WIRELESS TELEMEDICINE SERVICES OVER INTEGRATED IEEE 802.11/WLAN AND IEEE 802.16/WIMAX NETWORKS

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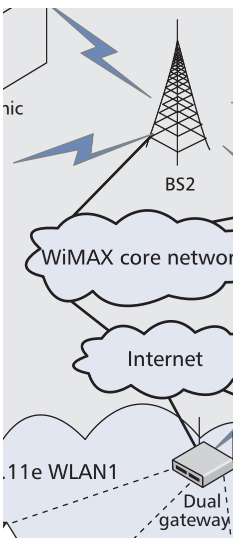

The authors investigate the application of integrated IEEE 802.16/WiMAX and IEEE 802.11/ WLAN broadband wireless access technologies along with the related protocol issues for telemedicine services.

ABSTRACT

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 any time, overcomes most of geographical, temporal, and even organizational barriers to facilitate remote diagnosis and monitoring, and transfer of medical data and records. In this article we investigate the application of integrated IEEE 802.16/WiMAX and IEEE 802.11/WLAN broadband wireless access technologies along with the related protocol issues for telemedicine services. We first review IEEE 802.11/WLAN and IEEE 802.16/WiMAX technologies, and make a comparison between IEEE 802.11/WLAN and IEEE 802.16/WiMAX. Then some open research issues in the integrated IEEE 802.16/WiMAX and IEEE 802.11/WLAN networks are discussed, especially regarding QoS support, radio resource management, scheduling and connection admission control schemes, as well as handover and mobility management. Finally, applications and deployment scenarios of integrated IEEE 802.16/WiMAX and IEEE 802.11/WLAN for telemedicine services are further deliberated.

INTRODUCTION

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. WiMAX has recently been implemented for telemedicine functionalities [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 Mobile Taiwan (M-Taiwan) [2] and WiMAX Extension to Isolated Research Data (WEIRD) networks [3]. The major goal of M-Taiwan is to build a standard-compliant environment as the foundation for lifestyle applications such as M-Service, M-Learning, and M-Life. In order to deliver such applications, WiMAX is expected to be the preferred technology. WEIRD aims to support novel applications, such as fire prevention, environmental monitoring, and telemedicine via WiMAX. Fourtest beds deployed in

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Europe have been used to implement, test, and validate the technical solutions developed within the WEIRD project. 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.

The remainder of this article is organized as follows. First, we briefly review WLAN and WiMAX technologies. Afterward, a comparison between IEEE 802.11/WLAN and IEEE 802.16/WiMAX is presented. A general telemedicine system architecture and telemedicine QoS requirements are introduced. Then some research open issues in the integrated IEEE 802.16/WiMAX and IEEE 802.11/WLAN networks are discussed, especially on QoS support, radio resource management, scheduling and connection admission control schemes, as well as handover and mobility management. Finally, application and deployment scenarios of integrated IEEE 802.16/WiMAX and IEEE 802.11/WLAN for telemedicine services are discussed and illustrated.

WLAN and WiMAX Overview

WLAN Overview

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 prthogonal 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 to 54 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.

WiMAX Overview

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:

- 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

Comparison between WLAN and WiMAX

The most fundamental difference between WLAN and WiMAX is that they are designed for totally different applications. WLAN 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.

Besides the obvious difference in transmission range, there are a number of improvements in the radio link technology that distinguish WiMAX from WLAN. WLAN standards describe four radio link interfaces that operate in the 2.4 GHz or 5 GHz unlicensed radio bands. WiMAX standards include a much wider range of potential implementations to address the requirements of carriers around the world. All WLAN implementations use unlicensed frequency bands, but WiMAX can operate in either licensed or unlicensed spectrum. A detailed comparison of WiMAX and WLAN technologies is summarized in Table 1.

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WLAN and WMAN: Basic Integration Issues

An integrated WiMAX and WLAN network can be used to extend the coverage area of a WLAN and augment the availability of e-healthcare service using mobile wireless systems. However, to realize integrated WiMAX and WLAN networks for e-healthcare service, many challenging problems such as QoS support, radio resource management, scheduling, connection admission control, and handover management have to be addressed. A taxonomy of related works is outlined in Table 2, and the major contributions of corresponding work on tackling various issues are highlighted in Table 3.

QoS Support

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/

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	2.7 Mb/s/Hz	FHSS or DSSS
802.11a	LAN < 100 m	5 GHz	6–54 Mb/s	20 MHz	2.7 Mb/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	0.44 Mb/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, 16QAM, 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 ODFM 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

Table 1. *Comparison of WiMAX and WLAN technologies.*

QoS	QoS architecture [4]
Radio resource management and admission control	Game-theory-based radio resource management [5]; Admission control [5]; Capacity analysis and radio resource management evaluation [6]
Scheduling	BS assisted [7]; Traffic rerouting enabled [8]
Handover	Trigger design [9]; Security [10]; Movement [11]; Performance [12]

Table 2. *A taxonomy of related works in WLAN and WiMAX heterogeneous networks.*

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. HCF uses both a contention-based channel access method, enhanced distributed channel access (EDCA), for contention-based transfer, and a controlled channel access, referred to as HCF controlled channel access (HCCA), for contention-free transfer. EDCA and HCCA provide QoS support over existing distributed coordination function and point coordination function schemes, respectively. EDCA defines four access categories (ACs): AC_VO with highest priority, AC_VI, AC_BE, and AC_BK with lowest priority corresponding to voice, video, best effort, and background traffic, respectively. The priorities are achieved by differentiating the contention window (CW) size and arbitration interframe space (AIFS) time. Therefore, higher-priority ACs have smaller CWs and shorter AIFSs. The EDCA mechanism can only provide relative differentiation among service categories, but not absolute guarantees on throughput and delay performance, and it may thus starve lower-priority flows. HCCA provides QoS service by using signaling, scheduling and admission control. It defines a superframe containing a contention-free period followed by a contention period. During the contention-free period, only nodes which are polled by the AP are eligible to transmit for a burst period assigned by the AP. IEEE 802.11e defines eight traffic categories (TCs): TC6 and TC7 for voice, TC4 and TC5 for video, TC0 and TC3 for best effort, as well as TC1 and TC2 for background information. When a new TC starts, the node needs to send a service request to the AP providing its traffic specifications so that the AP will perform admission control to decide whether to allow the new flow for service.

In the delivery of medical data, some type of data such as real-time medical video streaming requires strict QoS support. In order to support such requirements, the extension of the standard 802.11e EDCF scheme, referred to as medical channel-adaptive fair allocation, has been proposed [13].

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:

- 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.

Components	Key contribution
QoS architecture [4]	An architecture to provide end-to-end QoS in integrated WLAN/WiMAX networks
A Hierarchical Model for Radio Resource Management and Admission Control [5]	A game-theoretic model-based hierarchical bandwidth management and admission control framework for Iintegrated IEEE 802.16/802.11 wireless networks.
Resource Reservation for Handover Traffic [6]	A probabilistic resource reservation scheme for WLAN to WiMAX handover traffic, to reduce the dropping probability of handover calls.
Capacity Analysis and Evaluation [6]	A quantitative evaluation of the system capacity with QoS for VoIP to verify the effectiveness of integrating WiMAX and WLAN networks.
BS Assisted Scheduling [7]	ABS assisted adaptive scheduling mechanism implemented at the CPE to provide QoS guarantees.
Traffic Rerouting [8]	A scheduling algorithm to reduce WiMAX users' delay by rerouting traffic through lightly loaded WLAN APs.
Handover Trigger Design [9]	A user centric algorithm by combining a trigger to continuously maintain connections and another one to maximize user throughput.
Secure Handover [10]	A MIH-based secure handover mechanism by adopting symmetric cryptography and asymmetric cryptography to provide security protections.
Movement-Aware Handover [11]	A movement-aware handover avoiding frequent handovers between two base stations.
Handover Performance Optimization [12]	A handover algorithm that seeks to optimize a combined cost function involving the battery lifetime of mobile nodes and load balancing over the APs/BSs.

Table 3. *Key contributions of related works in WLAN and WiMAX heterogeneous networks.*

- 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).

From the analysis of the differences in the QoS frameworks of both technologies, the integration of WLAN and WiMAX has to take into account a QoS mapping procedure. Gakhar *et al.* [4] proposed an architecture to provide end-to-end QoS in an integrated 802.16/802.11 network. This proposal strives to map the QoS requirements of an application originated in an IEEE 802.11e network to those of a serving WiMAX network, and to ensure the transfer of data having appropriate QoS backward compatible with those in the IEEE 802.11e network.

Radio Resource Management, Scheduling, and Connection Admission Control

Efficient radio resource management, scheduling and connection admission control are still open issues in WiMAX networks, and therefore, they are also crucial in integrated WiMAX and WLAN wireless networks. In such an integrated network, radio resources need to be allocated by considering not only the local connections from the WLAN APs and standalone subscriber stations (SSs), but also the relay connections from other base stations (BSs) at a WiMAX BS. Without these scheduling and control techniques, we cannot provide e-healthcare service for a huge number of mobile users.

A hierarchical bandwidth management and admission control framework [5] was proposed for integrated IEEE 802.16/802.11 wireless networks. Specifically, a two-level game-theoretic hierarchical model for radio resource allocation was implemented. At the first level, a bargaining game between the set of standalone IEEE 802.16 SSs and the WLAN APs is formulated to determine the optimal burst size for WMAN and WLAN connections. At the second level, connections corresponding to different service types in the standalone IEEE 802.16 SSs establish a coalition to share the allocated bandwidth based on the results of the bargaining game. For standalone SS connections, the admission control scheme was devised based on the total utility of services. For WLAN connections, admission control based on a non-cooperative game between the corresponding WLAN AP and the WMAN BS is formulated to determine whether a new WLAN connection can be accepted or not. The admission control problem can be formulated as a general sum game between these two networks.

To demonstrate the effectiveness of integrating WiMAX and WLAN networks, a quantitative evaluation on the system capacity with QoS provisioning of an integrated WiMAX and WLAN for VoIP was reported in [6]. A proba-

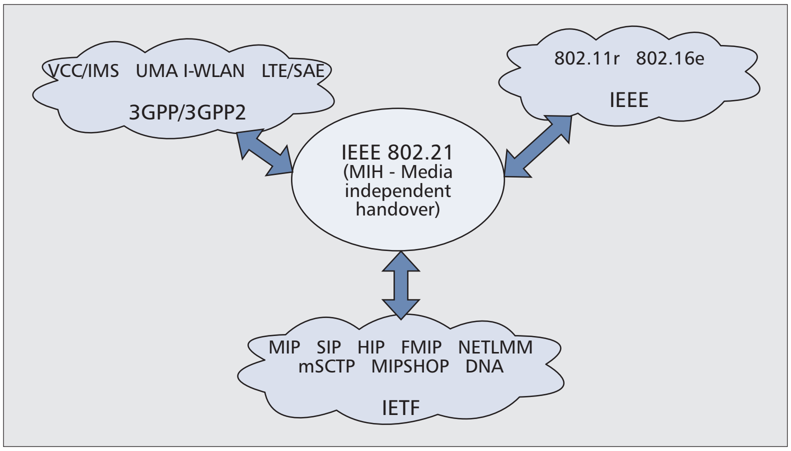

Figure 1. *Relationship of different handover standards proposed by different standardization organizations (IETF, 3GPP, IEEE).*

bilistic resource reservation scheme for WLAN to WiMAX handover traffic was proposed. This scheme takes blocking probability of new calls into consideration to reduce the dropping probability of handover calls.

A BS assisted adaptive scheduling mechanism [7] was proposed to be implemented at the customer premises equipment to provide QoS guarantees for real-time traffic and a buffer bound for non-real-time traffic over the backhaul network. Another scheduling algorithm [8] was proposed to reduce WiMAX users' delay by rerouting traffic through lightly loaded WLAN APs.

Although several solutions have been proposed for radio resource management, traffic scheduling, and connection admission control for integrated WiMAX and WLAN networks, performance comparison and applicability of various schemes for telemedicine require further studies.

Handover/Mobility Management

Handover management is one of the most challenging issues to be solved for seamless integration of wireless networks and providing continuous e-healthcare service for mobile users. For instance, the communication between a hospital and an ambulance must not be disconnected for pre-hospital care in spite of the movement of the ambulance. Handover and mobility management enable the moving ambulance to maintain communication to the hospital. Standardization organizations such as the Third Generation Partnership Project (3GPP), Internet Engineering Task Force (IETF), and IEEE have proposed different and, in some cases, complementary approaches to the design of architectures and protocols that enable seamless handover in heterogeneous networks. Some important handover standards are illustrated in Fig. 1. IETF protocols require optimizations and standardized triggers to provide seamless handover; they lack standardized transport layer triggers. On the other hand, 3GPP solutions are not flexible, and the proposed architecture is cellular-operator-dependent. Furthermore, 3GPP's solution for providing seamless handover is not yet well defined in current releases. IEEE 802.21 proposes a unified solution for providing seamless handover across heterogeneous networks. This framework provides universal link triggers to facilitate handover phases, and can be used in conjunction with various mobility management protocols for different layers and network architectures. Table 3 highlights key contributions of some recent work [9–12] on handover management in integrated WLAN and WiMAX networks.

Dai *et al*. [9] proposed a new user-centric handover algorithm that combines a trigger to continuously maintain the connection, and another one to maximize the user throughput by taking into account link quality and cell load.

The IEEE 802.21 draft standard has not defined security mechanisms. Sun *et al*. [10] proposed a secure handover mechanism that adopts symmetric cryptography and asymmetric cryptography to provide security protections during the vertical handover process.

Lee *et al*. [11] proposed a movement-aware vertical handover algorithm between WLAN and mobile WiMAX for seamless ubiquitous access. The proposed handover algorithm exploits movement patterns, adjusts the dwell time adaptively, and predicts the residual time in the cell of target BS to avoid unnecessary handovers in the integrated WLAN and mobile WiMAX networks.

Lee *et al*. [12] proposed a generalized vertical handover decision algorithm that optimizes handover performance by using a combined cost function involving the battery lifetime of the mobile nodes and load balancing over APs/BSs. An enhanced algorithm for the case when the ad hoc mobile nodes that form vehicular ad hoc networks (VANETs)/MANETs are included in heterogeneous networks was further proposed. This enhanced algorithm allows proxy nodes to provide connectivity to the nearest AP or BS for ad hoc mobile nodes (MNs) to share transit loads, with the goal of balancing their consumption of battery power.

WLAN and WiMAX Heterogeneous Network Deployment Scenarios 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 2 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 Fig. 2 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

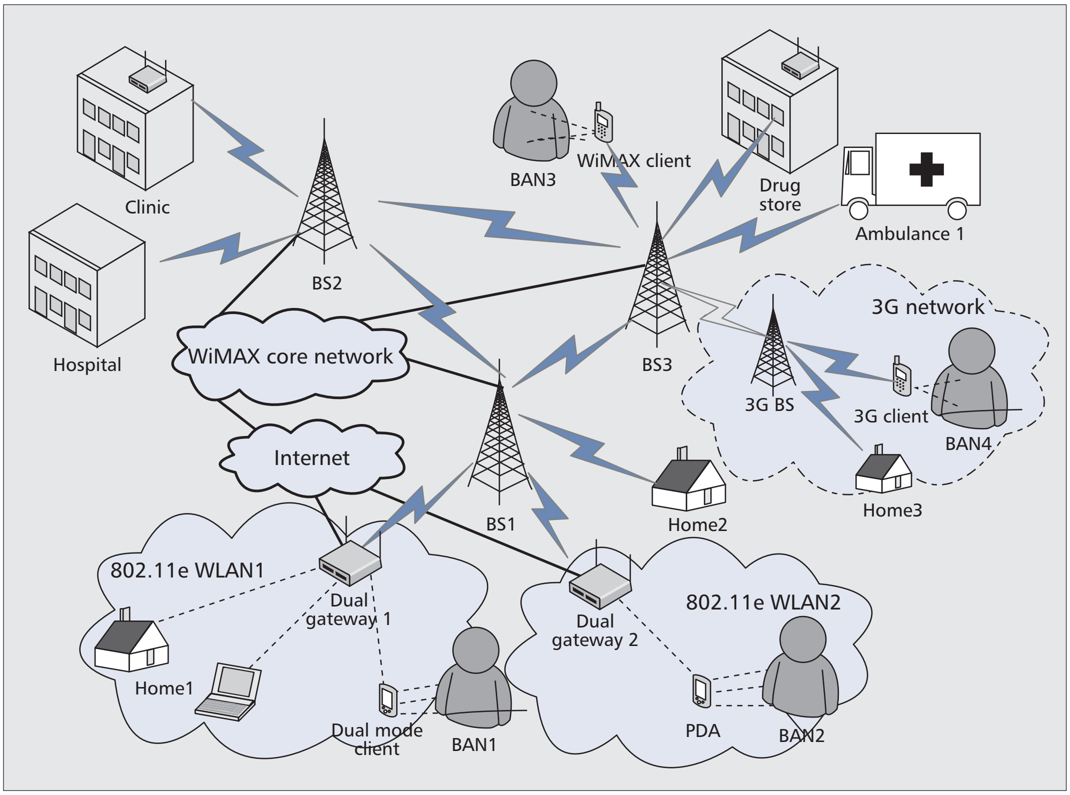

Figure 2. *IEEE 802.11e/WiFi and 802.16e/WiMAX based wireless telemedicine network.*

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

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 Fig. 2.

The integrated WiMAX and WLAN wireless telemedicine networks can be deployed in the following scenarios.

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. The integrated 802.16/802.11 wireless-network-based telemedicine system can also provide medical services for BANs through SM (BAN2 and BAN3) or DM (BAN1) mobile clients. The mobility of BAN2 is limited within WLAN2 due to only one WLAN interface being equipped with the client.

Home care network/TeleHomeCare: Home care is a growing field in health care and is a promising solution to the medical problems of modern society [14]. The population census indicates an increasing trend of the senior population. Furthermore, modern life is becoming more stressful than ever; therefore, prolonged treatment is becoming more necessary. Home care via treatments in the patient's house with the assistance of the family reduces the need to transport patients between homes and hospitals. 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 [1].

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.

Mobile Telemedicine Systems

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

WiMAX technology can also enhance pre-hospital care in an ambulance. Ambulance crews can access the medical information database in a hospital and can retrieve the required medical information of patients through WiMAX networks.

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) [15] 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.

Conclusion

The application of integrated WiMAX and WLAN broadband wireless access technologies for telemedicine services and the related protocol issues have been discussed in this article. An overview of WLAN and WiMAX networks has been provided, followed by a comparison of WLAN and WiMAX. Open research issues related to QoS support, radio resource management, scheduling, and connection admission control, as well as handover management in the WLAN and WiMAX heterogeneous networks have been discussed. Finally, potential applications and deployment scenarios of WLAN and WiMAX heterogeneous networks for telemedicine services are discussed and elicited.

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