33rd Annual International Conference of the IEEE EMBS
Boston, Massachusetts USA, August 30 - September 3, 2011

Mapping of Multiple Parameter M-health Scenarios to Mobile WiMAX QoS Variables

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Abstract—**Multiparameter m-health scenarios with bandwidth demanding requirements will be one of key applications in future 4G mobile communication systems. These applications will potentially require specific spectrum allocations with higher quality of service requirements. Furthermore, one of the key 4G technologies targeting m-health will be medical applications based on WiMAX systems. Hence, it is timely to evaluate such multiple parametric m-health scenarios over mobile WiMAX networks.**

In this paper, we address the preliminary performance analysis of mobile WiMAX network for multiparametric telemedical scenarios. In particular, we map the medical QoS to typical WiMAX QoS parameters to optimise the performance of these parameters in typical m-health scenario.

Preliminary performance analyses of the proposed multiparametric scenarios are evaluated to provide essential information for future medical QoS requirements and constraints in these telemedical network environments.

***Index Terms*—m-health, e-health, Mobile WiMAX, QoS, 4G systems**

I. Introduction

M-HEALTH is an evolving paradigm that brings together the evolution of emerging wireless communications and network technologies with the concept of 'connected healthcare' anytime and anywhere [1].

The recent advances in broadband mobile networks have resulted in the development of several new multimedia applications based on these emerging technologies. However, in comparison WiMAX based m-health domain and medical broadband applications have received less attention compared to other areas. M-health and wireless telemedical broadband services are considered as one of the key applications in the emerging mobile broadband systems. For example, the use of such services for providing expert real time mobile diagnostics in remote areas in developing countries is vital for enhancing the much needed healthcare services in these countries. However, these services need to be further validated and tested especially from the medical quality of service (m-QoS) perspective and their adaptability to clinical constraints and conditions.

It is well known that WiMAX is a wireless broadband system that provides enhanced QoS characteristics. WiMAX includes fixed and mobile standards based on IEEE 802.16-2004 and IEEE 802.16e-2005 respectively. In particular, the IEEE 802.16e (Mobile WiMAX) standard aims to provide broadband connectivity to mobile users in wireless metropolitan area network (WMAN) environments [2]. The IEEE 802.16/WiMAX technology is considered a suitable choice for providing broadband telemedical services in both fixed and mobile environments with clinically acceptable remote diagnostic quality and potential cost effective solutions [3]. Several telemedical scenarios using WiMAX have been defined in recent works [3, 4]. Furthermore, a new m-QoS has been introduced in conjunction with these telemedical studies [5].

Multiparameter evaluation of different telemedical scenarios using cellular networks (3G, GPRS, and HSPA) has been reported in earlier work [1]. However, to-date there is no such study addressing the performance of such multiparametric telemedical scenarios in WiMAX networks. In this paper we map the relevant m-QoS to typical WiMAX QoS network parameters to optimise the performance of these multiparametric telemedical scenarios in different wireless conditions.

The paper is organized as follows. In section II, we review some recent multiple m-health and wireless telemedical scenarios. In section III, we discuss the relevant medical quality of service indices related to different m-health applications considered in this work.

In section IV we explain WiMAX QoS parameters and provide a mapping between m-health services and WiMAX QoS parameters. In section V, we present the simulation results and discussion. Finally, section VI concludes the paper with recommendations for future work in this area.

II. M-health over Mobile WiMAX Network

M-health is one of the emerging application areas where WiMAX technologies can substantially contribute to improve the daily activities and enhance the quality of life [4, 6].

Manuscript received March 26, 2011.
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978-1-4244-4122-8/11/$26.00 ©2011 Crown

The advantages of using WiMAX technology especially for broadband scenarios are listed as follows: high bandwidth, integrated services, QoS support, and security [3]. In particular, this technology can benefit the healthcare services in poorer regions and developing countries. In general, m-health scenarios can be categorized as accident, clinical care and home care scenarios [3, 7]. The accident and emergency (A&E) category include transmission of multiparametric data such as blood pressure, heart rate, ROI (region of interest), ultrasound video streaming, video conference, and voice conference. Future ambulance units can be equipped with mobile WiMAX systems that have wireless connection to WiMAX base station and provide instant clinical diagnostics on the move. Clinical care category refers to local/remote clinic scenario where specialist experts are not available. This scenario includes multiple medical data and parameters such as ECG (electrocardiography), blood pressure, heart rate, ROI, radiology, MRI (magnetic resonance imaging), ultrasound video streaming, video conference, and voice conference from supported applications. Home care follow-up category provide medical/health services to especially elderly people to be monitored without the need to travel to the hospital. This scenario includes multiple medical applications such as transmitting simultaneous ECG, blood pressure, heart rate, ROI, ultrasound video streaming, video conference, and voice conference.

Fig. 1 shows typical m-health scenarios over mobile WiMAX network. All these categories necessitate the need for an alternative multiple medical parametric networking architectures that provide high bandwidth requirements with cost effective route compare to the cellular approach. In this paper, we address this challenge and in particular we address the mapping of medical QoS to typical WiMAX QoS parameters and the need to consider these boundaries in future m-health applications.

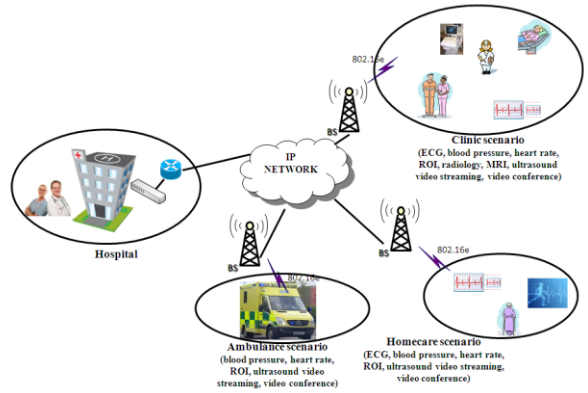

Fig. 1. Typical m-health scenarios over mobile WiMAX network

TABLE I

M-HEALTH SERVICE QOS REQUIREMENTS [7]

M-health service	Data rate	QoS indices
Electrocardiography (ECG) monitoring	24 Kb/s/12 channels	Delay
Blood pressure monitoring (Sphygmomanometer)	< 10 Kb/s	Delay
Heart rate (stethoscope)	~ 120 Kb/s	Packet loss, Delay
Region of Interest JPEG Image	15- 19 Mbytes	PSNR, Frame size, Packet loss,
Radiology	~ 6 Mbytes	PSNR, Frame size, Packet loss
Magnetic resonance imaging (*MRI*)	< 1Mbytes	PSNR, Frame size, Packet loss
Ultrasound video streaming	250 Kb/s – 1.2 Mb/s (WMV2)	PSNR, Frame Rate, Frame size, Packet loss, Delay

III. MEDICAL QUALITY OF SERVICE AND MULTIPARAMETER M-HEALTH APPLICATIONS

Different m-health applications such as emergency telemedicine, mobile patient monitoring, mobile medical data, mobile robotic system, post-hospital care, teleconsultation collaborative, and medical information management services all require specific data rates and QoS indices. These are summarised in Table I and the details of these applications are described elsewhere [7]. However, no study to-date mapped these QoS requirements to multiple data transmissions over WiMAX networks. In the next section, we will briefly present this approach and discuss the relevant challenges of such mapping process.

IV. MAPPING M-QOS WITH MULTIPLE TELEMEDICAL SERVICES

In general, QoS refers to different parameters that present different types of network traffic, network status, and the quality of experience which a user will encounter. QoS variables depend on specific application, in other words the required thresholds and traffic specifications. Most of the applications use bit error rate, jitter, latency, PSNR and throughput as basic QoS variables. To meet these QoS requirements, BS (base station) should have a suitable mechanism for resource allocation. However, the IEEE.802.16/WiMAX standard does not specify any specific resource allocation algorithm and the equipment suppliers have their own mechanisms and relevant algorithms to adapt. These include Fair Scheduling, Distributed Fair Scheduling, Max Min Fair Scheduling, Energy Efficient Scheduling, Feasible Earliest Due Date (FEDD), and Channel State Dependent Round Robin (CSD-RR) [8].

In general, IEEE 802.16 has five QoS classes classified as follows [2, 6]:

- UGS (Unsolicited Grant Scheme): This service class supports constant bit rate in other words it has a fixed periodic bandwidth allocation whenever the connection is established. The requirement grant size is calculated by the BS without any further requests or polls. It is suitable for applications with fixed periodic packet size such as VOIP without silence suppression.

- rtPS (Real Time Polling Service): This service class is for real time variable bit rate (VBR) traffic at periodic interval such as MPEG video. The bandwidth is allocated based on required QoS parameters such as delay or traffic arrival rates. Due to the traffic is variable; the BS needs to regularly poll each MS (mobile station) to determine what allocations need to be made.

- ertPS (Extended Real Time Polling Service): This service class is based on UGS and rtPS, it is suitable for VOIP with silent period, unlike the UGS, BS should poll the MS during the silent periods to determine when the traffic will be started.

- nrtPS (Non Real Time Polling Service): This service class is designed for non-real time variable bit rate traffic which the delay is not important however minimum band width is guaranteed, it is used for FTP traffic.

TABLE II
QOS PARAMETERS IN DIFFERENT CLASSES [6]

	UGS	ertPS	rtPS	nrtPS	BE
Maximum sustained traffic rate	√	√	√	√	√
Minimum reserved traffic rate			√	√	
Maximum latency	√	√	√		
Tolerated jitter	√	√			

TABLE III
MOBILE BROADBAND M-HEALTH SERVICE QOS MAPPING

M-health service	Traffic Priority (0 for No-priority 7 for high priority)			WiMAX QoS class
	Accident case	Clinical care case	Homecare case	
Electrocardiography (ECG) monitoring	NA	3	5	UGS
Blood pressure monitoring (Sphygmomanometer)	1	2	5	UGS
Heart Rate	1	2	5	UGS
Region of Interest JPEG Image	5	6	5	nrtPS
Radiology	NA	6	NA	nrtPS
Magnetic resonance imaging (*MRI*)	NA	6	NA	nrtPS
Ultrasound video streaming	7	7	5	rtPS
Videoconferencing (Teleconsultation)	2	5	3	rtPS
Voice conferencing (Teleconsultation)	4	5	3	rtPS

-BE (Best Effort): This service class is used for data stream with no support for delay or throughput. Telnet and web browser data use this class.

Table II shows a comparison list of these WiMAX QoS service classes [6]. The users can add the traffic priority to these service classes to differentiate connections even within the same service class. The details of these are described elsewhere [6].

Table III shows some of relevant m-health services and their allocations for each corresponding m-health scenario together with their traffic allocation priorities and WiMAX QoS classes. These traffic priority mappings were obtained based on our extensive clinical poll and advice with experimental work with NHS clinical partners in the UK. The traffic priority assigns the priority level for each service according to the proportionate level of clinical importance and the critical level of the service.

V. EXPERIMENTAL SET-UP AND RESULTS

In order to validate the medical scenarios and QoS mapping issues explained earlier, a simulated medical traffic model over mobile WiMAX using OPNET® is implemented; OPNET® is a software package that provides network simulation and analysis tools. The simulation scenario includes 3 BSs and 3 MSs, where the MSs are generated different types of m-health data traffic presented earlier. The medical expert's station is connected to the BS through a LAN as shown in the simulation set-up (Fig. 2).

Table IV shows the relevant WiMAX system parameters used in the simulation process. These are widely used in most of the earlier WiMAX networking studies in the literature [9].

Fig 3. shows a sample of the simulation results. This figure shows the probability density function of ultrasound video streaming and blood pressure delay based on QoS mapping, ultrasound video streaming service achieves better latency time in comparison to blood pressure data transmission. The preliminary results obtained in terms of the application end to end delay and jitter shows the successful correlation of the proposed multiparametric QoS mapping with the acceptable (m-QoS) bounds defined earlier [5]. The maximum delay is 160 ms, this represents an acceptable delay for ultrasound video streaming [5].

Fig. 4 shows delay jitter of the ultrasound video streaming in the three described scenarios (accident, clinical care and home care). Delay jitter needs to be guaranteed by the delivering network in order to provide a satisfactory video streaming service. These results indicate that the clinic and home care scenarios have higher jitter because of the higher medical applications load in these scenarios. However all jitter values are within the acceptable range (70ms) [5]. Table V summarises the comparative end to end delay results of different m-health services. These indicate that the obtained m-QoS bounds are within the acceptable range.

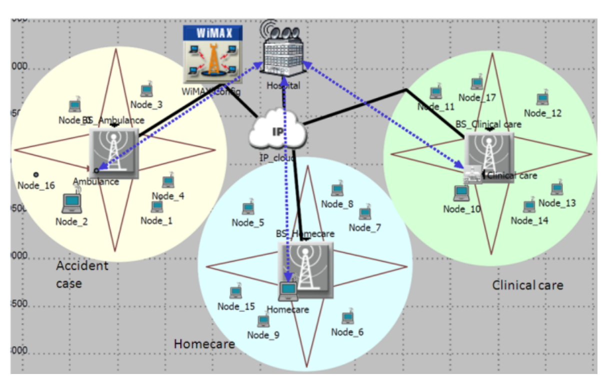

Fig. 2. Simulation set-up of the multiparametric m-health WiMAX network

Table IV
WiMAX simulation parameters

Parameters		Value
Duplex Mode		TDD
Carrier frequency		5.8 GHz
Bandwidth		5 MHz
Frame length		5 ms
Modulation/coding		64QAM 3/4
BS	Antenna Gain	16 dBi
	Noise Figure	5 dB
	Tx Power	35 dBm (3.162 W)
MS	Antenna Gain	0 dBi
	Noise Figure	7 dB
	Tx Power	27 dBm (0.501 W)
Path loss		Free Space

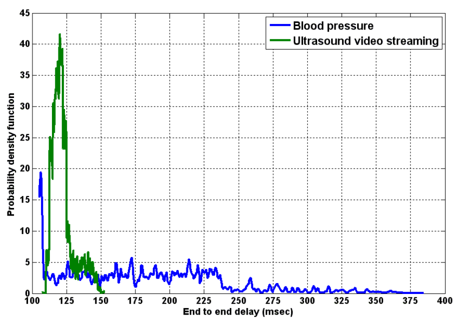

Fig. 3. Probability density function of ultrasound video streaming and blood pressure latency

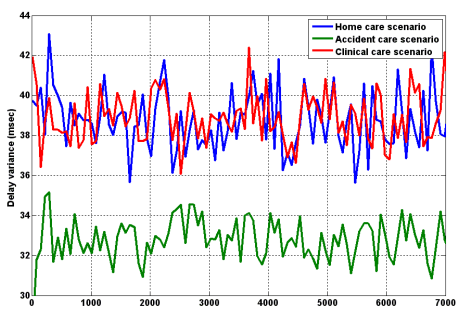

Fig. 4. Delay variance of ultrasound video streaming in clinic, homecare, and ambulance scenarios

TABLE V
AVERAGE DELAY RESULTS FOR M-HEALTH SERVICES [3, 5]

M-health service	Average delay (msec)		
	m-QoS	Single application	Multiparametric
ECG monitoring	<300	167	189
Blood pressure monitoring	<1000	160	185
Heart Rate	<1000	297	300
Ultrasound video streaming	<300	122	125

I. CONCLUSION AND FUTURE WORKS

In this paper we described the mapping of multiple parameter m-health scenarios to mobile WiMAX QoS variables. Three medical scenarios were defined over mobile WiMAX using OPNET® modeler to investigate the network performance and the functionality of the QoS mappings. The simulation results indicate the successful implementation of the QoS mapping with the defined m-QoS bounds. This work is part of an ongoing study on cross layer implementation of m-health services over WiMAX networks.

Ongoing work is currently underway to carry out further tests on the WiMAX model and to carry out real time testing of the defined m-health scenarios and provide experimental comparison with the simulated results.

ACKNOWLEDGMENT

The third author would like to acknowledge the support of the British council UKIERI (UK India Education and Research Initiative) and the Development Partnerships in Higher Education Programme (DelPHE) for funding this work. Also we would like to express our thanks to Dr. N. Amso from Cardiff University Medical School for his medical advice and for providing medical information.

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