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The difference between IEEE 802.16 / WiMAX and IEEE 802.11 / Wi-Fi networks for Telemedicine Applications

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Abstract*-- The term telemedicine refers to the use of telecommunications technology to enable or assist medical care when its participants are separated by distance. This connection could be achieved using any number of telecommunications technologies; the integration of wireless technologies into healthcare devices, infrastructure and systems offers the best hope for substantially improving the efficiency of healthcare delivery personnel and systems. Wireless telemedicine, also referred to as mobile health, which capitalizes on advances of wireless technologies to deliver health care and exchange medical knowledge anywhere and anytime, overcomes most of geographical, temporal, and even organizational barriers to facilitate remote diagnosis and monitoring, and transfer of medical data and records. In this paper we investigate the application of integrated IEEE 802.16/WiMAX and IEEE 802.11/Wi-Fi broadband wireless access technologies along with the related protocol issues for telemedicine services. The hybrid networks of Wi-Fi and WiMAX networks can provide high data rate and enhanced multimedia services. WiMAX (Worldwide Interoperability for Microwave Access) is a 4th generation cellular telecommunication technology currently based on IEEE 802.16e standard and it is a new telecommunications protocol that provides fixed and fully mobile Internet access. Both of them are evolved from IEEE 802.16 and IEEE 802.16a, the earlier versions of WMAN standards. The 802.16 standards only specify the physical (PHY) layer and the media access control (MAC) layer of the air interface while the upper layers are not considered. We propose and review IEEE 802.11/Wi-Fi and IEEE 802.16/WiMAX technologies, and make a comparison between IEEE 802.11/Wi-Fi and IEEE 802.16/WiMAX. Then some open research issues in the integrated IEEE 802.16/WiMAX and IEEE 802.11/Wi-Fi networks are discussed, radio resource management, Quality of Service (QoS) management, scheduling and connection admission control schemes, as well as handover and mobility management are reviewed and discussed in this paper. Finally, applications and deployment scenarios of integrated IEEE 802.16/WiMAX and IEEE 802.11/Wi-Fi for telemedicine services are further deliberated.

***Index Terms*—Telemedicine, WiMAX, Wi-Fi, QoS, OFDMA, Wireless Access Point.**

I. INTRODUCTION AND LITERATURE REVIEW

By deploying telecommunications technologies to deliver health care and share medical knowledge over a distance, telemedicine aims at providing expert-based medical care to any place and at any time health care is needed. When the first telemedicine services were provided, telemedicine applications were implemented over wired communications technologies such as Plain Old Telephone Network (POTN) and Integrated Services Digital Network (ISDN).

However, recent developments in telemedicine resulting from wireless advances are promoting wireless telemedicine, also referred to as m-health or mobile health. Normally, wireless telemedicine systems consist of wearable/implantable medical devices and wireless communications networks. Wireless communications overcomes most geographical, temporal, and organizational barriers to the transfer of medical data and records. In order to provide ubiquitous availability of multimedia services and applications, wireless and mobile technologies are evolving towards integration of heterogeneous access networks such as wireless personal area networks (WPANs), wireless local area networks (WLANs), wireless metropolitan area networks (WMANs) as well as third-generation (3G) and beyond 3G cellular networks. A hybrid network based on IEEE 802.11/WLANs and IEEE 802.16/WiMAX is a strong contender since both technologies are designed to provide ubiquitous low cost, high speed data rates, Quality Of Service (QoS) provisioning, and broadband wireless Internet access. IEEE 802.11/WLAN is the standard to provide moderate- to high-speed data communications in a short range generally within a building. The IEEE 802.16/WiMAX is the standard to provide broadband wireless services requiring high-rate transmission and strict QoS requirements in both indoor and outdoor environments. Furthermore, IEEE 802.16/WiMAX network is a promising solution to provide backhaul support for IEEE 802.11/WLAN hotspots [1].

The integrated network of IEEE 802.11/WLAN and IEEE 802.16/WiMAX can bring a synergetic improvement to the telemedicine services on coverage, data rates, and QoS provisioning to mobile users. There have been some ongoing projects related to mobile healthcare services using WLAN/WiMAX network such as WiMAX Extension to Isolated Research Data (WEIRD) networks. WEIRD aims to support novel applications, such as fire prevention, environmental monitoring, and telemedicine via WiMAX. Various advanced medical applications such as remote follow-up, remote diagnosis, intervention on non-transportable patients, remote monitoring, remote assistance, and medical e-learning are expected to be improved by using WiMAX [1],[2].

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In [3] a prototype of a portable wireless patient monitoring system was based on WLAN technology. The sensing devices to measure heart rate, three-lead electrocardiography, and oxygen saturation (SpO2) were connected with a PDA and a WLAN. This system was designed to have small size and light weight so that stable patients can carry it easily. While a patient can move around the hospital, doctors can monitor the physiology status of the patient continuously.

In [4] Airmed-Cardio, an out-of-hospital follow up service designed specifically for cardiac patients, was used Global System for Mobile Communication (GSM)-based services to facilitate monitoring of data transmission between the patient (who can be fixed or mobile) and the healthcare agents. The measurement devices were connected to the mobile equipment, which in turn was connected to the GSM network. The Wireless Application Protocol (WAP) stack was used for wireless data transmission.

In [5] a mobile healthcare service, was proposed. This system connects a wireless body area network (BAN) to the healthcare service provider and can be used not only by the doctors in the hospital, but also by the healthcare agents in other fields such as sports and clinical research. To transfer patient data, Mobile Health uses 2.5G and 3G wireless technologies (i.e.: (GPRS) General Packet Radio Service and (UMTS) Universal Mobile Telecommunications System). The system consists of sensing devices connected with Bluetooth or ZigBee devices to transfer measured data to the cellular network.

In [6] a prototype of a mobile teletrauma system using a 3G wireless network was developed. The objective of this system is to assist healthcare centers in providing prehospital care for patients at remote locations. This system is deployed on a tablet personal computer in an ambulance and the patient information (i.e.,video, medical image and ElectroCardioGram (ECG) signals) can be transmitted simultaneously through a cellular network. However, since the transmission rate is limited (i.e., 144 kb/s, 384 kb/s, and 2 Mb/s at zero mobilities, low and high, respectively), data compression software was integrated into the system. Also, a software-radio-based approach to schedule data transmission with different QoS requirements was proposed. In addition to that, there is a similar work (i.e., a mobile emergency care system) used for communication between an ambulance and the hospital.

II. TELEMEDICINEINTRODUCTION

Telemedicine services are provided by using wired networks such as telephones, and DSL or cable-modem-based broadband access systems to transmit biomedical data between a hospital and the point of care. However, these fixed systems have limitations in providing services to patients in remote localities and when the patients are mobile. Therefore, mobile telemedicine services with applications in emergency healthcare, telecardiology, teleradiology, telepathology, teledermatology, and tele-oncology have become popular to provide prompt and effective patient care. With emerging wireless technologies, patients can access healthcare services not only from hospitals, but also from rural healthcare centers, ambulances, ships, trains, airplanes, and homes. There are three types of wireless systems that can be used for telemedicine services: satellite communications systems, cellular networks, and wireless LANs for large, medium, and small coverage areas, respectively [1].

Wi-Fi Based on the IEEE 802.11/WLAN standard, many companies and families can connect to the internet in a limited range only with an Access Point (AP), which has accelerated the Wi-Fi network development. As a step toward providing Quality of Service (QoS) support in a Wi-Fi network, the 802.11 Working Group developed the IEEE 802.11e/WLAN standard provided differentiation mechanisms at the Medium Access Control (MAC) layer. A number of studies has evaluated the 802.11e standard by both analytical evaluation and simulation, and have demonstrated the usefulness of the proposed mechanisms in the 802.11e. For local telemedicine services (e.g., inside a hospital or healthcare center), WLAN-based systems would be the most suitable. However, WLANs have limitations in terms of mobility and coverage area. Cellular networks are suitable to provide prehospital treatment in a mobile scenario (e.g., in an ambulance). Even though cellular networks (i.e., 3G networks) offer a reasonable compromise between the mobility requirement and the cost of the system, transmission speed may not be high enough for high-quality diagnostic video and images [7].

In recent year, broadband Wireless technology has become life line of people of the world; the rapid growth of wireless communication technology improves the transmission data rate and communication distance. Although the transmission rate of wireless network still cannot catch up with the cable one, there are still increasingly applications on wireless network due to its features of mobility and low setup cost. WiMAX, based on the IEEE 802.16, is one of the new emerging technologies of broadband wireless system. Its a set of telecommunications technology standards aimed at providing wireless access over long distances in variety of ways- from point to point to full mobile cell type access. Its transmission rate and distance can reach up to 75 Mbps and 50 km. Compared with other wireless networks, WiMAX has the virtues of higher transmission speed and larger transmission coverage. In contrast with the traditional wire network, WiMAX has the advantages of rapid and cost-effective deployment and high scalability. It can solve the last mile problem of the metropolitan network because of the features of high bandwidth and long distance [8].

IEEE 802.16 is a series of Wireless Broadband standards written by the Institute of Electrical and Electronics Engineers (IEEE).The IEEE 802.16 group was formed in 1998 to develop wireless broadband. The group’s initial focus was the development of a line- of- sight (LOS) -based point to multipoint wireless broadband system for operation in the 10 GHz -66GHz millimeter wave band. The evolution of IEEE 802.16 since its first release in 2001, standards for Fixed WiMAX (IEEE 802.16-2004) were announced as final in 2004, followed by Mobile WiMAX (IEEE 802.16e) in 2005. In Europe, the standards for wireless MANs were formalized under the ETSI as HiperMANs, up to IEEE 802.16m version, expected to be completed at the end of 2012 [8].

Since the WiMAX technology is to be deployed as broadband wireless metropolitan area networks, IEEE 802.16 standard family is also called Wireless MAN.

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WiMAX technology has evolved through four stages :(1) narrowband wireless local –loop system,(2) first generation line- of- sight (LOS) broadband systems, (3) second –generation non-line-of-sight (NLOS) broadband systems, and (4) standards –based broadband wireless systems [8]. For E-health, WiMAX technologies can substantially contribute to improve the daily activities and thus enhance the quality of life. Remote Diagnosis is one of the possible cases where Mobile WiMAX plays an important role. For instance, a doctor is on duty on an ambulance and is called to intervene in a city street where a car accident occurred. The ambulance is equipped with a portable ultrasound device, connected to a notebook and to the hospital through a Mobile WiMAX channel. The doctor finds a laying man who might have internal injuries. To allow the fastest possible intervention, he charges the patient on the ambulance and, while going to the hospital, takes some images with the portable ultrasound and sends them via Mobile WiMAX to the hospital, where the surgery is being prepared. He also sets-up a video conference session with the surgeon at the hospital to inform him about the patient health condition and discuss the treatment options. Mobile WiMAX is important for other Telemedicine applications such as Remote Follow-up, Remote Monitoring and Remote Assistance. The Telemedicine scenario requires real time services and applications such as voice and video over IP in a mobility environment to support real time communication in case of emergency. So can be summarizing the advantages of using IEEE 802.16/WiMAX technology for wireless telemedicine/e-health services as follows [1]:

- **High bandwidth:** Due to the large transmission bandwidth, transmission delay for high quality images such as ultrasound and radiology images can be reduced considerably.
- **Integrated services:** In a clinical grade network that supports fully functional telemedicine services (e.g., diagnostic, physical monitoring, pharmaceutical, and drug dosage management services); the large network capacity can be exploited to communicate various types of monitoring and diagnostic data simultaneously.
- **QoS support:** With the predefined QoS framework, transmission of medical data can be performed efficiently. In a prehospital management system deployed in an ambulance, for example, conversation between a physician and a patient can proceed online while diagnostic images are being transmitted.
- **Security:** This is crucial for telemedicine services. Patient information must be communicated in a secure and reliable manner. The MAC layer security feature in the IEEE 802.16/WiMAX standard can provide access control and encryption functionalities for wireless telemedicine services.

Therefore we can consider IEEE 802.16/WiMAX-based Broadband Wireless Access (BWA) technology is a feasible choice for providing telemedicine services in both fixed and mobile environments.

III. INTRODUCTION – HISTORICAL OVERVIEW OF WI-FI IEEE 802.11

WLANs are commonly used in their 802.11a, 802.11b, and 802.11g versions to provide wireless connectivity in home, office and some commercial establishments; they are also widely deployed in telemedicine systems. Since the early 1990s, the industrial, scientific, and medical bands, 2.4 GHz and 5 GHz, have been made available for WLAN, among which the 802.11b and 802.11g protocols are the most popular. IEEE 802.11b operates in the 2.4 GHz band and accommodates data rates of up to 11 Mb/s, whereas 802.11g, based on orthogonal frequency-division multiplexing (OFDM), operates in the same band and provides data rates of up to 54 Mb/s. IEEE 802.11a also specifies an OFDM scheme, which is not backward compatible with the original 802.11b. It operates in the 5 GHz band with data rates of up to54 Mb/s within 10 m, dropping to about 6 Mb/s at a distance of 100 m. IEEE 802.11 WLANs are most suitable for local telemedicine services, IEEE 802.11e can be used for transmitting sensitive medical data with QoS support, and IEEE 802.11i provides security support as an amendment to the original IEEE 802.11 standard by specifying security mechanisms for WLANs. However, WLANs have limitations in terms of mobility and coverage area [7], [9].

IV. INTRODUCTION – HISTORICAL OVERVIEW OF WIMAX IEEE 802.16

The name "WiMAX" was created by the WiMAX Forum, which was formed in June 2001 to promote conformity and interoperability of the standard. WiMAX refers to interoperable implementations of the IEEE 802.16 wireless-networks standard (ratified by the WiMAX Forum), in similarity with Wi-Fi, which refers to interoperable implementations of the IEEE 802.11 Wireless LAN standard (ratified by the Wi-Fi Alliance). The WiMAX Forum certification allows vendors to sell their equipment as WiMAX (Fixed or Mobile) certified, thus ensuring a level of interoperability with other certified products, as long as they fit the same profile . The IEEE 802.16 standard forms the basis of WiMAX and is sometimes referred to colloquially as WiMAX, "Fixed WiMAX", "Mobile WiMAX", "802.16d" and "802.16e [10] ,[11].

The technologies behind WiMAX are better suited for larger geographic networks than Wi-Fi. Figure(1) shows a breakdown of common network sizes, with the technologies behind WiMAX covering the two largest geographic areas . wide area networks (WAN) and metropolitan area networks (MAN). WANs have traditionally been covered by two wireless technologies, national mobile networks and satellite providers. In contrast, wireless technologies have not found widespread adoption in the MAN coverage area of 50 km [12].

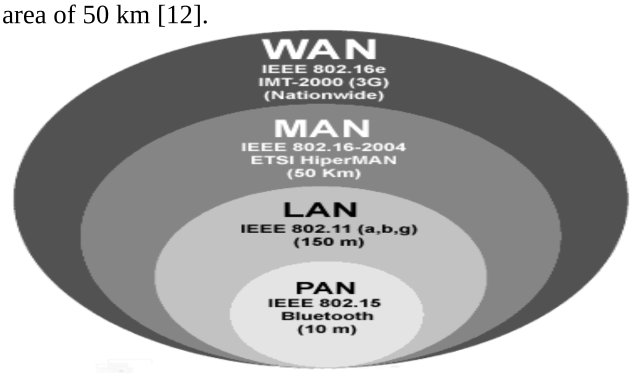

Figure (1). Typical network ranges

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IEEE 802.16 technologies are best suited for longer-range wireless communications.

The WiMAX Forum has estimated that new WiMAX equipment will be capable of sending high speed data over long distances (40 Mbit/s over 10 kilometers in a line-of-sight fixed environment). At these distances, WiMAX equipment could play a key role in helping bridge the digital divide as long-distance wireless links could help deliver higher-speed access to areas traditionally out of reach of fixed-line networks. WiMAX has also been attracting particular interest as a disruptive technology that could impact fixed and mobile markets, in both their voice and data segments. Finally, WiMAX has also been tapped as a potential key component of next-generation converged or ubiquitous networks [13].

Companies are deploying WiMAX to provide mobile broadband or at-home broadband connectivity across whole cities or countries. In many cases this has resulted in competition in markets which typically only had access to broadband through an existing incumbent DSL (or similar) operator. Additionally given the relatively low cost to deploy a WiMAX network (in comparison to GSM, DSL or Fiber-Optic), it is now possible to provide broadband in places where it may have not been economically viable .WiMAX is a possible replacement candidate for cellular phone technologies such as GSM and CDMA, or can be used as an overlay to increase capacity. Fixed WiMAX is also considered as a wireless backhaul technology for 2G, 3G, and 4G networks in both developed and developing nations [13], [14].

WiMAX is a broadband platform and as such has much more substantial backhaul bandwidth requirements than legacy cellular applications. Therefore, traditional copper wire line backhaul solutions are not appropriate. Consequently the use of wireless microwave backhaul is on the rise in North America and existing microwave backhaul links in all regions are being upgraded. Capacities of between 34 Mbit/s and 1 Gbit/s are routinely being deployed with latencies in the order of 1 ms. In many cases, operators are aggregating sites using wireless technology and then presenting traffic on to fiber networks where convenient [14].

IEEE 802.16/WiMAX is a good last-mile wireless access solution that provides baseline features for flexibility in spectrum to be used all over the world. Advantages of using WiMAX for wireless telemedicine applications over WLAN based systems can be summarized as follows [15]:

- Broadband wireless access in both fixed and mobile environments
- High bandwidth to reduce transmission delay of quality images significantly
- Integrated services provided by the large network capacity of WiMAX enabling fully functional telemedicine services such as various types of diagnostics, physical monitoring, pharmaceutical and drug dosage management services, good quality conversational communications between a physician and a patient, and consultation among medical specialists.
- Medium access control (MAC) layer security features of WiMAX providing access control and encryption functions for wireless telemedicine services
- QoS framework defined in 802.16e enabling efficient and reliable transmission of medical data.

A. IEEE 802.16 PHY Layer

The WiMAX physical layer is based on orthogonal frequency division multiplexing. OFDM is the transmission scheme of choice to enable high-speed data, Big files, video, Deficit Round Robin (DRR), and multimedia file and is used by a variety of commercial broadband systems, including DSL, Wireless, Digital Video Broadcast-Handheld (DVB-H), and MediaFLO, besides WiMAX. Basically, OFDM subdivides the channel to multiple subcarriers, where each subcarrier is orthogonal to the other. Figure(2) illustrates the types of the subcarriers in a 10 MHz channel bandwidth [16], [17].

There are three types of subcarriers:
Null Subcarrier: used as guard band or DC carriers.
Pilot Subcarrier: used for channel estimation and channel tracking.
Data Subcarrier: carrying the data information.

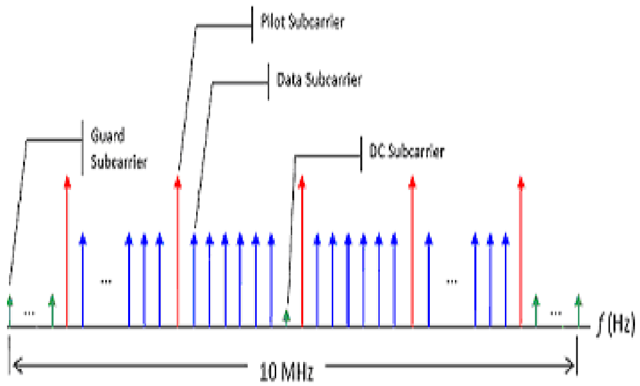

Figure (2): OFDM Sub carrier Structure.

Fundamentally, OFDMA is OFDM with the application of Subchannelization and Time Division Multiple Access (TDMA). Subchannelization basically means to group multiple subcarriers and allocate them to a single user over one, two or three OFDMA symbol time(s). Figure(2) could be modified to show Subchannelization for OFDMA, as illustrated in Figure(3):

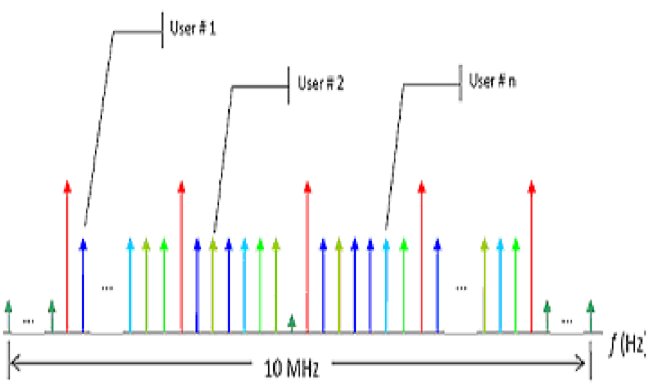

Figure (3): Subchannelization in OFDM

Note that different colors mean different users. Unlike OFDM, here in OFDMA data streams from different users are multiplexed, rather than using the whole band for a single user per one symbol frame.

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Note also that the subcarriers are not adjacently grouped, but in a random manner. This introduces frequency diversity which is specifically rewarding in the case of mobile communications (since the channel tends to vary the most among other cases). Adding to that, it allows a better application of fairness between the users since the probability of a user experiencing bad channel impulse response will be less [18].

B. IEEE 802.16 MAC Layer

IEEE 802.16 MAC was designed for point-to-multipoint broadband wireless access applications. The primary task of the WiMAX MAC layer is to provide an interface between the higher transport layers and the physical layer. The 802.16 MAC is based on collision sense multiple access with collision avoidance (CSMA/CA). The MAC incorporates several features suitable for a broad range of applications at different mobility rates, as the following [9], [18]:

- Broadcast and multicast support.
- Manageability primitives.
- High-speed handover and mobility management primitives.
- Three power management levels, normal operation, sleep and idle.
- Header suppression, packing and fragmentation for efficient use of spectrum.

Five service classes, unsolicited grant service (UGS), real-time polling service (rtPS), non-real-time polling service (nrtPS), best effort (BE) and Extended real time variable rate (ERT-VR) service. The five different traffic classes are provided in the standard conforming to the various kinds of traffics encountered in the networks. These are [19]:

(a) Unsolicited Grant Service (UGS): For service flows that generate fixed size data packets on a periodic basis, like, VoIP without silence suppression.

(b) Real-time polling service (rtPS): To support service flows that generate variable size data packets on a periodic basis, like MPEG video.

(c) Extended Real-time polling service (ertPS): To support variable sized data packets generated periodically such as in case of voice with silence suppression.

(d) Non-Real time polling service (nrtPS): Handles service flows that require variable size data grant burst types on a regular basis, like, high bandwidth FTP.

(e) Best Effort (BE): For the web browsing HTTP kind of delay tolerant data.

C. Services over WiMAX Networks:

WiMAX networks are designed to be able to interface with different types of networks (including IP, TDM voice, ATM, or others). A provision has also been kept for service-specific support by providing quality-of-service classes based on characteristics of different services. WiMAX networks can support VoIP, video, voice, or data using the same architecture by merely defining appropriate classes of service. They can also carry multicasts as well as web syndication feeds such as RSS simultaneously with other services, providing a rich user experience. All the advantages of WiMAX, however, do not mean that these networks will immediately start replacing the mobile networks. The bandwidth and range of WiMAX make it suitable for the following potential applications [15]:

- Providing portable mobile broadband connectivity across cities and countries through a variety of devices.
- Providing a wireless alternative to cable and DSL for "last mile" broadband access.
- Providing data, telecommunications (VoIP) and IPTV services (triple play).
- Providing a source of Internet connectivity as part of a business continuity plan.

V. COMPARISON BETWEEN WIMAX AND WI-FI

The most fundamental difference between WiMAX and Wi-Fi is that they are designed for totally different applications. Wi-Fi is the standard to provide moderate- to high-speed data communications within a short range, generally within a building. On the other hand, WiMAX is the standard to provide Internet access over a long range outdoor environment [20], [21].

Table (1): Comparison of WiMAX and Wi-Fi Technologies.

Standard	Network	Band	Bit rate	Channel bandwidth	Bandwidth efficiency	Radio technique
802.11	LAN <100 m	2.4 GHz	1 or 2 Mb/s	20 MHz	2.7Mb/s/Hz	FHSS or DSSS
802.11a	LAN <100 m	5 GHz	6-54 Mb/s	20 MHz	2.7Mb/s/Hz	OFDM (64-channel)
802.11b	High rate LAN <100 m	2.4 GHz	11 Mb/s (fallback 5.5,2, or 1 Mb/s)	25 MHz	0.44Mb/s/Hz	DSSS and CCK
802.11g	LAN	2.4 GHz	up to 22 Mb/s	20 MHz	2.7 Mb/s/Hz	OFDM (64-channel)
802.16	MAN, 1-3 mi	10-66 GHz	32-134 Mb/s (28 MHz channel)	20, 25 ,28 MHz	5 Mb/s/Hz	QPSK ,16 QAM ,64 QAM
802.16a	MAN, 3-5 mi	2-11 GHz	≤ 70 or 100 Mb/s (20 MHz channel)	Adjustable 1.25-20 MHz	5 Mb/s/Hz	256-subcarrier OFDM using QPSK ,16-QAM ,64-QAM and 256-QAM
802.16e	MAN, 1-3 mi	< 6 GHz	up to 15 Mb/s	5 MHz	5 Mb/s/Hz	same as 802.16a

Besides the obvious difference in transmission range, there are a number of improvements in the radio link technology that distinguish WiMAX from Wi-Fi. Wi-Fi standards describe four radio link interfaces that operate in the 2.4GHz or 5GHz unlicensed radio bands.

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WiMAX standards include a much wider range of potential implementations to address the requirements of carriers around the world. All Wi-Fi implementations use unlicensed frequency bands, but WiMAX can operate in either licensed or unlicensed spectrum. A detailed comparison of WiMAX and Wi-Fi technologies is summarized in Table (1).

WiMAX may enjoy a complementary relationship with Wi-Fi due to differences in the reach of each of the networks. WiMAX connections can be used to provide backhaul connections to Wi-Fi hotspots over longer distances. WiMAX could also play a key role in connecting Wi-Fi hotspots in a mesh-type network to quickly increase coverage and capacity as shown in Figure (4) [22].

Typical Wi-Fi installations can accommodate 54 Mbit/s of bandwidth within a 100 metre radius and among 32 users. WiMAX implementations will likely provide a similar amount of total bandwidth spread over a much larger area to many more users. Therefore, users will have access to faster connections via Wi-Fi when it is available and will likely move to WiMAX or competing mobile technologies when out of range of a Wi-Fi signal.

The Comparisons and confusion between WiMAX and Wi-Fi are frequent because both are related to wireless connectivity and Internet access [23], [24]:

1- WiMAX is a long range system, covering many kilometers that uses licensed or unlicensed spectrum to deliver connection to a network, in most cases the Internet.
2- WiMAX and Wi-Fi have quite different quality of service (QoS) mechanisms:
    a. WiMAX uses a QoS mechanism based on connections between the base station and the user device. Each connection is based on specific scheduling algorithms.
    b. Wi-Fi uses contention access - all subscriber stations that wish to pass data through a wireless access point (AP) are competing for the AP's attention on a random interrupt basis. This can cause subscriber stations distant from the AP to be repeatedly interrupted by closer stations, greatly reducing their throughput.
3- Wi-Fi uses unlicensed spectrum to provide access to a local network.
4- Wi-Fi is more popular in end user devices.
5- Wi-Fi runs on the Media Access Control's CSMA/CA protocol, which is connectionless and contention based, whereas WiMAX runs a connection-oriented MAC.
6- Both 802.11 (which includes Wi-Fi) and 802.16 (which includes WiMAX) define Peer-to-Peer (P2P) and ad hoc networks, where an end user communicates to users or servers on another Local Area Network (LAN) using its access point or base station. However, 802.11 supports also direct ad hoc or peer to peer networking between end user devices without an access point while 802.16 end user devices must be in range of the base station.

Wi-Fi and WiMAX are complementary. WiMAX network operators typically provide a WiMAX Subscriber Unit which connects to the metropolitan WiMAX network and provides Wi-Fi within the home or business for local devices for connectivity.

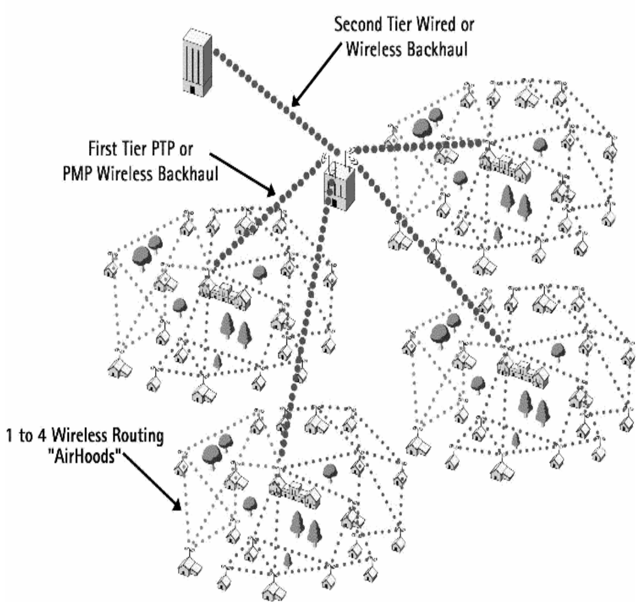

Figure (4): WiMAX as the backbone of meshed networks Darker lines represent WiMAX backhaul lines to neighborhoods. The lighter lines represent Wi-Fi connections between households

VI. INTEGRATED WIMAX AND WI-FI NETWORKS FOR TELEMEDICINE SERVICES

This section presents some envisioned futuristic scenarios that take advantage of integrated WiMAX and IEEE 802.11/WLAN networks for telemedicine services. Figure (5) shows a high level system model based on the integrated WiMAX and WLAN wireless network for a telemedicine network connecting hospitals, clinics, drugstores, mobile ambulances, a patient information management database, mobile specialists, and patients at home as well as mobile patients. Single-mode (SM) MNs equipped with one interface, dual-mode (DM) MNs, dual-mode WLAN APs, and WiMAX BSs are potential components of this heterogeneous wireless network. The scenarios described in Figure (5) elicit the benefits and illustrate some issues in integrated WLAN and WiMAX networks. The hybrid system can be divided into five subnetworks: Body Area Networks (BANs), home care network / telehomecare, intranet of a healthcare provider, including a hospital, a clinic, and a drug store, a network between the patient home and the healthcare provider, and a mobile telemedicine network for mobile patients and health service providers. A wireless heterogeneous network of WLAN, WiMAX, and 3G cellular networks (dashed lines) is also shown in Figure (5). The integrated WiMAX and WLAN wireless telemedicine networks can be deployed in the following scenarios [25], [26], [27]:

BANs: The BAN is a particularly appealing solution to provide information about the health status of a patient in medical environments such as hospitals or medical centers.

Home care network/TeleHome Care: Home care is a growing field in health care and is a promising solution to the medical problems of modern society.

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In the integrated WiMAX and WLAN networks, patients may reside at home for remote patient monitoring through either connecting directly to a WiMAX BS equipped with a WiMAX client like Home2, or connecting to WLAN dual-mode APs like Home 1.

Intranet of a healthcare provider/intra-hospital services: WiMAX is a more practical and cost-effective solution for hospital intranet deployment due to the relatively larger coverage area of WiMAX networks than that of WLAN APs. The deployment of a WiMAX network in a hospital will reduce operation and maintenance costs, while offering full mobility support for patients and medical staff.

Clinics and drugstores: In contrast to a hospital, WLAN APs can likely provide enough coverage for clinics and drugstores. Therefore, dual mode WLAN APs can be deployed at clinics and drugstores to communicate with healthcare centers through WiMAX interfaces and to provide local wireless coverage through WLAN interfaces.

Wireless video telephony: A number of telemedicine applications are based on the transmission of medical video, such as remote medical action systems, patient remote tele-monitoring facilities, and transmission of medical videos for educational purposes. High quality videos/images are required to ensure proper diagnosis and/or assessment. Video transmissions over a WiMAX network have proved to be an effective and efficient platform in providing proper video content delivery.

VoIP services: WiMAX can also be used for VoIP services. Telephone bills can be drastically reduced as a result of the use of VoIP for communications among hospitals.

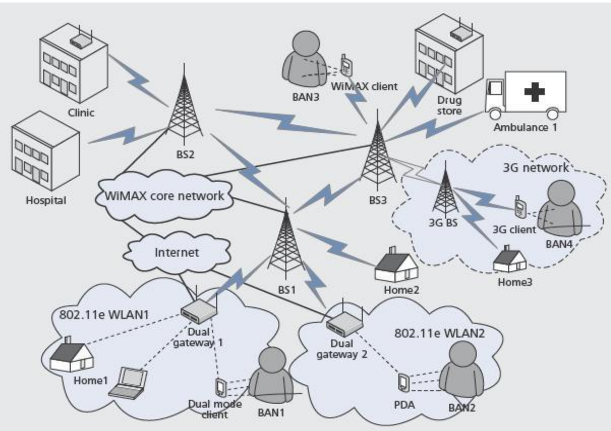

Figure (5): IEEE 802.11/WiFi and 802.16/WiMAX based wireless telemedicine network.

VII. QOS SUPPORT IN WIMAX

QoS support is vital in integrated WiMAX and WLAN for e-healthcare service because various types of time-sensitive data should be communicated in such a service. For example, real-time communications and large enough bandwidth is required for transmitting high-resolution digital videos and images in mobile robotic systems. Providing QoS in the integrated IEEE 802.16/WiMAX and IEEE 802.11/WLAN network is a challenging issue. The need for efficient interworking between IEEE 802.16/WiMAX and IEEE 802.11/WLAN arises in order to support QoS for delay-sensitive and bandwidth-intensive applications. IEEE 802.11e employs a channel access function, hybrid coordination function (HCF), to support QoS provisioning in IEEE 802.11/WLAN networks. In the delivery of medical data, some type of data such as real-time medical video streaming requires strict QoS support. Different from IEEE 802.11/WLAN, IEEE 802.16/WiMAX was designed from the beginning with QoS in mind and defines five different types of services for different types of traffic flows as follows [24]:

- Unsolicited grant service (UGS) supports constant bit rate traffic, such as voice over IP (VoIP).
- Real-time polling service (rtPS) supports real-time service flows which generate variable size data packets on a periodic basis (e.g., MPEG video). This scheme can guarantee QoS service to meet delay requirements.
- Extended real-time polling service (ertPS) is a new scheduling algorithm for VoIP services with variable data rates and silence suppression.
- Non-real-time polling service (nrtPS) is designed to support non real-time service flows that require variable size data grant burst types on a regular basis, such as high bandwidth FTP.
- Best effort (BE) supports services that do not provide QoS guarantees (e.g., Web and email traffic).

VIII. QOS SUPPORT IN WI-FI

The 802.11e standard uses two mechanisms to provide QoS, namely Enhanced Distributed Channel Access (EDCA) and Hybrid Coordinator Function Controlled Channel Access (HCCA). As the MAC in WiMAX is TDMA based, for closeness of channel access schemes, the HCCA mechanism is preferred in this strategy for the 802.11e interoperability. The coordination function is located in the QoS Access Point (QAP). The second important feature in 802.11e is the facility of traffic differentiation through the Traffic Specification (TSPEC) messages. Though, the draft supports both prioritized and parameterized QoS, in case of HCCA mechanism only parameterized QoS is relevant. In this case, the MAC Protocol Data Units (MPDUs) are treated depending upon the parameters associated with them. The applications are provided with per flow QoS service. The QoS is set through the following stages [28]:

1- The initial step is to setup a Traffic Stream (TS). TS is a set of MSDUs to be transferred subject to the QoS requirements of an application flow to the MAC. The non-AP QSTA station management entity (SME) decides on the creation of a new TS and assigns it a unique traffic stream identity (TSID).

2- The next step is user plane QoS traffic handling. The QoS control field in the MAC frame format facilitates the description of QoS requirements of a particular application flow. It is a 4 bit field that identifies the traffic category (TC) or TS to which a frame belongs and various other QoS related information. The bits 0-3 within QoS control field are the traffic identifier (TID) and take the value from 8-15 for parameterized TSs and are assigned TSIDs.

The HCF in QAP can start the controlled channel access mechanism in both the Contention Free Period (CFP) and Contention Period (CP).

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IX. MOBILE TELEMEDICINE SYSTEM

Mobile telemedicine systems can be deployed for emergency telemedicine services, mobile patient monitoring, and mobile health service provider [27].

Emergency telemedicine: A mobile telemedicine system has the potential to reduce medical complications of patients in need of emergency care such as in a disaster and rescue operation. It can improve emergency care survivals significantly. The mobile telemedicine system will transmit vital bio-signals (e.g., heart rate and blood pressure) and other data (e.g., images of injuries caused by accidents) from an emergency site to the hospital, and medical experts can provide suggestions and instructions accurately in a timely manner.

Mobile patient monitoring and healthcare provider: Mobile patient monitoring enables real-time patient monitoring that can use smart sensors to collect patients' vital signs so that medical specialists can perform diagnoses anywhere and at any time.

Mobile medical data: Entire patient histories are accessible wirelessly. Medical data can be searched from other patients with similar symptoms in order to learn from other previous experiences. Taking privacy into consideration, only medical information is available, without disclosing the identity of the particular patient. Both patients and medical staff can wirelessly access patients' medical data.

Mobile robotic systems: Mobile robotic systems enable medical experts to control medical devices such as ultrasonic devices at the patient side in isolated areas. Since medical experts can control devices through networks, they can efficiently measure precise medical information, and patients do not need to operate medical devices. Mobile Tele-Echography Using an Ultra-Light Robot (OTERO) is a good example of this type of service. In order to realize mobile robotic systems, real-time communications and large enough bandwidth for transmitting high-resolution digital videos and images should be provided, and WiMAX technology fulfills these requirements.

Pre-hospital care: WiMAX technology can also enhance pre-hospital care in an ambulance. Ambulance crews can access the medical information database in a hospital and retrieve the required medical information of patients through WiMAX networks. Combination of video streaming and robotics systems will allow a doctor in a hospital to perform the required inspection and diagnosis until the ambulance arrives at the hospital.

- ***Telemedicine Video Streaming***

Telemedicine Video Conferencing has become a vital component in all human activities. Telemedicine System is not apart in this field. There are video conferencing systems that allow doctors from different hospitals to communicate with minimum requirements such as a Webcam and of course an Internet connection.

But ensuring mobility in video conferencing is always a challenge from the network point of view. That is in an emergency condition one of the parties can be in a vehicle. Figure (6) gives the idea of a typical idea of remote assistance via telemedicine. The efficacy of this video conference depends on the network that can successfully tackle the handover [27].

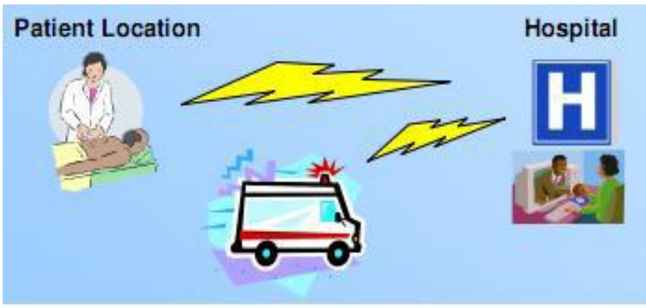

Figure (6): Remote assistance through Telemedicine

- Mobile WiMAX with its scheduling service i.e. Real Time Polling Service (rtPS), Enhanced Real Time Polling Service (ertPS) which support audio and video streaming and VOIP with activity detection can resolve this scenario.
- In fact, ertPS supports IEEE 802.16 for VOIP support with variable packet size with silence suppression.
- Things will get even brighter with the arrival of IEEE 802.16 with WiMAX release 2 & LTE associated by its upgrades.

X. FUTURE DEVELOPMENT

The IEEE 802.16m standard is the core technology for the proposed WiMAX Release 2, which enables more efficient, faster, and more converged data communications. The IEEE 802.16m standard has been submitted to the ITU for IMT-Advanced standardization. IEEE 802.16m is one of the major candidates for IMT-Advanced technologies by ITU. Among many enhancements, IEEE 802.16m systems can provide four times faster data speed than the current WiMAX Release 1 based on IEEE 802.16e technology.

WiMAX Release 2 will provide strong backward compatibility with Release 1 solutions. It will allow current WiMAX operators to migrate their Release 1 solutions to Release 2 by upgrading channel cards or software of their systems. Also, the subscribers who use currently available WiMAX devices can communicate with new WiMAX Release 2 systems without difficulty.

It is anticipated that in a practical deployment, using 4X2 MIMO in the urban micro cell scenario with only a single 20-MHz TDD channel available system wide, the 802.16m system can support both 120 Mbit/s downlink and 60 Mbit/s uplink per site simultaneously. It is expected that the WiMAX Release 2 will be available commercially in the 2012-2013 timeframe.

XI. CONCLUSION

Specific circumstances in the Republic of Macedonia enforce the use of wireless technologies for various applications. Modern wireless telecommunication technologies like WiMAX enable the provision of telemedicine services to places previously unreachable by landlines. New telecommunication technologies that emerge constantly and the development of software enable implementation of novel telemedicine services that were previously only imaginable. Web services and XML enable integration of various Medical Information Systems into an Integrated System for E-Medicine.

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High bandwidth and reliability of WiMAX helps the integration with bringing remote hospitals ever closer. Furthermore, new telemedicine services are implemented every day thanks to advances in technology. Experiences gained in this project could be useful in countries or areas where conditions are similar. The mobility and quick deployment offered by wireless communications will help change our former views of the medical treatment in general, enabling high quality health service remotely and inexpensively. The application of integrated WiMAX and Wi-Fi broadband wireless access technologies for telemedicine services and the related protocol issues have been discussed in this article. An overview of Wi-Fi and WiMAX networks has been provided, followed by a comparison of Wi-Fi and WiMAX. Open research issues related to QoS support, radio resource management, scheduling, and connection admission control, as well as handover management in the Wi-Fi and WiMAX heterogeneous networks have been discussed. Finally, potential applications and deployment scenarios of Wi-Fi and WiMAX heterogeneous networks for telemedicine services are discussed and elicited. Using WiMAX as a next generation access network, both for fixed and mobile connectivity, is a promising technology for a large number of real application scenarios in the academic, scientific and research community. This paper also described how the WEIRD project is facing this challenging problem when the technology has to be used in few novel scenarios with high requirements in terms of mobility and Quality of Service. The analysis of these requirements highlighted the necessity to smoothly integrate, from the beginning, the WiMAX technology into the Next Generation Network architecture in order to be incorporate the existing features and to be compliant with the infrastructure that will be present A first prototype of the WEIRD system will be released for evaluation in the test-beds in June 2007, while the final results of the tests and trials will be ready for the end of the project, expected in June 2013.

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