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A CONCEPTUAL FRAMEWORK OF WMN ENABLED WBAN SYSTEM FOR PILGRIMS' HEALTH MONITORING DURING HAJJ IN THE KINGDOM SAUDI ARABIA

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ABSTRACT

Due to the hardship of expedition, instability, and fluctuation of rough weather, continuous walking, hassle and mental stress during the Hajj at Makkah in Saudi Arabia, many pilgrims get injured, sick and tired. Besides, those who are suffering from various chronic diseases may also contract severe heart, chest, abdominal, and kidney diseases along with some infectious diseases like influenza and thus complicate the overall physiological functions of the patients. Other than the problems of diseases, overcrowd at religious sites also cause other noteworthy problems including trauma, missing and lost pilgrims, and even death. And so, it is a vital issue and a big challenge to provide the best healthcare facilities and services for pilgrims and their real-time monitoring during Hajj. Wireless body area network (WBAN) is a promising technology for healthcare. But, providing suitable communication network between WBAN and healthcare providers is another challenging issue. Modern information and communication technology (ICT) systems can make it feasible that WBANs will connect itself to the Internet to transmit data and efficiently administer the proper delivery of healthcare services among the pilgrims during Hajj. Therefore, integration of the medical technology and ICT in the healthcare sector is a prominent research issue especially for WBAN. However, the coverage of a WBAN is limited to only about 1-2 meter. Therefore, to largely extend its coverage area it should interwork with other wireless networks which will facilitate connectivity between those sensor devices of WBAN and the outside world. Due to the limitations of self-expandable, self-configuring and self-healing nature of other existing conventional wireless communication technologies, wireless mesh network (WMN) is the suitable and potential communication technology for transferring pilgrims' health information to the healthcare stations crowd environment at Hajj ritual sites. WMN, due to its self-expandable nature can be deployed with WBAN during Hajj for pilgrims' health monitoring which requires extending the coverage of the environment. Therefore, the main objective of this research is to design a conceptual healthcare framework for pilgrims' health monitoring during Hajj by integrating WBAN and WMN technologies.

Keywords: hajj, pilgrim, WBAN, WMN, healthcare, integrating, conceptual framework.

INTRODUCTION

Every year during Hajj, the largest religious mass gathering, an amount of 2 to 3 million pilgrims from 184 countries congregate in Haram at Makkah in Saudi Arabia, and the number of pilgrims is increasing every year at the rate of about 3.5 percent. During the Hajj period, the crowd density can increase to seven individual per m^2 which is an indicator of overcrowding and one of the leading causes of loss of pilgrims and injury. Moreover, during Hajj in Makkah, the temperature ranges between 38°C and 50°C with a relative humidity of 25% to 50% thus favour heat stroke, heat exhaustion along with the development of various communicable and non-communicable diseases [1] [2]. Hence it is a vital issue and a significant challenge to provide best healthcare facilities and services for pilgrims and their real-time monitoring during Hajj.

Modern information and communication technology (ICT) systems can make it feasible that WBANs will connect itself to the Internet to transmit data and efficiently administer the proper delivery of healthcare services among the pilgrims during Hajj. Therefore, integration of the medical technology and ICT in the healthcare sector is a prominent research issue especially for WBAN

IEEE 802.15.6 TG6 or wireless body area network (WBAN) or body sensor networks (BSNs) are a subgroup of wireless personal area network (WPAN) which was formed in November 2007 offered the quick evolution in patients' medical data and thus providing healthcare services. To fully exploit wireless technology for healthcare, telemedicine, and m-health, Van Dam et al. first introduced the concept of WBAN in 2001. Original motivation and advanced development of body sensor networks (BSNs) for healthcare were coined by Prof Guang-Zhong Yang of Imperial College in the early 2000s and then illustrated in his book 'body sensor networks' in 2006 [3] [4].

Adopting IEEE 802.15.6 standard for health monitoring during Hajj which is designed explicitly for

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WBANs is a challenge. And, the main concerns are its uncompromising quality of service and priorities to transfer medical data to the medical server. Moreover, WBAN estimates are time sensitive. Thus it is vital that time-critical WBAN data arrives at its destination quickly. To successfully transfer the medical data, a wireless communication network for the next hop is needed to preserve the end-to-end service superiority. Wireless mesh networks (WMNs), a subset of IEEE 802.11s standard is widely selected and used for applications in the environment because it provides rerouting functions as a distributed network, determines the optimal multi-hop transmission path, and automatically discovers the topology change. During Hajj, it is notable that, the mortality rate is higher due to specific non-communicable health hazards followed by communicable diseases. Indeed, if patients monitoring and medical care can be performed wirelessly, the patient is no longer constrained in his movements thus reducing the mortality rate. In addition, this can shorten hospital stays thereby reducing convalescent period and patient costs.

The significant advantages what WBAN and associated suitable communication network can provide for transferring data to a healthcare station and remote server are the mobility and flexibility of patients due to use of movable or portable monitoring devices and the location independent monitoring facility [5]. Modern information and communication technology (ICT) systems can make it feasible that WBANs will join itself to the Internet to transmit data and efficiently administer the proper delivery of healthcare services among the pilgrims during Hajj [6]. Therefore, integration of the medical technology and ICT in the healthcare sector is a prominent research issue especially for WBAN [7]. Moreover, due to economic and reliable communication reasons, wired communication cannot be expanded for long distances and is restricted for short-range transmission [5] [8]. Thus wireless sensor deployment for health monitoring is a new and scorching topic of discussion among researchers.

Also, existing WBANs differ from conventional wireless sensor networks technologies because it has a very different network environment related to human body aiming to monitor the surrounding environment and functions of the body continuously and in real-time [9]. Because of the characteristics of the body, a wireless network environment for the human body has several properties including limited and inconsistent bandwidth that is prone to more interference, limit to short and long-range communications, heterogeneous and energy-dependent nodes, and each node should consume minimal transmission power due to radio frequency (RF), and the devices attached to the body are movable [10].

Notwithstanding the information presented earlier, it is also significant that the coverage of a WBAN is limited to about 1 to 2 meter, in some cases 2 to 5 meter. Hence, to largely extend its coverage area it should interwork with other wireless networks which will facilitate connectivity between those sensor devices of WBAN and the outside world [1] [3]. Wireless body-area networks (WBANs) incorporate different networks and wireless devices to form special purpose wireless-sensor network enabling remote monitoring for various medical environments. WBAN RF signal propagation, its environment at data link level and realistic channels on network level need to characterise extensively for more effective life-saving network architecture [10]. Hence, one of the major challenges of WBAN is to monitor a large number of patients in healthcare system thus requires a complete wireless sensor network by eliminating collisions of two sensor signals and interference from other external wireless networks. WBAN can provide better rehabilitation which will improve patient's quality of life.

Communication between sensor devices and Hajj ritual sites (e.g. smart environment) using wireless networking and computing technology (e.g. ICT) should facilitate remote patient monitoring. As a result healthcare providers would be able to collect disease-specific metrics (healthcare information) from wireless biomedical devices e.g. body sensors used by pilgrims in their body and surrounding environment or other settings outside of a clinical facility. Distance or remote monitoring systems typically collect patient readings and then transmit it to a medical server or remote server to give immediate medical care and also for storage and later examination by the health care professionals [11].

Among various wireless networking technologies, wireless mesh networks (WMNs) system of IEEE 802.11s standard presents multiple points of Internet access thus facilitate resource pooling across all available paths to the Internet backhaul which refers to the process of getting data to the core network or network backbone. According to the mail functions of WMNs, a backhaul (method of communication) is the portion that connects the backbone (central routing system) and the edge networks (local networks) thus providing backbone services to mesh clients to get accessed to Internet gateways or application servers on the network [12] [13]. Universal and wider access to the Internet is crucial for crowd environment and crowd management during Hajj thus requires extending the coverage which can be supported by WMNs.

WMN provides rerouting functions as a distributed network, determines the optimal multi-hop transmission path, and automatically discovers the topology change. Due to the multi-hop routing capability, WMNs can significantly improve the customer coverage area by applying the point-to-multipoint solution with the fast deployment of WMNs services. It also can significantly increase the reliability by using its multiple-gateways facility. WMNs eliminate the usage of cables thus decrease the cost of the technology. The bridging features of the WMNs also help for efficiently forward data packets among different model that hence increase the data transmission speed.

To increase the usefulness of present health care situation worldwide particularly in over crowded places, it is vital to incorporate WBANs technology in favourable wireless communication technology. For massive enhancement of patients' quick identification, fast

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verification for providing real-time medical care to the patients with security and suitably; a WMNs would be used to transmit patients' physiological data where ever it is necessary, and whenever it is required in a real-time mode. WBANs technology can provide very cheaper, easier and quick respondent history of the patient. Therefore, the design of WMNs enabled WBANs could be the best solutions for continuous health monitoring of the pilgrims during Hajj.

DESIGN REQUIREMENTS

Design requirements of WBANs for pilgrims' health monitoring during hajj

In WBANs, where a maximum of 256 nodes can exist per network within a volume of $6m^3$ and an operating range 3m [14]. Moreover, while connecting to the Internet, WBANs ranging from a few sensors up to tens to hundreds of sensors communicating with a gateway. According to the IEEE 802.15.6 working group one-hop or two-hop star topology is used in WBANs when all nodes in the network are directly connected to the sink. The coordinator of WBAN is known as the sink node to which all nodes talk, however, nodes are connected to access points via other nodes in a multi-hop architecture. WBANs are regarded as dynamic because the body may sometimes in motion walking, running. Hence, reliable communication from WBANs to personal server (PS) and from PS to medical server (MS) or medical centres or emergency stations through access points (APs) using various networks for example in short-range communication cellular networks, ZigBee, Wi-Fi, Bluetooth. And Internet for long-range communication e.g. WLAN, WMAN, or particularly WMN and therefore is considering as part of WBANs infrastructure and can be placed in a dynamic environment to handle emergency situations as illustrated in Figure-1.

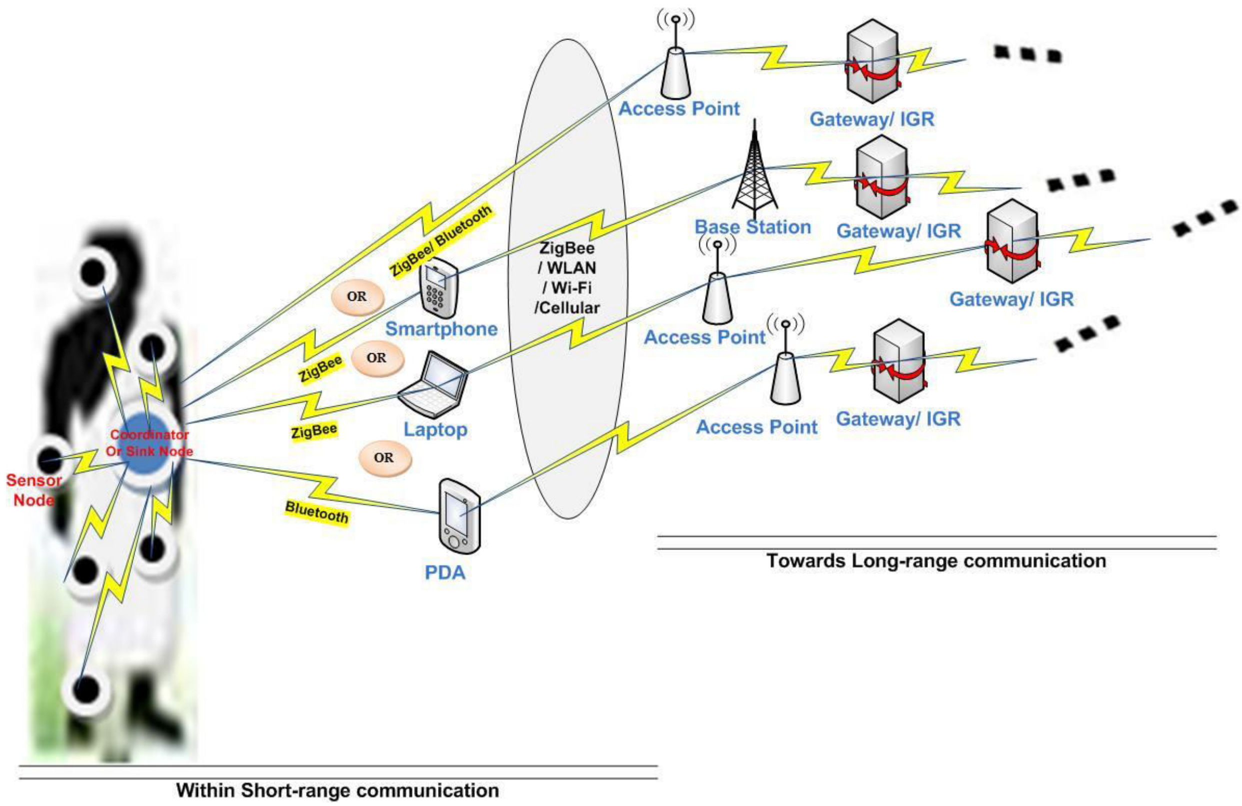

Figure-1. Design requirements of WBANs.

Moreover, essential requirements within an implant WBAN channel model are the capability to support long transmission distances and high transmission data rates that can connect and work with prospective medical servers [11]. Also, health care centres need to have constant awareness and consistent over medical data received from patients to provide suitable solutions in case of emergency [15]. Furthermore, collected medical data from WBANs' coordinator to PS is sent from PS through AP or gateway to MS via the wireless communication channel to the gateway which serves as a relay node to the monitoring system through a backbone network e.g. Wi-Fi, satellite, and others. Therefore, communication of WBANs with other wireless networks becomes crucial [11].

Furthermore, WBANs have to ensure consistent data transfer amongst the different wireless technologies being used to be scalable, promote information exchange, provide uninterrupted connectivity and ensure efficient migration across networks. Hence, the chosen wireless technology must be capable of handling a mixture of these requirements in terms of WBANs actual

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application, intra-WBAN communication, inter-WBAN communication, beyond-WBAN communication and the sensors being used.

Design requirements of WMNs

A wireless mesh networks (WMNs) which are also called as a multi-hop wireless network is used to transmit the acceleration data and was comprised of ruggedised mesh routers dispersed around the search area. It is also essential to assess the effectiveness of the transmission of the pilgrims' data across the network. Any significant delays in the transmission would result in the healthcare providers or emergency centres not being aware of the pilgrims' behaviour at that particular moment. The consequence of this would be that the health care providers or emergency centres would be delayed in reacting to the situation.

WMNs configuration is comprised of **I.** least mobility or static wireless mesh routers (WMRs), also called as mesh capable node or mesh points (MPs). MPs use IEEE 802.11 MAC and physical layer protocols for wireless communication. This node supports automatic topology discovery, automatic route discovery, and data packet forwarding. II. Mobile or static wireless mesh clients (WMCs) also called as non-mesh stations or stations (STAs). STAs are terminal devices, mainly including smart phones, laptops, and tablets. Each STA associates with one of its nearest MAPs, and accesses the Internet through multi-hop wireless links to an MPP. III. Mesh access points (MAPs), where each MAP is equipped with a WLAN AP function. Basically, MAPs are MPs that support the AP function and provides access for STAs. Finally IV. Mesh router with gateway or Internet gateway router (IGR), also called as backbone mesh capable node or mesh point portals (MPPs). Primarily, MPP is an MP that connects to a WMN or another type of network. This node has the portal function and enables mesh nodes to communicate with external networks. MPs, MAPs, and MPPs have minimal mobility and construct a multi-hop wireless backbone.

The wireless routers are interconnected with each other via wireless links which are called as hops and provide communication services to mobile or static clients where mesh clients can access the Internet via backbone wireless mesh networks formed by wireless mesh routers [16]. More precisely, mesh routers form the mesh backbone and serve mesh clients to communicate with the Internet or with other mesh clients via gateway or Internet access gateway (mesh router with gateway capability). Mesh clients can be on users' laptops and PDAs which are either mobile or stationary. Links between mesh routers are wireless, and the mesh routers could use multi-radio interface to connect to each other. Some of the routers are directly attached to a fixed infrastructure (i.e., a wired network like the Internet) and serve as gateways for other wireless routers. On the other hand, the clients can connect to the external network through the gateway nodes, as presented in Figure-2.

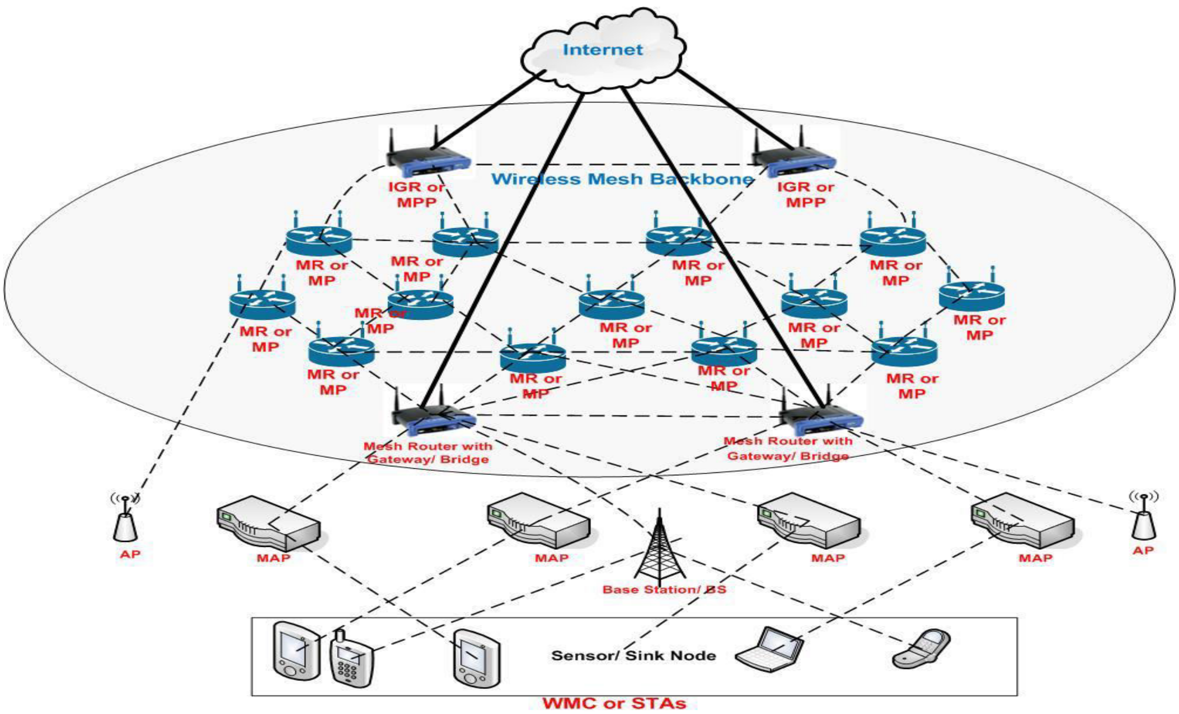

Figure-2. Design requirements of WMNs.

CONCEPTUAL FRAMEWORK OF WMNS ENABLED WBANS

The proposed conceptual framework consists of four phases on the usability of technologies and standards. The main objective is to collect and process pilgrims' vital medical data or parameters and to transfer data quickly and securely, and finally to diagnose and monitor them accurately and promptly. The four phases are Phase I:

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Intra-WBAN; Phase II: Inter-WBAN; Phase III: Beyond-WBAN and Phase IV: Back-end application.

Intra-WBAN is a small network around the body (about 1-2 meters, in some cases 2-5 meters) [11] [12], inter-WBAN is a gateway (sink) bridging to another network types that can be another node with some routing and data aggregate features, and beyond-WBAN is a wide network that can be an Internet or intranet network [17].

Phase-1: Intra-WBAN

Intra-WBAN or on-body communication controls and manages wearable or implanted sensors are used to forward body signals to a personal server (PS) also called body control unit (BCU) or body gateway or central node or personal device (PD). Intra-WBAN communication makes the body sensor and personal server communicate around 2 meters of a person. In Phase-1, the base station which is the network coordinator or central coordinator deals with the activities of individual nodes by periodically or occasionally requesting data. In addition to data integration and analysis, the base station (BS) also relays processed data to display devices e.g. laptop, smartphone or personal digital assistants (PDAs) in Phase-2 [18]. Initially, in Phase-1 the collected data from sensor nodes may either be transmitted or relayed to a network coordinator or central coordinator on the body or may be sent directly to the upper layers for further processing. It can be further sub-categorised as: (1) communications between body sensors, and (2) communications between body sensors and the portable PS [19]. In this phase, the patient's processed physiological data which is called as vital signs are collected and transmitted to the sink or access point in Phase-2. To avoid additional energy consumption due to direct and short-range communication between nodes and the sink, sensor nodes in a WBAN should transfer data to the sink node with the multi-hop communications.

Phase II: Inter-WBAN

Inter-WBAN or body-body communication is between the PS and one or more access points (APs) where APs are the part of the infrastructure [20]. Inter-WBAN communication makes the PS and an AP communicate. Also, APs can be placed strategically in a dynamic environment to handle emergency situations.

Moreover, Phase-2 communication aims to interconnect WBANs with various wired and wireless networks, e.g. Wi-Fi, cellular networks and the Internet. In Phase-2 collected information from the body is forwarded to a gateway.

Again, the function of multiple APs is to transmit information inside medical centers which form a mesh structure which is easily expandable hence provides larger radio coverage due to multi-hop dissemination and support patient mobility; it also facilitates flexible and fast operation. Due to larger coverage range network infrastructure with mesh structure facilitates movement around larger areas. Also, this interconnection extends the coverage area of WBANs from 2 meters to100 meters, which is appropriate for both short and long-term arrangement [22].

The communication standards deployed in Phase-2 include Bluetooth/Bluetooth Low Energy (IEEE802.15.1), ZigBee (IEEE802.15.4/ WPAN), Wi-Fi (IEEE802.11.1), UWB, Cellular and WLAN (IEEE802.11), wired networks or relevant standard networks [21]. Monitoring devices are being used in this standard are smartphones, laptops or PDAs, etc. Collected data from this layer is required to be transferred to an upper layer (Phase-3) to be prepared for the final destination.

Phase III: Beyond-WBAN

Beyond-WBAN or off-body communications develop communication between the gateway and the doctors or emergency stations or medical centres. A gateway such as a PDA or smartphone can be used to bridge the connection between Phase-2 and Phase-3; in essence from the Internet to the medical server (MS) in a particular application. The communication standards deployed in Phase-3 include WiMAX (IEEE 802.16), GSM, GPRS, and WMN (IEEE 802.11s) [23]. The beyond-WBAN communication is used in wide area connectivity.

The beyond-BAN phase communications can enhance the application and coverage range of healthcare system in the crowd and the larger environment by enabling authorised healthcare personnel, e.g., doctor or nurse or emergency healthcare providers to remotely access a patient's medical information using wired or wireless networks e.g. cellular network or the Internet [24].

In large-scale systems of WBANs especially in the inter-WBAN and the beyond-WBAN communications, WMN infrastructure can facilitate network management. WMN infrastructure can deal with the most significant challenges posed by the management of large-scale systems of WBANs. Integration of WBAN and WMN technology can provide flexible data processing and management to perform both online and offline analysis of body sensor data streams. WMN technology promotes different WBANs applications to integrate more smart stations and provide more convenience and entertainment for patients.

Phase IV: Back-end application

This phase is called as back-end application which is mainly application-specific. In general, in a medical environment, web applications and a database are one of the most essential components of Phase-4 as it includes the medical history and profile of the user [25]. Thus, doctors or patients can be warned or notified of an urgent or emergency status through wired or wireless networks e.g. the Internet, Short Message Service (SMS). Additionally, for further treatment, Phase-4 allows restoring all necessary information of a patient. However, depending on the applications, the personal server (PS) in Phase-2, received processed data from Phase-1 can send to Phase-4 either through Phase-3 by talking to an AP or can

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use GPRS/3G/4G instead of talking to an AP. In this layer, healthcare personnel may provide two different types of services: health services and emergency services. The proposed conceptual framework is presented in Figure-3.

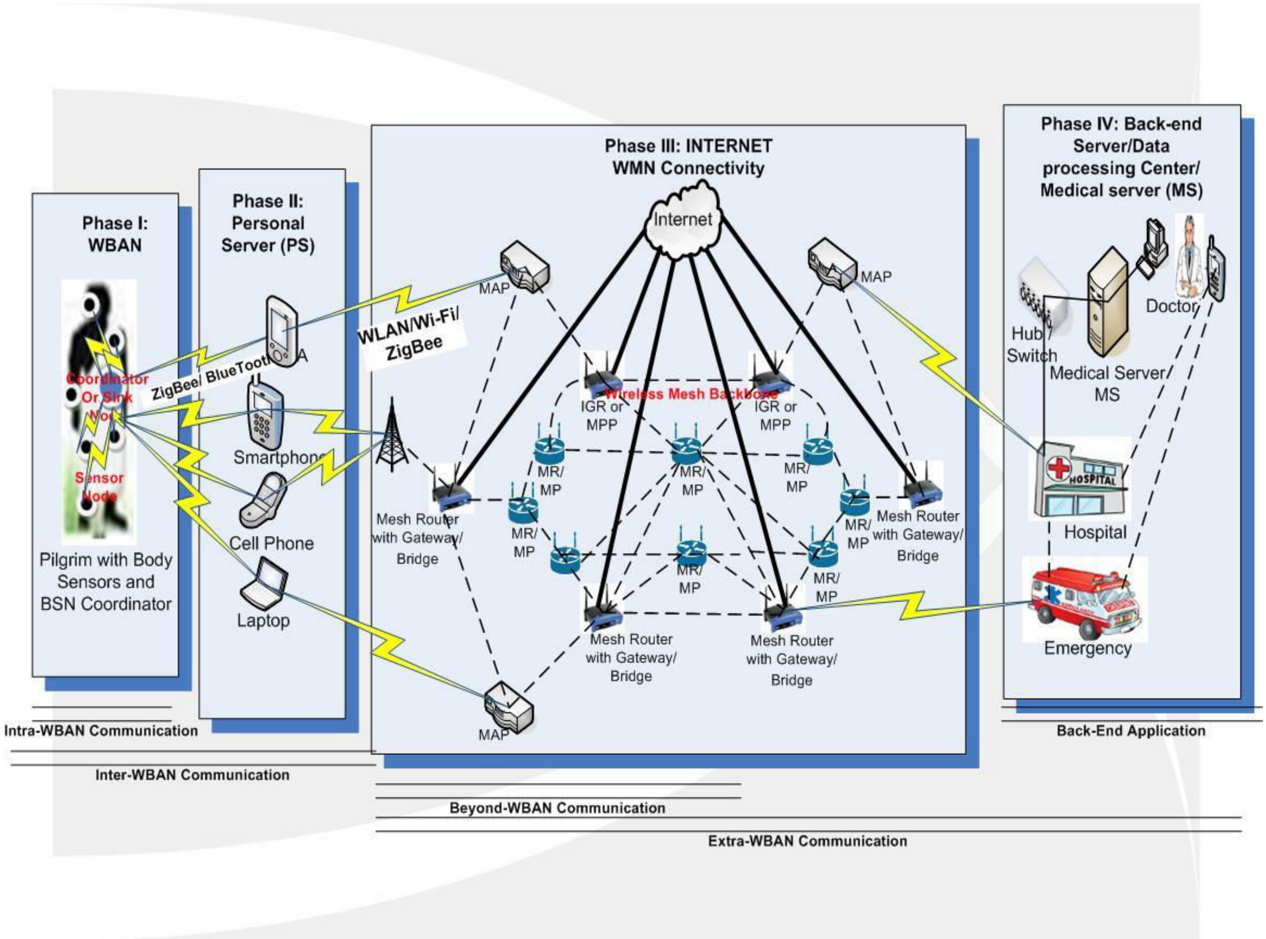

Figure-3. Proposed conceptual framework of WMNs enabled WBANs system.

DISCUSSION AND FUTURE WORK

As discussed previously, the wireless body sensor network is made up of one or more body area networks and a base station. Sensor network forwarded all the gathered information to the base station. Hence a relay station received the information and passed on through a backbone network to monitoring stations that are connected to the network [11]. Therefore, the energy-efficient and reliable communication protocol for improving the network lifetime is one of the major challenges in WBANs [26]. IEEE 802.15.4 and ZigBee are two widely used radio standards in WBAN applications where the primary purpose of both standards is to provide low power solution for battery-powered devices. The physical (PHY) and medium access control (MAC) layer protocols of EEE 802.15.4 technology focusing on low data rate and medium-range wireless communications which make it an appropriate solution for health-monitoring applications. For residential environment healthcare system with limited range do not need full meshing capability of any wireless communication platform, however, for the long range and crowd environment, the infrastructure must be extended so that the site or premises is fully covered. Hence, multi-hop based routing of wireless communication is the best solution that provides the required range of the application.

CONCLUSIONS

Proficiently and efficiently monitoring pilgrims health status during Hajj using WBANs universal and broader access to the internet is crucial. In addition, for crowd environment and crowd management requires extending the coverage which can be supported by WMNs due to its self-expandable nature. This study showed that WBANs have different environment characteristics than those of WSNs thus WBANs require wireless communication technology which is different from conventional sensor networks.

Moreover, in this research paper, a feasibility study was performed to identify the design requirements in order to integrating WBAN with WMN for pilgrims' health monitoring at crowded Hajj ritual site. We then finaly proposed a conceptual framework incorporating WBAN with WMN for pilgrims' health monitoring during

Hajj and a plan for bridging the gaps for further exploitation of the system is also discussed.

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