WIRELESS FIDELITY (Wi-Fi) BROADBAND NETWORK TECHNOLOGY: AN OVERVIEW WITH OTHER BROADBAND WIRELESS NETWORKS

by

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ABSTRACT

Wireless Fidelity (Wi-Fi) broadband network technology has made tremendous impact in the growth of broadband wireless networks. There exists today several Wi-Fi access points that allow employees, partners and customers to access corporate data from almost anywhere and anytime. Wireless broadband networks are expected to grow in terms of broadband speed and coverage, while Wi-Fi can be integrated with WiMAX networks to provide Internet connectivity to mobile Wi-Fi users. This paper explores the Wi-Fi broadband wireless network technology, its uses, advantages and disadvantages, comparison with other broadband wireless networks and integration with WiMAX network.

Key Words: Broadband, Wireless Fidelity (Wi-Fi), World Wide Interoperability for Microwave Access (WiMAX), IEEE 802.11 standards.

1.0 INTRODUCTION

Wi-Fi stands for "Wireless Fidelity" and was used to describe Wireless LAN (WLAN) products that are based on the IEEE 802.11 standards. Wi-Fi uses both single carrier direct-sequence spread spectrum radio technology and multi-carrier OFDM (Orthogonal Frequency Division Multiplexing) radio technology. These regulations then enabled the development of Wi-Fi and its onetime competitor HomeRF, and Bluetooth. Wi-Fi's first wireless products were brought on the market under the name WaveLAN with speeds of 1 Mbit/s to 2 Mbit/s and standards designed as IEEE 802.11b, and 802.11a [12]. Wi-Fi is owned by the Wi-Fi Alliance which is a consortium of separate and independent companies agreeing to a set common interoperable products based on the family of IEEE 802.11 standards [11].

Wi-Fi certifies products via a set of established test procedures to establish interoperability. Those manufacturers that are members of Wi-Fi Alliance whose products pass these interoperability tests can mark their products with the Wi-Fi logo [10].

Wi-Fi technologies have gone through several generations since their inception in 1997. Wi-Fi is supported to different

extents under Microsoft Windows, Apple Macintosh and open source UNIX and Linux operating systems.

The intent of this paper is to examine Wi-Fi fixed broadband technology, explore its relationship with other networks (fixed and mobile), its advantages and disadvantages, and future prospects in broadband wireless network technology, especially its integration with WiMAX network.

2.0 BROADBAND WIRELESS NETWORKS

Broadband wireless networks can be categorized into two types: fixed and mobile wireless. The broadband fixed wireless network technologies of interest are Wireless Fidelity (Wi-Fi), which is an IEEE 802.11 standard and Worldwide Interoperability for Microwave Access (WiMAX), which is also an IEEE 802.16 standard. The two broadband mobile wireless network technologies here are the Third Generation (3G) and Fourth Generation (4G) networks. The 3G standards are defined by ITU-T, IMT2000 and the standards for the 4G are still evolving.

2.1 Fixed Broadband Wireless Network

Fixed broadband wireless technologies can be defined as high-speed wireless networks that connects to stationary locations and are intended to serve nomadic users [5]. Wireless Fidelity (Wi-Fi) and Worldwide Interoperability for Microwave Access (WiMAX) technologies which are discussed in this paper are governed by IEEE 802.11 and 802.16 specifications respectively. There specifications are as shown in Table 1.

Table 1: Fixed Broadband Wireless Technologies

Technology	Standard	Usage	Throughput	Range	Frequency
Wi-Fi	802.11a	WLAN	≤ 54 Mbps	≤ 100 m	5 GHz
Wi-Fi	802.11b	WLAN	≤ 11Mbps	≤ 100 m	2.4 GHz
Wi-Fi	802.11g	WLAN	≤ 54Mbps	≤ 100 m	2.4 GHz
WiMAX	802.16d	WMAN	≤ 75Mbps (20 MHz BW)	5-10 km	Sub11GHz
WiMAX	802.16e	WMAN	≤ 75Mbps (20 MHz BW)	5-10 km	2.4 GHz

* Wireless Fidelity Network Technology

Wi-Fi is the first high-speed fixed wireless technology to enjoy broad deployment, therefore there exist today many wireless products based on Wi-Fi technologies which include the approved IEEE 802.11a, b and g specifications, as well as the yet-to-be ratified 802.11n specification [8]. The different characteristics of the various Wi-Fi standards are given in Table 1. Wi-Fi as a high-speed wireless technology has enjoyedbroad deployment, most notably in hotspots around the world including homes and offices, and increasingly in cafes, hotels and airports [4].

Today, Wi-Fi hotspots are very popular and have been applauded for their ability to improve productivity for mobile corporate users. Wi-Fi is limited by its

coverage area and high-speed connectivity is only possible as long as a user remains within range of the wireless access point, which is optimally within 100m.

The Wi-Fi architecture consists of a base station to which wireless hosts are connected in order to access network resources. The base station is responsible for sending and receiving data to and from the wireless host that is associated with the base station. The connection between the host and the base station is the wireless communication link. This communication link is responsible for data transport between the base station and the hosts [6].

The main strength of Wi-Fi is its simplicity and ease of deployment given that it uses unlicenced radio spectrum. Wi-Fi allows users to be mobile for up to 100m from the base station and still have access to the network. Also, the cost for rolling out this wireless solution is low because no expensive wiring is required. Finally, there is also availability of many other Wi-Fi compatible products, which can interoperate with other network technologies [9].

As a fixed broadband access technology, Wi-Fi has its weaknesses. The user can only use the technology within the confines of 100m radius thus limiting the level of mobility. Also, the fact that the technology operates in the 2.4 GHz band which does not require any licensing renders it susceptible to interference from other devices such as Bluetooth, cordless phones, etc. In terms of security, the encryption standard used such as Wired Equivalent Privacy (WEP) has been shown to be easily breakable [5].

* Worldwide Interoperability for Microwave Access (WiMAX) Network Technology

Worldwide Interoperability for Microwave Access (WiMAX) is a fixed broadband wireless technology that is gaining acceptance and delivers last kilometer broadband connectivity in a larger geographic area than Wi-Fi. It provides canopies of anywhere from one to ten kilometers wide. Such WiMAX coverage range provides fixed and nomadic wireless broadband connectivity without necessarily having a line-of-sight (LOS) with a base station [2]. WiMAX will also enable greater mobility, higher speed data applications, range and throughput [5].

WiMAX uses the IEEE 802.16 standards specifications (802.16d and g). The IEEE 802.16d specification is primarily tailored to wireless wide area networks (WWANs). The IEEE 802.16e specification on the other hand is primarily used for mobile wireless metropolitan networks (WMANs). These two specifications render WiMAX architecturally ideal for the last kilometer, the backhaul, Internet Service Providers, cellular base stations that bypass PSTN's, hotspots, and enterprise networks [4].

Abilities such as high bandwidth frequencies between 2 GHz and 11 GHz, makes WiMAX ideal for data transport. WiMAX has a total range of up to 50 km [1]. This ability is enhanced by WiMAX's cell radius of 5 -10 km. Also, WiMAX has the ability to support various data transmitting rates of up to 75 Mbps as shown in tables 1 and 2. There are several advantages that can be derived from the

deployment of WiMAX. Firstly, it supports higher throughput rates, higher data speed rates and wider operating range. These make the technology very useful for deployment in bad terrain areas or in environments with limited wired infrastructure. Secondly, WiMAX supports and interfaces easily to other wired and wireless technologies such as Ethernet, ATM, VLANs, and Wi-Fi. Thirdly, WiMAX provides network connectivity that explores multipath signals without the stringent requirement of a direct line of sight. Finally, WiMAX provides a better Quality of Service (QoS) by taking advantage of smart antenna technology that utilizes the spectrum more efficiently.

The main drawback to the deployment of WiMAX is proprietary equipment [4]. WiMAX equipment must be able to utilize power efficiently in order to deliver optimum functionality. For WiMAX, output power usage is based on a ranging process that determines the correct timing offset and power settings.

The transmissions for each subscriber station are supposed to be such that they arrive at the base station at the proper time and at the same power level. When WiMAX is deployed outdoors, in non-line of sight environments it may encounter delay, which can cause potential intersymbol interference. Though the use of Orthogonal Frequency Division Multiplexing (OFDM) is meant to try and alleviate this problem, OFDM usage has the problem of generating phase noise, which increases the RF subsystem cost and complexity [5].

2.2 Mobile Broadband Wireless Network

Mobile Wireless evolution started with the first generation (1G) networks, which was implemented based on Frequency Division Multiple Access (FDMA) and these networks were basically for voice communication. The 2G (second generation) network that replaced the 1G are still mainly for voice applications. These 2G systems provided circuit-switched data communication services at low speed. The competitive rush to design and implement digital systems led to a variety of different and incompatible standards [5].

The 2.5G is an enhancement of the 2G technologies to provide increased data capacity on the 2G networks. This led to the introduction of technologies such as General Packet Radio Service (GPRS) and Enhanced Data Rates for Global Evolution (EDGE). The Third Generation G3 mobile networking systems has replaced the 2G and 2.5G networks. The 3G systems have higher quality voice channels, as well as broadband data capabilities, up to 2 Mbps. Unfortunately, the 3G has no single standard due to the clamour to replace the 2G networks by various equipment manufacturers. The 4G is expected to replace the 3G. Features of the two broadband mobile technologies (3G and 4G) are compared with fixed broadband technologies in table 2.

3.0 WIRELESS FIDELITYF (Wi-Fi) NETWORK IMPLEMENTATION

A Wi-Fi enabled device such as a PC, game console, cell phone, MP4 player or PDA

can connect to the Internet when within range of the wireless network connected to the Internet. The area covered by one or more interconnected access points is called a hotspot. Hotspots can cover as little as a single room with wireless-opaque walls or as much as many square kilometers covered by overlapping access points. Wi-Fi has been used to create mesh networks, and are used in community networks.

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. Business and industrial application of Wi-Fi is widespread as of 2007. In business environments, increasing the number of Wi-Fi access points provide redundancy, support for fast roaming and increased overall network capacity by using more channels or creating smaller cells. Wi-Fi enables wireless voice applications (VoWLAN or WVOIP). Over the years, Wi-Fi implementations have moved toward 'thin' access points, with more of the network intelligence housed in a centralized network appliance, relegating individual Access Points to be simply 'dumb' radios. Presently, Wi-Fi installations can provide a secure computer networking gateway, firewall, intrusion detection system and other functions. Wi-Fi is publicly available at Wi-Fi hotspots provided either free of charge or to subscribers through various providers. Free hotspots are often provided by businesses such as hotels, restaurants, and airports who offer the services to attract or assist clients. Metropolitan-wide Wi-Fi (Mu-Fi) is currently enjoying great success in enhancing Wi-Fi.

3.1 Advantages of Wi-Fi Technology

i. Wi-Fi allows LANS to be deployed without cabling for client's devices, typically reducing the costs of network deployment and expansion. Spaces where cables cannot be run, such as outdoor areas and historical buildings, can host wireless LANS.

ii. Wi-Fi is widely available in more than 250,000 public hotspots and tens of millions of homes, corporate and university campuses worldwide . Wi-Fi Protected Access (WPA and WPA2) is not easily cracked if strong passwords are used and WPA2 encryption has no known weakness. New protocols for Quality of Service make Wi-Fi more suitable for latency-sensitive applications.

iii. As of 2007, wireless network adapters are built into most modern laptops. The prices of chipsets for Wi-Fi continues to drop, making it an economical networking option included in ever more devices. Wi-Fi has become widespread in corporate infrastructures, which also helps with the deployment of Real Time Location Systems (RFID) technology that can ride on Wi-Fi [7].

iv. Different competitive brands of access points and client network interfaces are Inter-operable at a basic level of service. Products designated as 'Wi-Fi Certified' are backwards inter-operable. Wi-Fi is a global set of standards. Unlike mobile telephones, any standard Wi-Fi device will work

anywhere in the world.

3.2 Disadvantages of Wi-Fi Technology

i. Wi-Fi networks have limited range. A typical Wi-Fi home router using 802.11b or 802.11g with a stock antenna might have a range of 32m (120ft) indoors. Range also varies with frequency band. Wi-Fi in the 2.4 GHz frequency block has slightly better range than Wi-Fi in the 5 GHz frequency block. Outdoor range with improved (directional) antennas can be several meters or more with line-of-sight.

ii. Wi-Fi performance also decreases exponentially as the range increases. Wi-Fi is also less reliable and fast as Ethernet or other cable systems. 802.11g networks have a maximum of 54 Mbit/s while cables can reach speeds of 1000 Mbit/s or more. Wi-Fi is not suitable for servers or users who need fast LAN access. In practice, measured rates across the Wi-Fi network will be much less than the headline rate, so 5 Mbit/s is typical as a real, measured transfer rate. 802.11n improves this, but again does not achieve the headline rate for real use. For Internet access, those with faster broadband rates- such as 20 Mbit/s will notice an increase in performance using a wired connection rather than Wi-Fi. This is because of protocol overheads.

iii. Wi-Fi pollution, or an excessive number of access points in the area, especially on the same or neighbouring channel can prevent access and interfere with the use of other access points by others, caused by overlapping channels in the 802.11g/b spectrum, as well as with decreased signal-to-noise ratio (SNR) between access points. This can be a problem in high-density areas, such as large apartment complexes or office buildings with many Wi-Fi access points. Additionally, other devices use the 2.4 GHz band; microwave ovens, security cameras, Bluetooth devices, Amateur radio, video senders, and cordless phones, can cause significant additional interference. General guidance to those who suffer these forms of interference or network crowding is to migrate to a Wi-Fi 5GHz product, (802.11a or the newer 802.11n) as the 5 GHz band is relatively unused and there are many more channels available. This also requires users to set up the 5 GHz band to be the preferred network in the client to configure each network band to different name.

iv. Each node on the network is typically able to see all the communication between other nodes and the access point, allowing network traffic to be easily captured with a packet snuffers. Hence, when a Wi-Fi network is not encrypted, as most public hotspots are, the network is vulnerable to sidejack attacks.

v. It is also an issue when municipalities, or other large entities such as universities, seek to provide large area coverage. Everyone is considered equal for the base standard without

802.11e/WMM when they use the band. This openness is important to the success and widespread use of 2.4 GHz Wi-Fi, but makes it unsuitable for most public service functions or where reliability is required [12].

4.0 COMPARISON OF Wi-Fi NETWORK WITH OTHER BROADBAND NETWORKS

Table 2: Comparison of Broadband Wireless Technologies

Technology	**Wi-Fi**	**WiMAX**	**3G**	**4G**
Design	1997	2002	1990	2000
Implemented	2002	2006	2002	2010
Standard	802.11 (a,b,g)	802.16 (d,e)	WCDMA, CDMA2000,etc	One standard expected
Throughput	≤ 54 Mbps	≤ 75 Mbps	≥ 2 Mbps	≤ 200 Mbps
Multiplexing	DSSS/OFDM	OFDM	WCDMA, CDMA2000	OFDM & OFCDM
Frequency	2.4 & 5 GHz	2 & 11 GHz	900, 1800, 1900 & 2100 MHz	2-8 GHz
Usage	WLAN	WMAN	WWAN	WWAN
Coverage	≤ 100m	≤ 50km	Up to 10km	≥ 50km
Services	Fixed Wireless broadband	Fixed wireless multimedia	Mobile wireless broadband	Mobile wireless multimedia
Air Interface	OFDMA	OFDMA/FDD	CDMA2000/ WCDMA	OFDMA/ OFCDMA

Table 2 shows a comparison of Wi-Fi technology with other wireless broadband technologies discussed in this paper. Each of the broadband wireless technologies has many standards, except for the 4G where one single standard is expected. Wi-Fi is best deployed for Wireless Local Area Network (WLAN) with limited coverage, while the 3G and 4G are well suited for Wireless Wide Area Network and the WiMAX is suited for Wireless Metropolitan Area Network. Wi-Fi has a coverage area of just 100m, WiMAX a coverage of 50 kilometers which is also the expected coverage of 4G, while the 3G coverage is up to 10 km. The Air Interface of the various technologies differs from OFDMA for Wi-Fi, to OFDMA/FDD for WiMAX, CDMA2000 or W-CDMA for 3G, and OFDMA/OFCDMA for 4G. The throughput of Wi-Fi is 54 Mbps, 75 Mbps for WiMAX, 2 Mbps for 3G and up to 200 Mbps for 4G.

While mobile wireless technologies cater for mobile users that need access to the network with large geographical area, fixed wireless technologies meet the need for broadband services at the last kilometer where traditional wired infrastructure does not exist due to the terrain or not cost effective. In terms of cost and easy deployment, Wi-Fi is cost effective and has considerable high data transfer rate.

5. CONCLUSION

Broadband wireless access networks based on WiMAX can currently provide backhaul support for mobile Wi-Fi hotspots. The integrated WiMAX/WiFi network for such an application where licensed WiMAX spectrum is shared by WiFi access point/routers to provide Internet connectivity to mobile WiFi users brings to fore the expected mobility network. Here, WiMAX backbone network and WiFi hotspots are operated by different service providers where issues of protocol adaptation, quality of service support, and pricing for bandwidth sharing has to be resolved. This will open the way for seamless communication, ubiquitous computing and use of the main strength of Wi-Fi, which is its simplicity and ease of deployment.

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