The Trends in Broadband Wireless Networks Technologies

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ABSTRACT

Since the beginning of this millennium, there has been an unprecedented growth in broadband wireless networks. This can be attributed to high demand for wireless multimedia services such as data, voice, video, and the development of new wireless standards. The growth of wireless broadband networks is expected to gradually outpace landline communications because advancements in these technologies have continued to enable higher broadband speeds. This paper explores broadband fixed wireless and broadband mobile technologies. The characteristics of these technologies are examined. This paper also explores the relative strengths and weaknesses of each of the technologies as well as their relationship to each other.

(Keywords: telecommunications, wireless standards, network technologies, mobile networks, wireless)

INTRODUCTION

Mobile and wireless telephony and high speed data communications have tremendously enhanced the way business is conducted since the new millennium. The technology allows employees, partners, and customers to access corporate data from almost anywhere and anytime.

The need for universal data access, combined with increased worker productivity and effectiveness is driving the demand for enterprise mobile applications. The growth of wireless broadband networks is expected to gradually outpace landline communications as advancements in these technologies are enabling higher broadband speeds.

The growth in broadband wireless networks can be attributed to high demand for wireless multimedia services such as voice, data, video and the development of new wireless standards [1, 2, 5]. There are lots of other driving factors, which have been addressed elsewhere [6, 11, 17] that have led to the rapid and continuous change of the wireless networks worldwide. Mobility is a major driver for mobile broadband networks because mobile professionals continue to demand access to their corporate networks remotely anywhere and anytime.

The ever growing need for mobile Internet access, interactive services, training, and entertainment; the need for a single standard for seamless roaming; interoperability across networks; and upward integration of earlier wireless network technologies are also driving factors for new developments in wireless networks.

The market potential is also a major factor pushing operators' investment in broadband wireless. In a recent study [16], the value of the mobile entertainment market is forecasted to increase from $17.3B in 2006 to nearly $77B by 2011.

Other driving factors are improvements in RF performance that are attributable to improved antennas, reduction in sources of interference, and the ability to support multiple frequency bands. Moreover, the need to improve the security in wireless networks is also a factor impacting the new development in wireless networks. Advances in digital signal processing (DSP), Vocoder, packet technology, network

convergence, and adaptive intelligent antenna have been discussed elsewhere [7, 11, 17] as the main technologies fueling the developments in the broadband wireless technologies.

Generally, broadband wireless networks can be categorized into two types: fixed and mobile wireless as shown in Figure 1. The broadband fixed wireless network technologies of interest here 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 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 currently being defined.

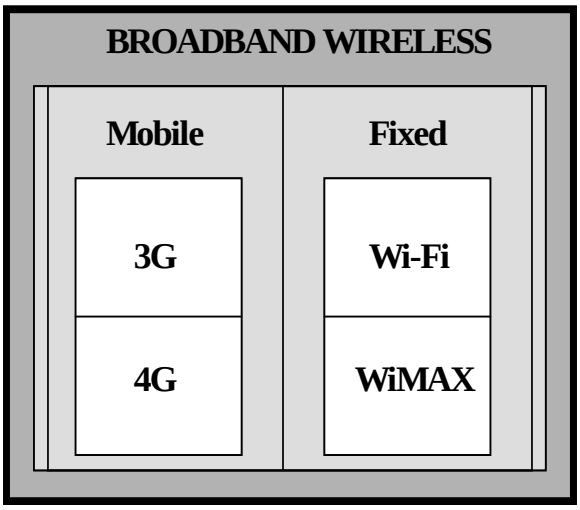

Figure 1: The Broadband Wireless at a Glance.

Both mobile technologies have been discussed in more detail elsewhere [6, 7, 11]. It must be noted that these technologies are converging and hence there are now mobile handsets that support Wi-Fi technology.

In a recent report [18], In-Stat stated that although Wi-Fi, WiMax, and 3G Cellular are very different from one another, but they complement each other in many ways, while also competing with each other in some areas as well. It was for these reasons that it was speculated that in the future there will be no mobile or fixed networks, but only "mobility networks" [14].

The intent of this paper is to examined the attributes of the two different types of wireless technologies and explore the relationship between them. In section one, the fixed broadband wireless network technologies are discussed. In section two, the broadband mobile wireless technologies are considered. Next, the features of the two different types of the wireless broadband networks are compared and a conclusion drawn.

FIXED BROADBAND WIRELESS NETWORKS

Fixed broadband wireless technologies can be defined as high-speed wireless networks that connect to stationary locations and are intended to serve nomadic users [4]. Wireless Fidelity (Wi-Fi) and Worldwide Interoperability for Microwave Access (WiMax) technologies are the fixed wireless technologies that are examined in this paper. These two technologies are respectively governed by IEEE 802.11 and 802.16 specifications as shown in Table1.

Wi-Fi

Wi-Fi is the first high-speed fixed wireless technology to penetrate the fixed wireless broadband market. The first WLAN (802.11) which was introduced in 1997 was capable of supporting 2 Mbps [21] and 802.11b was approved by IEEE in 1999. There are currently many wireless products based on Wi-Fi technologies which include the approved IEEE 802.11a, b and g specifications, and a yet to be defined 802.11n specification.

The impact 802.11n might have when it finally goes to the market may difficult to quantify at this time, but it is expected to deliver up to 600 Mbps. In a report in 2006, In-Stat stated that during 2008, more than 50% of the chipset shipped out will be based on 802.11n. The different characteristics of the various Wi-Fi standards are given in Table1.

Wi-Fi as a high-speed wireless technology has enjoyed broad deployment, most notably in hotspots around the world including homes and offices, and increasingly in cafes, hotels, and airports [3].

Table 1: Fixed Broadband Wireless Technologies.

Technology	Standard	Usage	Throughput	Range	Frequency
Wi-Fi	802.11a	WLAN	<= 54Mbps	<= 300feet	5Ghz
Wi-Fi	802.11b	WLAN	<= 11Mbps	<= 300feet	2.4Ghz
Wi-Fi	802.11g	WLAN	<= 54Mbps	<= 300feet	2.4Ghz
WiMax	802.16d	WMAN	<= 75Mbps (20Mhz BW)	4-6 miles	Sub 11Ghz
WiMax	802.16e	WMAN	<= 75Mbps (20Mhz BW)	4-6 miles	2.4Ghz

Source: ***www.intel.com***

Wi-Fi hotspots have become commonplace and have been applauded by road warriors for their ability to improve productivity. Wi-Fi coverage area is limited to a maximum of 300 feet radius and high-speed connectivity is only possible as long as a user remains within the coverage range of the wireless access point.

The Wi-Fi architecture is shown in Figure 2. It 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 the data transport between the base station and the hosts [5].

The main strength of Wi-Fi is its simplicity and ease of deployment. Furthermore, because it uses unlicensed radio spectrum, Wi-Fi allows users to be mobile for up to 300 feet from the base station and still have access to the network. Moreover, the cost for rolling out this wireless solution is low because no expensive wiring is required. Finally, there is also availability of many 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 a 300 feet radius thus limiting the level of mobility. Also, the fact that the technology operates in the 2.4GHz 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 [4].

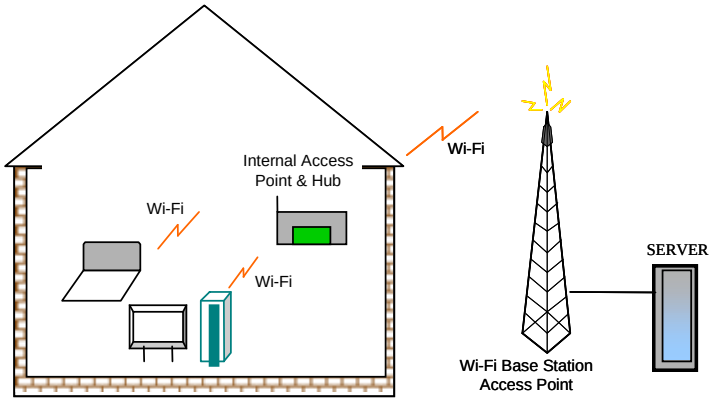

Figure 2: Wi-Fi Architecture.

WiMax

Worldwide Interoperability for Microwave Access (WiMax) is an emerging fixed broadband wireless technology that will deliver last mile broadband connectivity in a larger geographic area than Wi-Fi. It is expected to provide coverage anywhere from one to six miles wide. Such WiMax coverage range is expected to provide fixed and nomadic wireless broadband connectivity without necessarily having a line-of-site (LOS) with a base station [12]. WiMax will also enable greater mobility, higher speed data applications, range and throughput [4] than its counterpart, Wi-Fi.

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 recently approved IEEE 802.16e specification, the mobile version of WiMax, on the other hand is primarily used for mobile wireless metropolitan networks (WMANs). These two specifications

render WiMax architecturally ideal for the last mile, the backhaul, Internet Service Providers, cellular base stations that bypass PSTN's, hotspots, and enterprise networks [3].

Abilities such as a high bandwidth frequencies between 2 GHz and 11GHz, makes WiMax ideal for data transport. WiMax has a total range of up to 30 miles [13]. This ability is enhanced by WiMax's cell radius of 4-6 miles. More so, WiMax has the ability to support various data transmitting rates of up to 75Mbps as shown in Tables 1 and 2. WiMax is gaining tremendous popularity each day. In the recent 3GSM Congress [19], dozens in the field touted WiMax, the way forward. In fact, on August 8, 2006 Sprint [20], the number three ranked mobile operator in the US announced that it has selected WiMax technology for its 4G initiatives.

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. Moreover, WiMax supports and interfaces easily to other wired and wireless technologies such as Ethernet, ATM, VLANs, and Wi-Fi. Furthermore, 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 [3]. WiMax equipment must be able to utilize power efficiently in order to deliver optimum functionality. For WiMax, the output power usage is based on a ranging process that determines the correct timing offset and power settings. Therefore, 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 scalable orthogonal frequency division multiplexing (SOFDM) 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 [8,9].

THE BROADBAND MOBILE WIRELESS NETWORKS

The evolution of mobile service 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 1G network was replaced by second-generation (2G) networks, which are mainly used for voice applications.

These 2G systems provided circuit-switched data communication services at a low speed. The competitive rush to design and implement digital systems led to a variety of different and incompatible standards [8]. 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).

While some 2G and 2.5G systems are still available, third generation (3G) mobile networking systems are replacing them gradually. 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.

The 4G is expected to replace the 3G. The two broadband mobile technologies are further discussed below. Table 2 gives a comparative view of the fixed and mobile broadband network.

THIRD-GENERATION NETWORKS

Third-generation (3G) networks started with the vision to develop a single global standard for high-speed data and high-quality voice services. The goal was to have all users worldwide to use a single standard that would allow for true global roaming. It was not possible because it was realized that backward compatibility with 2G networks and frequency differences among countries were too much of a barrier to overcome, so agreement on a single 3G implementation could not be reached.

Table 2: Comparison of Broadband Wireless Technologies.

Technology	Wi-Fi	WiMax	3G/3.xG	4G
Designed	1997	2002	1990/2001	2000
Implemented	2002	2006	2002/2005	2010
Standard	802.11 (a,b,g)	802.16 (a,d)	WCDMA, CDMA2000 / EVDO, etc.	One Standard Expected
Throughput	<= 54Mbps	<= 75Mbps	>= 2Mbps	<= 200 Mbps
Multiplexing	DSSS/ OFDM	OFDM/ SOFDM	WCDMA, CDMA2000	OFDM & OFCDM
Frequency	2.4 & 5 GHz	2 & 11 GHz	900,1800,1900, and 2100MHz	2 – 8 GHz
Usage	WLAN	WMAN	WWAN	WWAN
Coverage	<= 300ft	<= 30miles	Up to 6miles	>= 30miles
Services	Fixed wireless broadband	Fixed wireless multimedia	Mobile wireless broadband	Mobile wireless multimedia
Air Interface	OFDMA	OFDMA/ FDD	CDMA2000/EVDO, WCDMA	OFDMA/ OFCDMA

Thus, all 3G technologies do not posses the same performance capabilities. Generally 3G technologies can be split into the following: Code Division Multiple Access (CDMA2000), IxEV-DO/DV, and WCDMA and its enhancements commonly referred to as High Speed Downlink Packet Access (HSDPA) and High Speed Uplink Packet Access (HSUPA). HSDPA and HSUPA promise rates above 5 Mbps. A detailed discussion is given elsewhere [6, 11].

FOURTH GENERATION NETWORKS

The 4G is a new generation of wireless intended to complement and replace the 3G systems, in the near future. Accessing information anywhere, anytime, with a seamless connection to a wide range of information and services, and receiving a large volume of information, data, pictures, video, and so on, are the key features of the 4G infrastructures.

The future 4G infrastructures will consist of a set of various networks using IP (Internet protocol) as a common protocol so that users are in control because they will be able to choose every application and environment. Based on the developing trends of mobile communications, the 4G will have broader bandwidth, higher data rate, and smoother and quicker handoff and will focus on ensuring seamless service across a multitude of wireless systems and networks. The key concept is integrating the 4G capabilities with all of the existing mobile technologies through advanced technologies [10].

Application adaptability and high dynamism are some of the main features of 4G services of interest to users. These features mean services can be delivered and available to the personal preference of different users and support the users' traffic, air interfaces, radio environment, and quality of service. Connection with the network applications can be accomplished in various forms and at various levels correctly and efficiently. The dominant methods of access to this pool of information will be the mobile telephone, PDA, and laptop to seamlessly access the voice communication, high-speed information services, and entertainment broadcast services.

The fourth generation will encompass all systems from various networks: public to private; operator-driven broadband networks to personal areas; and ad hoc networks. The 4G systems will interoperate with 2G and 3G systems, as well as with fixed wireless broadband systems. The expected relationship of 4G to other network technologies is depicted in Figure 3. In addition, 4G systems will be fully IP-based wireless Internet. With 4G, a range of new services and models will be available [6, 11].

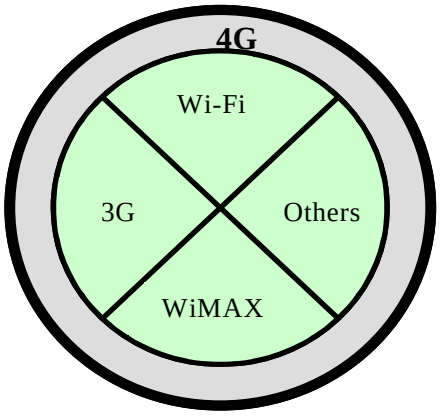

Figure 3: 4G Relationship with all other Network Types.

The demand for higher data rates and the non-compatibility of the 3G standards has shifted industry focus to fourth generation (4G) wireless networks and when the technology finally goes to market, it will support rates above 100 Mbps, it will integrate all wireless network, and it is expected to be application independent [6]. The high bandwidth that 4G supports provides an ideal mode for data transport. It is expected that users who demand high quality video and audio will benefit because of the Orthogonal Frequency Division Multiplexing (OFDM) and Orthogonal Frequency Division Multiple Access (OFDMA) which are planned for 4G networks.

Both these technologies allocate network resources effectively to multiple users. Moreover, 4G is expected to have better security and low latency data transmission. The emerging 4G would be an entirely packet-switched network. It is expected to support all IP end-end [6, 7]. All the network elements must be digital and would be a network that is water-proof-security. The 4G would support global mobility and service portability [6].

COMPARISON OF MOBILE AND FIXED WIRELESS BROADBAND

In Table 2 the various wireless broadband technologies discussed in this paper are compared. The Table shows, that the throughput for 4G and the WiMax could be up to 200Mbps and 75Mbps respectively. Thus, they are suitable for backhauling and backbone configurations.

Each of the broadband wireless technologies has many standards, except for the 4G where one single standard is expected. In terms of multiplexing and access methods, scalable OFDM and OFDMA are the main technologies in use for 4G and WiMax, though the method for each of the other technologies varies in terms of design and implementation. The 3G and 4G are well suited for Wireless Wide Area Network; whereas, the WiMax is well suited for Wireless Metropolitan Area Network (WMAN). On the other hand, the Wi-Fi is best deployed for Wireless Local Area Network (WLAN) with limited coverage.

The 4G Network is expected to have coverage of up to 30 miles and similarly, the WiMax is also expected to have a total coverage of up to 30 miles between point to point backhaul and much lower for other operating methods. Furthermore, the coverage a WiMax base station can achieve is substantially lower than 3.xG (3G enhancements) and hence 3.xG operators will be able to deploy a smaller number of base stations to cover the same geographic area. The 3G coverage is in range of up to 6 miles and the Wi-Fi has a coverage area of just 300 feet.

The Air Interface of the various technologies differs from OFDMA for Wi-Fi to OFDMA/FDD for WiMax. Furthermore, the 3G uses CDMA2000 or W-CDMA and 4G uses the OFDMA/OFCDMA. In a recent report by Arthur D. Little, a management consultant firm, finds that the HSPA, the 3.5G would account for the majority of investment in global mobile broadband networks over the next five years, while WiMax will account for at most 15% [15].

Despite this observation, the tide seems to be turning in favour of WiMax because in the recent 3GSM World Congress [19], many executives of prominent telecom operators pushed for WiMax as the way-forward and Sprint [20], the number three ranked operator in the US has adopted WiMax for its 4G initiative. Figure 4 gives a relative comparison between the fixed and mobile wireless broadband technologies with respect to speed of data transfer and mobility.

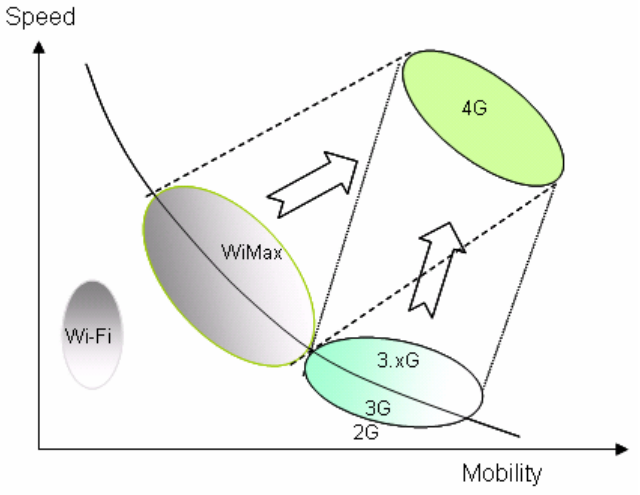

Figure 4: Relationship between Fixed and Mobile Wireless.

The mobile wireless network technologies cater for mobile users that need access to the network with a large geographical area while the fixed wireless network technologies will helps to meet

the need for broadband services at the last mile where traditional wired infrastructure does not exist due to the terrain, or is not cost effective. On the surface, the fixed wireless broadband technologies would appear to be competing within the broadband mobile technologies, but when 4G is fully defined, it would integrate other technologies. In other words, the broadband fixed wireless would compliment the broadband mobile technologies.

CONCLUSION

This paper examined the fixed and mobile broadband wireless networks and provides a comparative view of both technologies. There has been an unprecedented rapid growth in the demand for mobility globally, seamless communication, data services, and ubiquitous computing. Fixed broadband wireless networks are helping users meet the growing need for broadband wireless access at hotspots and beyond, while broadband mobile technologies are expected to enable broadband wireless network access for highly mobile users.

Advances in DSP and antenna technologies along with earning potentials are fuelling the tremendous growth in broadband wireless. Enhancements in High Speed Packet Access (HSPA) are expected to be a major investment area in this decade while the fixed broadband wireless would be more of a niche service for operators during the same period. The fixed and mobile broadband wirelesses in many ways complement each other and also in some ways compete with each other.

There are now many mobile handsets with embedded Wi-Fi technology. 3G which was first deployed in 2002 by Do Como is becoming a commonplace, but its very existence has been challenged by WiMax. In the 3GSM Congress held in February 2007, most of the doyens in the field were evangelizing WiMax as the way forward. Sprint, the third ranked operator in the US chose WiMax in August 2006 for 4G technologies. In 2006, In-Stats reported that the WiMax subscribers will exceed 14 million by the end of 2011. However, it is the contention of the authors that although WiMax is gaining momentum, it would take more than a decade to catch up with 3G, during which time the technologies should have matured and also tending towards obsolescence.

Ultimately, 4G is the way forward and would integrate fixed, mobile, and other broadband technologies in order to provide robust, scalable, seamless communication, high speed data transfer,r and unfettered mobility to users of all kinds. Overall, broadband wireless is revolutionizing communication by enabling integration of various networks multimedia applications to allow sharing of resources among multiple users. As access speed continues to improve the trend would be a continuous shift from fixed services to mobile wireless broadband services.

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