34th Annual International Conference of the IEEE EMBS
San Diego, California USA, 28 August - 1 September, 2012

# Dynamic Subframe Allocation for Mobile Broadband m-health using IEEE 802.16j Mobile Multihop Relay Networks

Ali Alinejad, *Student Member, IEEE*, R. S. H. Istepanian, *Senior Member, IEEE*, N. Philip, *Member, IEEE*

*Abstract*—The concept of 4G health will be one of the key focus areas of future m-health research and enterprise activities in the coming years. WiMAX technology is one of the constituent 4G wireless technologies that provides broadband wireless access (BWA). Despite the fact that WiMAX is able to provide a high data rate in a relatively large coverage; this technology has specific limitations such as: coverage, signal attenuation problems due to shadowing or path loss, and limited available spectrum. The IEEE 802.16j mobile multihop relay (MMR) technology is a pragmatic solution designed to overcome these limitations. The aim of IEEE 802.16j MMR is to expand the IEEE 802.16e's capabilities with multihop features. In particular, the uplink (UL) and downlink (DL) subframe allocation in WiMAX network is usually fixed. However, dynamic frame allocation is a useful mechanism to optimize uplink and downlink subframe size dynamically based on the traffic conditions through real-time traffic monitoring. This particular mechanism is important for future WiMAX based m-health applications as it allows the tradeoff in both UL and DL channels.

In this paper, we address the dynamic frame allocation issue in IEEE 802.16j MMR network for m-health applications. A comparative performance analysis of the proposed approach is validated using the OPNET Modeler®. The simulation results have shown an improved performance of resource allocation and end-to-end delay performance for typical medical video streaming application.

***Index Terms*—m-health, 4G-health, WiMAX, Mobile WiMAX, IEEE 802.16j, 4G systems, Dynamic subframe allocation, medical QoS.**

## I. Introduction

THE introduction of 4G technology is one of the major breakthroughs and turning points in m-health evolution [1]. It is well known that 4G systems aim to provide such high speed, high capacity, and IP based personalized services for nomadic and mobile wireless environment. In general, mobile multimedia service, mobile ubiquitous network, and AAA (Anytime, Anywhere, and Always on) access are main targets of beyond 3G (3rd Generation) networks [2]. Mobile WiMAX network technology is one of the significant mobile wireless network technologies that constitutes part of the 4G evolution. In general, WiMAX aims to provide wireless broadband services on the scale of the metropolitan area network (MAN) and is based on the IEEE 802.16 standard. The main objective of the Mobile WiMAX standard is to cover the major weaknesses of Wireless LAN and 3G cellular systems such as coverage area and data rate respectively. Because WLAN has short range coverage and 3G networks cannot support high data rate despite of their long range coverage. To this aim, this standard deploys a specification that supports a mobile broadband access system and high data rate [3].

Despite the fact that WiMAX is able to provide a high data rate in a relatively large coverage; it has specific limitations [3, 4]:

(i) Limited coverage area
(ii) signal attenuation due to shadowing or path loss
(iii) limited available spectrum

To overcome these challenge, a new mobile multihop relay (MMR) technology was developed to deploy relay stations instead of using more expensive BSs [4].

IEEE 802.16j standard was introduced in July 2009 with MMR capabilities [4]. The relaying is the most cost-effective approach to extend the wireless coverage area [5]. In other words, a relay station (RS), with less functionality than a base station, can provide high data rate in remote areas [6].

In recent years, several performance analysis and bandwidth allocation mechanisms have been carried out [4, 7]. However, to-date there is no study addressing the performance analysis of optimised subframe allocation for mobile broadband m-health scenarios in WiMAX networks. From the m-health perspective the dynamic bandwidth allocation is important due to the asymmetry of the UL and DL data rates and bandwidth allocations required for different broadband m-health applications. In this paper, we introduce the application of the 802.16j standard for typical m-health broadband system i.e. real-time ultrasound video streaming. The fairness issue is also investigated and an algorithmic solution is proposed for best end-to-end QoS parameters.

Manuscript received March 15, 2012.
A. Alinejad is with the Department of Computer Engineering, Islamshahr Branch, Islamic Azad University, Islamshahr, Iran, and also with the Medical Information and Network Technologies Centre, Kingston University, London, KT1 2EE, U.K. (e-mail: a.alinejad@iiau.ac.ir, alinejad@ieee.org).
R. S. H. Istepanian and N. Y. Philip are with the Medical Information and Network Technologies Centre, Kingston University, London, KT1 2EE, U.K. (e-mail: r.istepanian@kingston.ac.uk; n.philip@kingston.ac.uk).

The paper is organized as follows. In section II, we describe mobile multihop relay network specification and architecture. In section III, we review the relevant m-health scenarios and applications considered in this work. This section also explains optimised fairness subframe allocation and provides a dynamic subframe allocation model for m-health services.

In section IV, we present the simulation set-up, results, and discussion. Finally, section V concludes the paper with recommendations for future work in this area.

## II. Mobile Multihop Relay Network

Historically, the first generation of wireless communication technology aimed to provide analogue voice services, the second generation aimed to provide digital voice services, the third generation aimed to provide mobile multimedia services, and the fourth generation aims to provide high data rate services with reliable broadband communication systems [8-10]. However, the high date rate with reliable system is difficult to obtain at cell edges due to signal to noise (SNR) issue. The IEEE 802.16j can overcome these issues with increasing coverage area and efficient spectral usability [5, 10]. In the following sections, a brief introduction of WiMAX architecture and its specification will be explained.

In recent years, several WiMAX standards have been ratified including the IEEE 802.16e and the IEEE 802.16j. The aim of IEEE 802.16j standard is to expand the IEEE 802.16e's capabilities with including multihop capability [5]. In Multihop WiMAX configuration, the BS is in charge of managing wireless access for SSs in each coverage area. There is no limitation on the number of hops between MS and BS [5]. Each MS in the coverage area can communicate with BS directly (one hop) or through a RS (two hops) that will structure a two level communication tree illustrated in Fig. 1 [7].

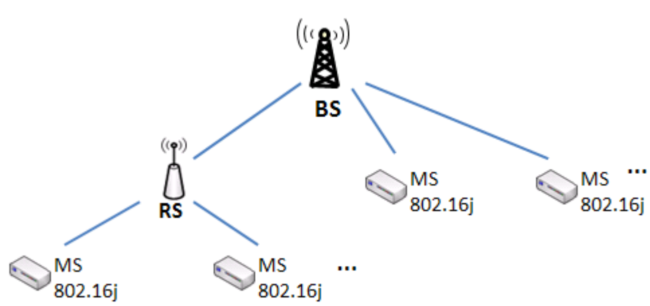


Figure 1. Mobile multihop relay communication hirarchy [7]

Fig. 2 shows a typical m-health based multihop WiMAX network [10]. The WiMAX network includes a group of WiMAX cells that BSs are connected to core network (CN). In WiMAX network configuration, the WiMAX cell consists of one base station, one or more subscriber stations either fixed or mobile and one or more relay stations located in the coverage area.

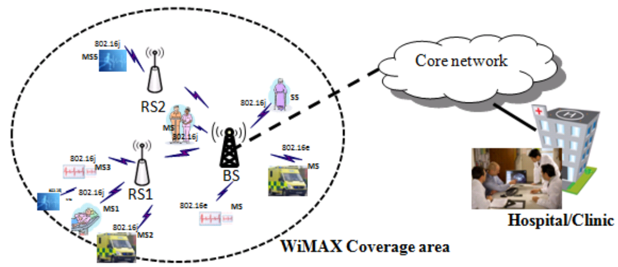


Figure 1. General 802.16j based broadband m-health system

## III. 802.16j Based Broadband M-Health System Architecture

The advantages of WiMAX technology for m-health scenarios include: High bandwidth, integrated services, QoS support, and security. As result, this technology is a suitable choice for different m-health applications and scenarios.

In general, m-health scenarios can be categorized as accident and emergency (A&E), clinical care, and home care scenarios [2, 10].

Fig. 3 shows the multihop WiMAX broadband m-health system. In this work, the ambulance (A&E) scenario traffic includes blood pressure, heart rate, ROI (region of interest), ultrasound video streaming, voice, and video conference. The different medical traffic specifications and QoS indices are shown in Table I [10].

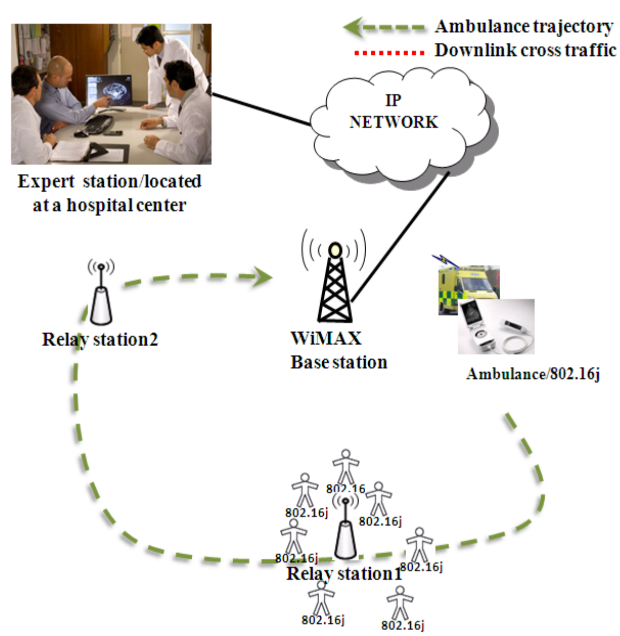


Figure 3. Typical Ambulance scenario over IEEE 802.16j MMR network

The WiMAX TDD (Time Division Duplex) is the most common WiMAX implementation in which the Uplink subframe follows the downlink subframe with specified timing gap. In other words, DL and UL subframes share same frequency at different time. WiMAX frame structure is shown in Fig. 4.

Table I
Data Traffic specification of m-health emergency scenario

| m-health service | Data rate | QoS indices |
|---|---|---|
| Electrocardiography (ECG) monitoring | 24 kb/s/12 channels | Delay |
| Blood pressure monitoring | < 10 kb/s | Delay |
| Digital audio stethoscope (heart sound) | ~ 120 kb/s | Packet loss, Delay |
| Region of Interest JPEG Image | 15- 19 Mbytes | PSNR, Frame size, Packet loss, |
| Ultrasound video streaming | 250 Kb/s – 1.2 Mb/s (WMV2) | PSNR, Frame Rate, Frame size, Packet loss, Delay |
| Video/Audio conference | ~ 1 Mb/s | Packet loss, Delay |

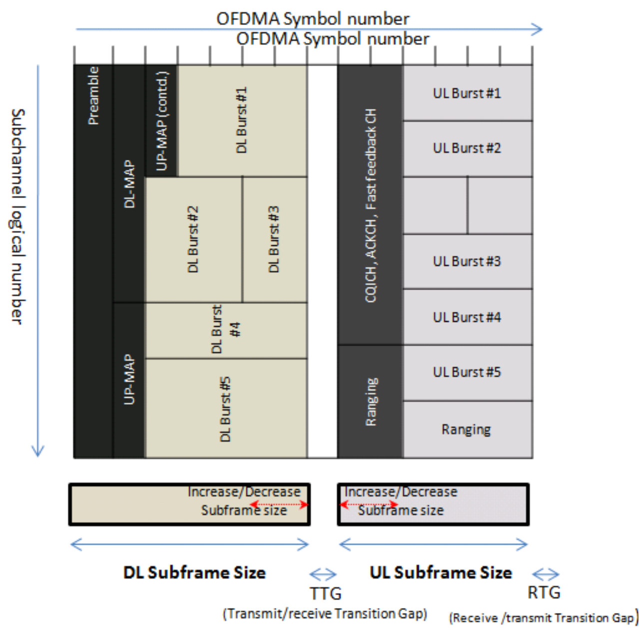


Figure 2. Typical WiMAX Frame structure [11]

In general, the DL traffic load is usually greater than UL traffic load. However, in the most of m-health applications, the UL traffic is more significant. The UL and DL subframe allocation is usually fixed. However, dynamic frame allocation is a useful mechanism to optimize uplink and downlink subframe size dynamically based on the traffic conditions through real-time traffic monitoring.

The proposed mechanism shown in Fig. 5 monitors DL and UL subframe usage size (percentage), UL/DL block error rate, and radio link delay (ms) to optimize the UL and DL subframe split ratio.

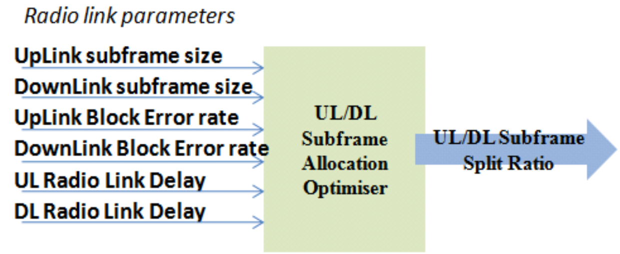


Figure 3. The proposed UL/DL subframe allocation optimiser

## IV. Simulation Results

In order to validate the proposed dynamic subframe allocation, a simulated medical traffic model over mobile WiMAX using OPNET Modeler® is implemented. The simulation scenario includes 1 BS, 2 RSs, and 8 MSs where the 7 MSs are generating cross traffic to increase subframe usage (percentage). The medical expert's station is connected to the BS through an IP network. The implemented IEEE 802.16j (MMR) m-heath scenario was shown in Fig. 3. The ambulance trajectory starts from BS direct coverage to RS1 and RS2 coverage area. In this work, we use ambulance scenario including ultrasound video streaming, ECG, voice and video conference applications.

Table II shows the relevant WiMAX system parameters used in the simulation process. These parameters are widely used in most of the earlier WiMAX networking studies in the literature [12].

Table II
WiMAX simulation parameters

| Parameters | | Value |
|---|---|---|
| Duplex Mode/ Frame length | | TDD / 5ms |
| Carrier Freq/ Bandwidth | | 5.8 GHz/5MHz |
| Modulation/coding | | Adaptive |
| 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. 6 (a) shows the DL data burst usage (%) in both dynamic and fixed frame allocation. And Fig. 6 (b) compares the UL subframe allocation results in these methods. Fig. 7 shows a comparative end-to-end delay. It is clear that the optimised subframe scenario gains better end-to-end delay and frame utilization especially in high rate uplink traffic.

The preliminary results obtained in terms of data burst usage and the application end-to-end delay shows the successful deployment of the proposed allocation mechanism. These performance analysis results are based on the simulation tests carried out using the proposed approach. However, further experimental studies are required to validate these performance results in real-time clinical environments.

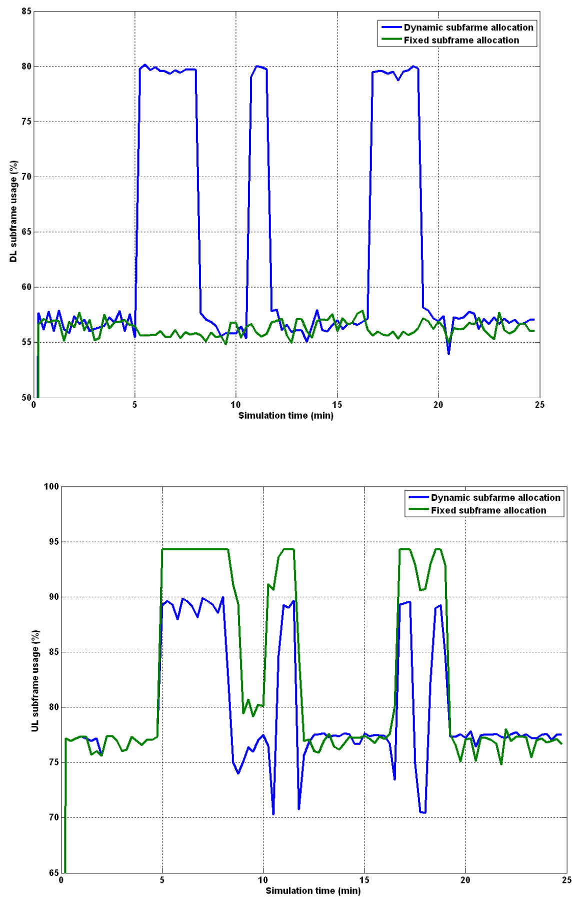


Figure 6. Fixed and dynamic subframe allocation. (a) Downlink subframe utilization. (b) Uplink subframe utilization

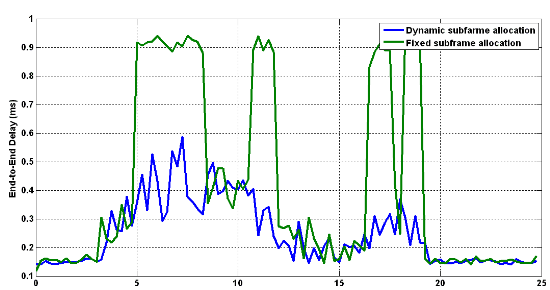


Figure 7. Ultrasound video streaming end-to-end delay comparison of fixed and dynamic subframe allocation

## V. CONCLUSION AND FUTURE WORKS

In this paper we described a dynamic subframe resource allocation mechanism for broadband m-health over IEEE 802.16j MMR network. A typical m-health ambulance scenario has been simulated over IEEE 802.16j using OPNET® modeler to investigate the subframe utilization improvement and end-to-end delay performance. The simulation results indicate the successful implementation of the proposed mechanism and efficient subframe utilization. The proposed approach takes into account the radio link block error rate, delay, and subframe size as well as the real-time m-health timing considerations.

Future studies are going on the experimental validation of this approach in real-time medical streaming applications. Furthermore, real testbed performance analysis of the proposed mechanism in clinical setting need to be further investigated as a part of the future work in this area.

## ACKNOWLEDGMENT


All the authors would like to acknowledge the support of the British council UKIERI (UK India Education and Research Initiative) for funding this work.


## REFERENCES


[1] Istepanian, R. S. H. and Zhang Y.T., "4G health: The Long Term evolution of m-health- Editorial," IEEE Transactions on Information Technology in Biomedicine, vol. 16, no. 1, pp. 1-5, Jan. 2012.

[2] Alinejad, A. ,Philip, N.Y., and Istepanian, R.S.H., "Cross-Layer Ultrasound Video Streaming Over Mobile WiMAX and HSUPA Networks," IEEE Transactions on Information Technology in Biomedicine, vol. 16, no. 1, pp. 31-39, Jan. 2012.

[3] Teo, K.H., Tao, Z. and Zhang, J. 'The Mobile Broadband WiMAX Standard', *Signal Processing Magazine, IEEE*, vol. 24, no. 5, Sep, pp. 144 – 148, 2007.

[4] Chen, Y., and Darwazeh, I. End-to-end delay performance analysis in IEEE 802.16j Mobile Multi-hop Relay (MMR) networks. 18th International Conference on Telecommunications (ICT), pp. 488-492, 2011.

[5] S. W. Peters and R. W. Heath Jr., "The Future of WiMAX: Multihop Relaying with IEEE 802.16j," IEEE Commun.Mag., vol. 47, no. 1, pp. 104–11, Jan. 2009.

[6] M. Salem, A. Adinoyi,M. Rahman, H. Yanikomeroglu, D. Falconer, Y.-D. Kim, W. Shin, and E. Kim, "Fairness-aware radio resource management in downlink OFDMA cellular relay networks," IEEE Trans. Wireless Commun., 2010.

[7] J.-M. Liang, Y.-C. Wang, J.-J. Chen, J.-H. Liu, Y.-C. Tseng, Energy-efficient uplink resource allocation for IEEE 802.16j transparent-relay networks, Computer Networks, vol. 55, no. 16, pp. 3705–3720, 2011.

[8] B. Fong A. C. M. Fong, P. B. Rapajic, and G. Y. Hong, "Mobile telemedicine for accident and emergency scenes in tropical regions," WSEAS Trans. Commun., vol. 2, pp. 361–364, Oct. 2003.

[9] L. Chin-Feng, "Mobile telemedicine: A survey study," J. Med. Syst., vol. 2, pp. 1–10, 2010.

[10] Alinejad, A. ,Philip, N.Y., and Istepanian, R.S.H., Mapping of Multiple Parameter m-health Scenarios to Mobile WiMAX QoS Variables in *33rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC '11)*, IEEE, Aug 30 - Sep 3, Boston, USA, pp. 1532-1535, 2011.

[11] IEEE Standard 802.16-2009, *802.16-2009 IEEE Standard for Local and metropolitan area networks Part 16: Air Interface for Broadband Wireless Access Systems.* IEEE, 2009.

[12] Chen K.C. and De Marca J.R., "Resource Scheduling with Directional Antennas for Multi-hop Relay Networks in a Manhattan-like Environment," in *Mobile WiMAX*,, West Sussex: Wiley and Sons, pp. 165–180, 2008.