

A High Mobility Multipurpose Patient Monitoring System for Inter-building Communication

K.F. Tsang, H.Y. Tung, Philip Tsang, Jeffrey Soar

Abstract— A Multipurpose Patient Monitoring System embedded (MPMS) with mobile management profile and inter-building transmission is proposed and developed. This system enables the mobility of ZigBee devices and WiMAX long-distance transmission. Architecture, mobility framework and Adaptive Modulation/Coding (AMC) performance are discussed in details. It is evaluated that the new algorithm offers good efficiency and thus resulting in low management cost. The MPMS aids life saving by providing panic button and location tracking service. The system may be used in telemedicine applications.

Index Terms— ZigBee, WiMAX, mobile application profile, AMC

I. INTRODUCTION

AGING is a problem with no boundary. The worldwide population over age 65 is expected to more than double from 357 million in 1990 to 761 million by 2025.3 Older adults already constitute one-fifth of the total population in both Western Europe and Japan. Meanwhile, longevity has given rise to expensive age-related disabilities and diseases, such as Alzheimer's. In addition to the standard medical treatment for these conditions, a study in 1997 revealed that almost one-third of US adults, most of whom also held full-time jobs, served as informal caregivers—mostly to an elderly parent [1]. The cost of replacing this assistance to older Americans in 1997 was estimated to be no less than \$45 billion.

To solve the global aging problem, scientists proposed ubiquitous healthcare applications monitoring and managing the healthcare profile of patients. To lower further the healthcare cost, mobile computing is proposed to be used in the patient monitoring system. Various researchers [2] – [4] support that ZigBee is one of potential candidates for the mobile patient monitoring system and different solutions have been proposed. There is one former work [5] justifying that ZigBee could be the solution for short range data transmission inside operation rooms and intensive care units. These solutions mainly focus on the remote patient monitoring system which is used outside hospitals. However, monitoring patient with ZigBee device inside hospital is entirely another different story. Both short distance communication within one building and distant communication among buildings are required. So In this paper, another wireless technology, Worldwide Interoperability for

Microwave Access (WiMAX) allowing the deployment of cellular wireless metropolitan area networks (MAN) with non-line-of-sight (NLOS) radio conditions, is employed.

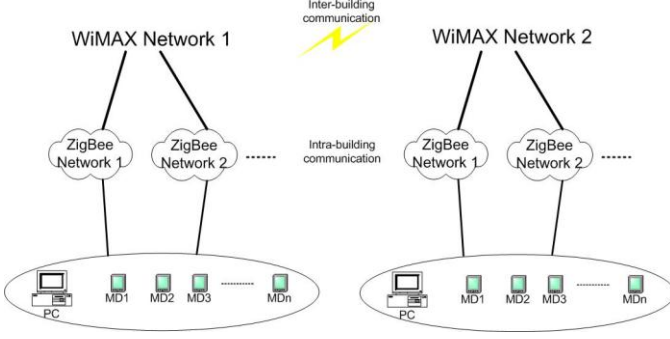
WiMAX is a Broadband Wireless Communications Technology based on IEEE 802.16[6]. The 802.16 standard was published in March 2002, which delivers high capacity, high mobility, and large coverage. In 2004, the IEEE 802.16d standard [7] was published for Fixed Wireless Access (FWA) applications. In December 2005 the IEEE ratified the 802.16e [8] amendment, which aimed to support Mobile Wireless Access (MWA) with seamless network coverage. This mobile WiMAX standard is now receiving considerable industrial attention. ZigBee is a standard providing specifications for communication protocols of the network layer based on the IEEE 802.15.4 standard for wireless personal area networks (WPANs) [9]. The protocols used in embedded applications requires low data rates and low power consumption [9]-[11]. With the use of WiMAX and ZigBee, a Multipurpose Patient Monitoring system (MPMS) for hospital usage is developed. The MPMS is a system combining medical equipment monitoring, patient tracking as well as personal paging. The MPMS collects medical data from patients and tracks the location of patient regularly. In addition, medical assistance can be called for immediately by simply pressing a panic button. The system further facilitates the operation of outpatient clinics and also helps to page patients to return to the hospital for medical treatment or examination. The main goal of the MPMS is to facilitate WiMAX and ZigBee systems to provide value-added high mobility capability. Functionally, the MPMS provides the mobility management and inter-building communication.

The remaining sections of this paper are organized as follows. The structure of MPMS and ZigBee mobile management profile handling handover issue in the system will be presented in section II. Adaptive Modulation/Coding (AMC) in WiMAX network enabling security transmission and testing result will be described in section III. And finally a conclusion will be given in section IV.

II. MOBILITY MANAGEMENT OF MPMS

Fig 1 shows the system structure of MPMS. ZigBee network is installed in every ward and it is responsible for transmitting monitoring signal within a building. Mobile Devices (MDs) are carried by patients for monitoring their health indexes, which

are going to be recorded in PC. All the MDs and PCs are enabled to roaming among the ZigBee Network ($ZN_1, ZN_2 \dots$ etc). When the monitoring signal should be transmitted from one building to another, WiMAX network is employed because each WiMAX station can cover long distance, with desired operating ranges of 1.5 km per cell, which can only achieved by the ZigBee network with thousands of ZigBee nodes. In a word, MPMS is a hybrid system in which ZigBee is adopted for inter-building communication while WiMAX is responsible for inter-building communication.



There are many small ubiquitous MDs moving from one ZigBee network (ZN) to another in MPMS. The small MDs should be recognized and joined into ZigBee network automatically to implement monitoring function. Proposed MPMS enables the mobility management to handle the handoff procedure.

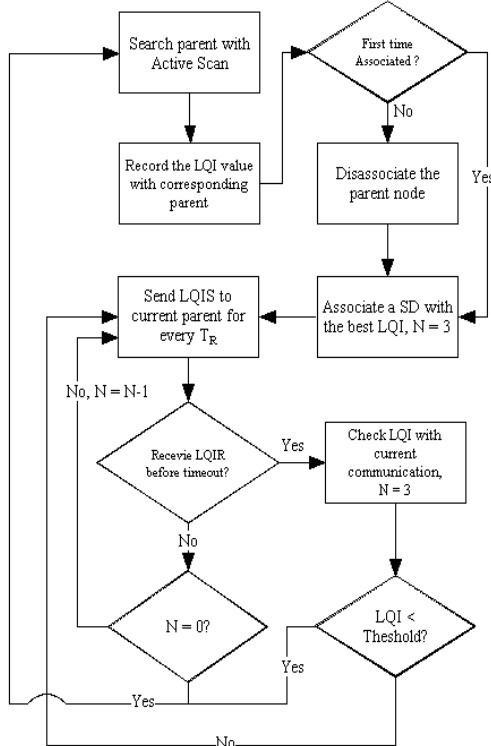
Basically, the decision for handoff is based on the signal strength. Traditionally the Received Signal Strength Indicator (RSSI) is used as an indication of the received signal strength. In essence, usually the Link Quality Indicator (LQI) is given instead of the RSSI in characterizing the signal strength of a

ZigBee device. In order to conform to ZigBee specifications [14], LQI will be used thereafter. The program flow chart shown in Fig. 2 is designed for MDs to handle the handover, say from ZN_1 to ZN_2 . Referring to both Fig. 1 and Fig. 2, MD_2 is associated to ZN_2 originally. When MD_2 roams, it sends a Link Quality Indicated Signal (LQIS) to ZN_2 between a time interval T_R and ZN_2 will respond to MD_2 by returning a Link Quality Indicated Reply (LQIR). The LQIR basically provides the Link Quality Indicator (LQI) between the MD_2 and the ZN_2 . If the LQI of ZN_2 is below a threshold value, say v_1 , MD_2 will look for a new router for association by carrying out an active scan. If MD_2 does not receive LQIR before it timeouts, it will retransmit the LQIS. If LQIR cannot be successfully received for three times ($N = 3$ in Fig. 2), MD_2 will carry out an active scan directly. If MD_2 has successfully haunted a router with a better LQI, it will disassociate from the ZN_2 . In the same manner, when MD_2 discovers that ZN_i has the highest LQI, it will associate to ZN_i . In contrast, if MD_2 cannot identify a qualified router within its coverage, it will try an active scan after the period t_s .

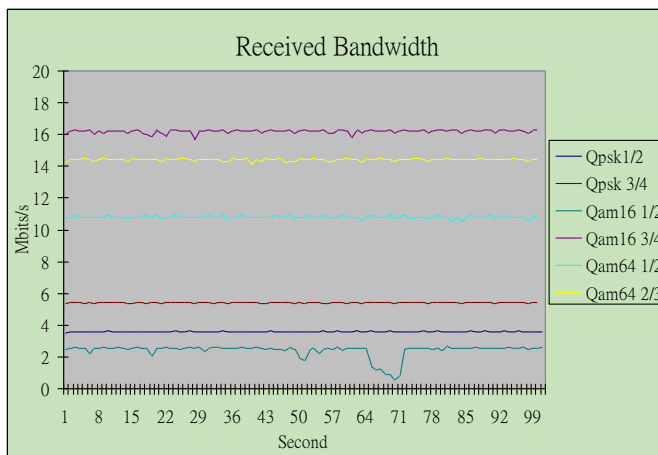
The developed mobility management fully considers the QoS requirement for the mobile applications. With the message forward ability, the probability of message loss due to handoff is minimized. MD always associates to a ZigBee network before it terminates the relationship with the old one (seamless handoff). Such approach can minimize the probability of service suspension due to a delay in the location update.

III. INTER-BUILDING COMMUNICATION

As introduced in previous section, Inter-building communication is in charge of WiMAX network broadband wireless connection over long distance. Moreover, WiMAX is capable of delivering differentiated and optimized service models. Mobile WiMAX technology (IEEE 802.16e) is to improve system coverage and capacity. In order to increase data transmission throughput and system reliability, WiMAX uses Adaptive Modulation/Coding (AMC) in Orthogonal Frequency Division Multiple Access (OFDMA) base. By employing AMC, the coding scheme and/or modulation method are changed depending on channel-state information. OFDMA adopts multiple sub-carriers, which are divided into groups. Each group named a sub-channel can be allocated to from Base Station (BS) to Subscriber Station (SS)[8]. SS can get continuous sub-channels or discrete ones. Sub-channels are allocated from BS to SSs depending on their channel conditions and data requirements. With AMC based on OFDMA, modulation and/or coding can be chosen differently for each sub-carrier, and it can also change with time. Different constellation sizes are used on different sub-carriers. Coherent modulation schemes are used starting from low efficiency modulations to very high efficiency ones depending on the user position in the cell. This results in lower throughput for users further away from the base station.



A testing based on WiMAX network is conducted. Equipment SQN1130 and SQN2110 are used as SS and BS respectively. The distance between SS and BS is selected as 25m. Six modulation/coding schemes (QPSK $\frac{1}{2}$, QPSK $\frac{3}{4}$, QAM16 $\frac{1}{2}$, QAM16 $\frac{3}{4}$, QAM 2/3) are used in the testing. Transmitting bandwidth is configured as 20 Mbits/s. Fig 3 shows that, with the same transmitting bandwidth, received bandwidths for the different modulation/coding scheme varied from 2.5 Mbits/s to 16 Mbits/s. In each scheme, the received bandwidth is stable in the whole testing time period. Scheme QPSK $\frac{1}{2}$ gains the best performance with average bandwidth around 16 Mbits/s. The testing result indicates that with AMC and OFDMA in WiMAX, modulation/coding scheme-- QPSK $\frac{1}{2}$ performs very well in resisting path loss, and therefore, the quality of inter-building communication is ensured.



IV. CONCLUSION

In this paper, a ZigBee-WiMAX Multi-purpose Patient Monitoring System (MPMS) has been proposed and developed to support mobile applications. The system aims at providing real time medical data monitoring service, patient location tracking service and as well as patient paging service. In this paper, a new mobile application profile of ZigBee has been proposed to facilitate efficient handover for mobile ZigBee devices. Adaptive modulation/coding, based on OFDMA in WiMAX is also studied. Six modulation/coding schemes are investigated and a testing is conducted. The testing results show that WiMAX network ensures the quality of inter-building communication in MPMS as a result of the outstanding performance of chosen QPSK $\frac{1}{2}$ scheme. The MPMS finds important applications in telemedicine area.

ACKNOWLEDGMENT

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