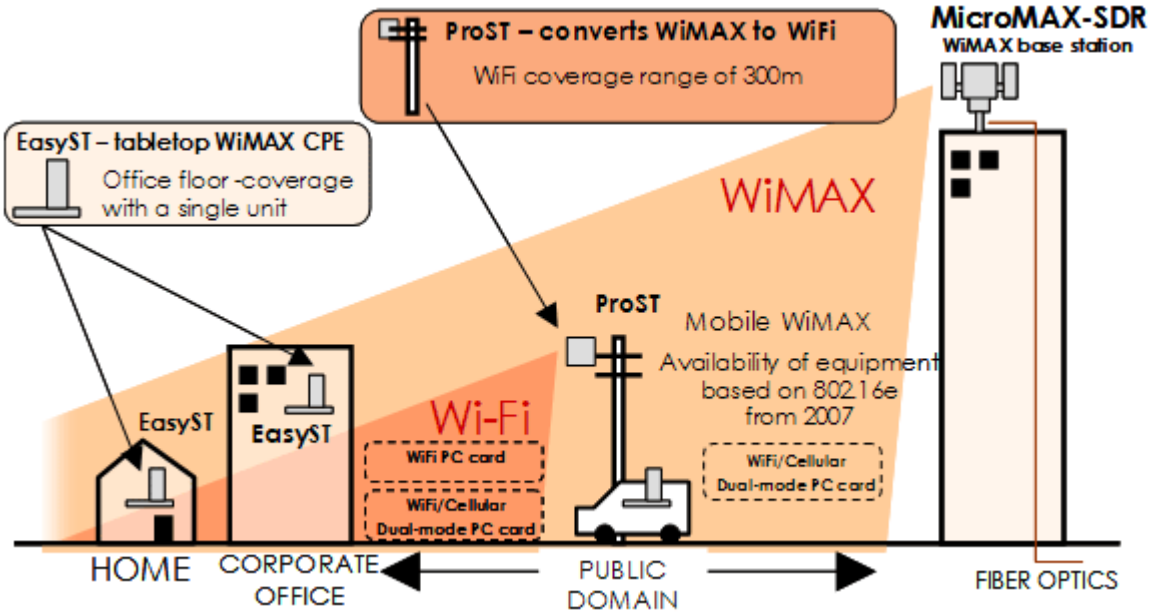

Figure 2: WiMAX Network3

Not only it supports "last mile" broadband connectivity to individual home or business locations but also its data rates are comparable with cable and Digital Subscriber Line (DSL) rates. Many telephone companies also desire that WiMAX will be a replacement for their aging legacy wired networks. WiMax was first developed for the wired broadband connection but with 802.16m new technology LTE which looks to be more suitable for mobile markets.[12] WiMAX has the ability to allow a subscriber to connect to a wireless Internet service provider even when they roam outside their offices or homes.

With the larger coverage range and high data transmission rate WiMAX's attributes open the door of the technology to a variety of applications. WiMAX can be used as a backbone for IEEE 802.11 hotspots for connecting to the global world, as well as a subscriber can connect WiMAX enabled mobile devices such as laptops PDA or cell phones directly to WiMAX base stations without using IEEE 802.11[11].Currently many service providers, providing a DSL or T1/E1 service for a business customer to a relatively remote location or outer suburbs can take several months and the cost associated with it is very high. With the help of WiMAX, a service provider can provide that service in a short time and in a very cost effective way [3].Efforts are reduced because cabling are not included. One of the main application of the WiMAX is that it can be used in disaster recovery scenes

where the wired networks have broken down. In recent times during disasters, WiMAX networks were installed to help in recovery missions such as Aceh, Indonesia, after the tsunami in December 2004. Similarly, WiMAX can also be used as a backup links where the traditional wired links breaks. WiMAX mainly operates in two frequency ranges. One is high frequency, which is between 11 – 66 GHz and another one is low frequency, which is sub 11 GHz [3]. Line-of-sight is very essential when operating in the high frequency range. This frequency range allows this wider channel, resulting in very high capacity links. For the low frequency range (sub 11 GHz) non line-of-sight is essential. WiMAX, with a theoretical data rate of 70 Mb/s in 20 MHz channels (2-11GHz spectrum) , allows a few hundreds of DSL connections but it operates up to 124Mbps in the 28MHz channel (in 10-66GHz), [5]. The maximum range WiMAX, covered is about 50 km [5]. But in practice this range may be decreased to 20 km and even 8 km when there are obstacles [5].

III. KEY CHARACTERISTICS OF WIRELESS TECHNOLOGY

This paper focuses on the comparison as to which wireless technology, WiMAX or Wi-Fi provides a better solution or an integrated technology is needed to create the desired infrastructure. The characteristics for which the most powerful next generation wireless technology (WiMAX and Wi-Fi) is evaluated in this research paper are: efficiency, maximum range, dependability, security, market issue and mobility.

3.1 Efficiency

Efficiency of wireless technology is measured in terms of bandwidth and latency. Efficiency is a major issue to determine what type of applications can be run on a network. A short bandwidth network is only feasibly for small application and normally support simple data application for example surfing on internet or file transfer. A higher bandwidth network is used for voice propagation and video navigation and many more powerful applications such as gamming devices. Another major issue in case of real-time applications like voice is latency which is very crucial issue. The maximum range of latency should not be more than 20 ms, anything higher than that can be warring for establishing echo free wireless network.

3.2 Maximum Range

Maximum range is calculated from the distance between the two base stations, and like cell phone. Another major issue that must be considers here is that the technology must have the capability to support hand-off between base stations without loosing connection from the global world. Maximum coverage range is a major issue, the reason behind that, it determines how long a contiguous wireless area can be? Also, maximum coverage range of wireless technology's is very much crucial according to cost, since operators can reduce their initial capital investments if they can give the coverage of the same area with smaller number of base stations.

3.3 Dependability

Dependability is defined as how much a wireless technology is dependable to the end user. Whether end user think that is it reliable to use or not? Dependability is measured with few important metrics like average number of packet loss, average number of disconnects of calls, and whether the wireless technology is hampered by environmental issues such as line of sight, weather, etc. Dependability is very crucial because some applications may require a reliable connection. If a connection is not dependable, in that case packets may loss and that affect the network for that reason the speed of the network will decrease. This would have certainly impact on the performance of any applications, hence decreasing the applications that will use on the wireless network.

3.4 Security

Today's internet is open for all. And user exchange many personal data on internet. So normally end user wants security. Security is obtained from the level of encryption of the data and the authentication of the device is provided by each technology. For many applications such as exchanging bank information require a secure connection to transmit confidential information. Mainly

the end user will not want to expose themselves and they also want that the secret information not being viewed by unauthorized individuals. That's why security is needed in wireless connection.

3.5 Mobility

Mobility is one of the major issues in case of building wireless access infrastructure. It is the speed of the mobile access point at which the technology can remain connected to the global world without losing packets or service interruption. Naturally, a wireless infrastructure environment needs to be mobile to provide connection to the end user at any place they visit. The network must sustain connection at vehicular speeds.

3.6 Market comparison

The last characteristic which to consider when evaluating wireless technology is market. Actually the popularity of any technology is determined by the market. Mainly markets certify a technology whether it is accepted by end user or not. So based upon the market we can decide which technology is most attractive to the wireless world. Devices in the market have demonstrated up to 11dB of variance across these performance parameters.

Operators should evaluate the device performance balanced with the device cost and, most importantly, the impact to the total cost of ownership of the WiMAX network.[12]

IV. WI-FI VERSUS WIMAX

4.1 Radio Technology:

WiMAX differs from Wi-Fi in the radio technology sector. The IEEE 802.11 WLAN standards describe four radio link interfaces that operate mainly in unlicensed radio band having range from 2.4 G to 5 GHz [9]. The WiMAX 802.16a standard released in January 2003 operates between 2 GHz, 11 GHz and 20GHz [9]. The lower frequency bands support Non-line-of-sight (NLOS) for that reason customer unit need not be aligned with base station. Wi-Fi mainly operates in unlicensed frequency bands, but WiMAX can operate in both licensed and unlicensed spectrum. Within IEEE 802.16a's 2-11 GHz range, four bands are most attractive [9]:

* Licensed 2.5-GHz MMDS
* Licensed 3.5-GHz Band
* Unlicensed 3.5-GHz Band
* Unlicensed 5 GHz U-NII Band

4.1.1 Radio transmission Modulation techniques:

The IEEE 802.11b radio link uses a technique direct sequence spread spectrum that is called complementary coded keying (CCK) for radio transmission [9]. Bit stream is mainly processed by a special coding and modulated with the technique called Quadrature Phase Shift Keying (QPSK). The 802.11a and 802.11g uses the radio link technology 64-channel orthogonal frequency division multiplexing (OFDM) [9]. Here the bit streams is encoded on the 64 sub carriers using Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK), or one of two levels of Quadrature Amplitude Modulation (16-, or 64- QAM) [9].

The IEEE 802.16a specifies three techniques for radio link [9]:

* SC-A: Single Carrier Channel.
* OFDM: 256-Sub-Carrier Orthogonal Frequency Division Multiplexing.
* OFDM-A: 2,048-Sub-Carrier Orthogonal Frequency Division Multiplexing.

4.2 Efficiency:

Maximum channel bandwidth for Wi-Fi is 25 MHz for IEEE 802.11b and 20 MHz for either IEEE 802.11a or g networks [9]. The maximum bit rates it provides is 54 Mbps. Wi-Fi has latency in the range of 50 ms hence little bit higher latency. In WiMAX, the channel bandwidths are in the range of 1.25 MHz to 20 MHz [9].

Lot of confusion is related to the Bit Rate, but many articles give a range of 70 Mbps or 100 Mbps, basically exact transmission rate depends on the assigned bandwidth of the channel. WiMAX have

latency in between the range of 25 to 40 ms, quite considerable range. Now have a close look at the Bandwidth efficiency of the both technologies. Basically it is measured by the number of bits per second that can be carried on one cycle of radio bandwidth (i.e. bps/Hertz). Lets have a data rates supported on its 25 MHz channel (1 M to 11 Mbps), 802.11b have bandwidth efficiency in between 0.04 to 0.44 bps/Hertz [9]. In 802.11 a or g on its 20 MHz have a transmission rate from 6 M to 54 Mbps yields a bandwidth efficiency in between .24 to 2.7 bps/Hertz [9]. In case of WiMAX, for 70-Mbps transmission rate on a 14-MHz radio channel yields bandwidth efficiency up to 5- bits/Hertz [9].

Performance is one of the key elements that sets WiMAX apart from other technologies and makes it unique. However, a successful WiMAX deployment that delivers the services promised in a cost-effective way requires much more than a spectrally efficient, high-throughput, low-latency radio interface. A WiMAX ecosystem is emerging to meet the demand from operators for efficient, cutting-edge network elements that together will create powerful endto-end Mobile WiMAX networks, that are appropriately dimensioned to the operator's requirements.[13]

4.3 Maximum Coverage Range:

OFDM modulation has a high spectral effectiveness that why WiMAX ranges 8 km (NLOS) to 50 km (LOS) [5]. It handles many users who are widely spread out. Mesh topologies in case of WiFi and smart antenna techniques in WiMax(802.16m) can be used to improve the coverage.

The OFDM designed for the BWA and main goal is to provide long range transmission. 802.16 is designed for high power OFDM which is used to maximize coverage up to tens of kilometers [5].

In contrast, IEEE 802.11 standard have a basic CDMA and OFDM approach with a quite different vision. It requires a very low power consumption of energy that is why it can support very limited range of coverage. It is mainly designed for indoor use. Optimize range of this technology is around 100 meters [5].

4.4 Security:

If we differentiate WiFi to WiMax on bases of security its quite clear which technology have a upper hand. It's a major issue because it protects transmissions from eavesdropping. But security has been one of the major lacking in Wi-Fi, encryption is optional here. But better encryption techniques are now available.Some of the different techniques used are [9]:

- Wired Equivalent Privacy (WEP): An RC4-based 40- or 104-bit encryption technique.
- Wi-Fi Protected Access (WPA): A new standard from the WiFi Alliance that uses the 40-bit or 104-bit WEP key.
- IEEE 802.11i/WPA2: It is a IEEE standard which will be based on a more robust encryption technique called the Advanced Encryption Standard.

WiMAX is designed for public network so security is very much crucial here. So all the data that is transmitted in WiMAX network is virtually encrypted. The main encryption technique that is used here is 168-bit Digital Encryption Standard (3DES), the same encryption also used on most secure tunnel VPNs. There are also plan to include the Advanced Encryption Standard (AES) in WiMAX to maximize the security.

4.5 Mobility

Mobility is supported by WiMAX. The latest IEEE 802.16e is made for Mobile WiMAX. This standard supports mobile capability with the support of hand-offs capability, mainly for users when they moved between cells. But according to the new standard 802.16m mobility technology LTE is developed by cellular industry. Its support data rates up to 500 kbps, equivalent to the highest speed cellular offerings (e.g. Verizon Wireless' xEV-DO service) [9]. Currently mobility management is not supported by Wi-Fi. But recently IEEE has begun to development of a roaming standard for Wi-Fi. However, WLAN switch vendors like Cisco, Aruba, and Airespace have developed their own proprietary hand-off protocols [9].

4.6 Market Comparison

Up to this point we have focused on technical issues but now we will consider, some market issues of these two products. Some market oriented works have been established for Wi-Fi service. The two examples are Wireless ISPs and Wi-Fi mesh networks.

4.6.1 Wireless ISPs (WISPs)

The idea behind Wireless ISP (WISP) is to provide an Internet access service using WLAN technology and a shared Internet connection in a public location designated as a hot spot. TMobile and Wayport are currently providing this type of service [9].But it has two problems, one is technical and another is business oriented. From a technical viewpoint, to access the internet you have to be within the hot spot. From a business viewpoint, users have to pay on monthly basis for the internet then the users have to be in the hot spot always to access the internet which is not a feasible solution. So markets of wireless ISP are in a threat now.

4.6.2 Wi-Fi Mesh Network

Wi-Fi mesh networks are mainly used to support public safety applications and also to provide Internet access to end users. However, mesh technologies are not within the range of the Wi-Fi standards.

4.6.3 WiMAX Market

The market goals of WiMAX are not clear at the moment. But in a sense we can say that the major goal will be broadband wireless access or Wireless DSL. But it will succeed only if it provides lower cost service and also provide some extra features which the other broadband like DSL do not provide. WiMAX compatible chipsets first appeared in late-2004 by the Intel and consumer devices costing $100 or less [9]. But in case of WiMAX, before investing in this field, they have to think and analyze that whether they have enough demand in the market or not.

Here's a look at WiMax Forum's data by region:

- Asia Pacific: 237 million people covered and 100 network deployments.
- Central/Latin America: 113 million people covered and 109 deployments.
- Africa/Middle East: 108 million people covered with 142 deployments.
- Europe: 115 million people with 153 deployments.
- North America: 47 million people with 51 deployments.

Clearly WiMax will soon emerge as a growing technology.

4.7 Quality of Service (QoS)

Wi-Fi is based on a contention based MAC (CSMA/CA). The Wi-Fi is connection less i.e. “talk without listen”. The Standard does not permit for different service level for each user. There is a plan to incorporate QoS in the 802.11-e standard. In this standard two operating modes will be included to improve service for voice one is Wi-Fi Multimedia Extensions (WME) and another one is Wi-Fi Scheduled Multimedia (WSM)QoS in IEEE 802.16 is based on a request/grant protocol. Its support multiple QoS which is build in MAC. It is designed to supports different service levels such as, T1/E1 for business and best effort to consumer. This protocol support delay sensitive services such as voice and video. The dynamic TDMA based technique allows the suitable support for multicast and broadcast.In the below the key difference between Wi-Fi and WiMAX is described.

Table:1 Comparison between IEEE 802.11 and IEEE 802.16

	WiFi	**WiMax**
Primary Application	Wireless LAN	Broadband wireless Access
Standards	IEEE 802.11a/g/n	IEEE 802.16e/m
Range	Upto 300 feet(about 91.4m)	Upto 30 miles(48.3kms)
Coverage	Optimized for indoor Performance, Short range	Outdoor Non-Line-Sight(NLOS) performance
Scalability	Channel bandwidth is wide(20Mhz) and fixed.	Flexible use of available spectrum

Bit Rate	2.7bits/s/Hz	5bit/s/Hz and up to 75Mbit/s in a 20MHz channel
QoS	No QoS support	Support for Qos at MAC
Security mechanism	Wired Equivalent Privacy(WEP) authentication, pre-shared key	Extensible Authentication Protocol(EAP), Advanced Encryption Standard(AES)
Mobility	In development	Mobile WiMax(802.16e)
Frequency band	Unlicensed Band 2.4 GHz To 5 GHz	Licensed and Unlicensed Band 2 GHz to 11 GHz
Channel Bandwidth	On the range from 20-25 MHz	Adjustable range from 1.25 to 20 MHz
Radio Technique	OFDM 64 channels and Direct Sequence Spread Spectrum	OFDM 256 Channels

V. RESULT AND DISCUSSION

The key characteristics used to compare the two technologies Wi-Fi and WiMAX were described in section 3: efficiency, maximum coverage range, dependability, measurement of security, mobility issue and market comparison. Using empirical data, we can evaluate which technology has the best capability to design wireless access infrastructure.

- Mainly efficiency is measured from bandwidth and latency. WiMAX (IEEE 802.16e) has the better performance with a maximum bandwidth of 100Mbps and a low latency of 25-40 ms. In WiMax2 (IEEE 802.16m) there is a higher order of antenna capability and optimized performance that increases the number of VoIP calls and the traffic you can support. As you can see, we are building on a foundation. WiMax 1 is a basic foundation. On top of that, you have WiMax 1 Enhanced. Then emerges the WiMax 2. All of it is based OFDMA technology and built on an all-IP network model.
- Maximum Coverage area is the distance between base stations. We see from the empirical data that WiMAX has better coverage range 50 km than Wi-Fi which supports only 100 meter.
- Estimates of dependability or reliability are best obtained by simulating a network. Both technologies are trying to minimize loss packets and decrease the number of disconnects. Without comparable simulations it is tough to say which technologies support the best dependable solution.
- Security mainly deals with the level of encryption and the device authentication supported by each technology. Each technology has some level of security. Since security feature is very much poor in Wi-Fi. But recently some security feature is added to provide the security more. But WiMAX have a better encryption technique, 3DES. So end user can happily exchange their data in WiMAX. Data is transferred through tunneling via private VPN because WiMax is connection oriented and reliable.
- Mobility is the speed at which the technology can connect and remain connected. Wi-Fi doesn't support mobility. But 802.16e support mobility. So again we get a better result here for WiMAX. From this summary it is apparent that WiMAX is a better technology to build wireless access infrastructure.

VI. CONCLUSION AND FUTURE WORK

This paper has studied two emerging wireless standard technologies; Wi-Fi (IEEE 802.11), WiMAX (IEEE 802.16e/m), in terms of how they could be applied to the creation of a wireless access infrastructure. Limited range and data capability of WiFi helps WiMAX to make a promise of taking high speed wireless out of home to the road and everywhere. The main advantage of the WiMAX technology is that it is flexible.

Well suited for fixed and nomadic users and also give another advantages by operating in licensed or unlicensed bands, on this paper, it is seen that WiMAX looks like a strong contender to build wireless access infrastructure. To conclude, it's obvious that the WiMAX standard aim not to replace Wi-Fi in its applications but rather to enhancement it in order to form a modern wireless access infrastructure.

WiMAX is short for the Worldwide Interoperability for Microwave Access known as IEEE 802.16. WiMAX has several advantages over WiFi. Besides reaching several miles instead of a hundred feet, WiMAX is designed to be more reliable than WiFi. In WiFi, the system uses contention access — all subscriber stations that want to pass data through an access point have to compete for the access point's attention on a random basis. This can cause distant nodes to be repeatedly interrupted by closer nodes. The further away you are, the less reliable your service. This problem makes services such as VoIP or IPTV difficult to work properly with WiFi because they depend on a constant and relatively stable access system.

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