Study on Low-Power Transmission Protocols for ZigBee Wireless Network-Based Remote Biosignal Monitoring Systems

Young-Hyuk Kim, Il-Kown Lim, Jae-Pil Lee, Jae-Gwang Lee and Jae-Kwang Lee

Abstract This study uses low-power, low-speed ZigBee sensors with defined network and application layers based on the media access and physical layers of Wireless Personal Area Networks (WPAN). ZigBee sensor nodes were connected to Personal Health Devices (PHD), which measure the biosignals of patients, to form a wireless network. We do not apply generalized ad-hoc routing protocols or tree structures but instead are proposing modified hop-count routing protocols using the WBSS characteristic of IEEE 802.11p. This is because sensor nodes operate from fixed positions and smartphones, which play the gateway role, has the characteristic of constantly shifting location, from the patient's hand and ears to neraby desks. We used 3 PHDs (ECG, pulse and blood pressure) and connected ZigBee modules using external batteries to confirm whether normal service was being performed.

Keywords ZigBee · PHD · Hop-count · Bio-information

Y.-H. Kim · I.-K. Lim · J.-P. Lee · J.-G. Lee · J.-K. Lee (✉)
Department of Computer Engineering, Hannam University, Daejeon, Korea
e-mail: jklee@netwk.hnu.kr

Y.-H. Kim
e-mail: yhkim@netwk.hnu.kr

I.-K. Lim
e-mail: iklim@netwk.hnu.kr

J.-P. Lee
e-mail: jplee@netwk.hnu.kr

J.-G. Lee
e-mail: leejk@netwk.hnu.kr

Y.-H. Han et al. (eds.), *Ubiquitous Information Technologies and Applications*, Lecture Notes in Electrical Engineering 214, DOI: 10.1007/978-94-007-5857-5_76,

1 Introduction

The expansion of wired/wireless communications infrastructure and the development of communications devices such as smart devices dramatically improved information and communication technology. These new information and communication technologies, which can be used anywhere, have combined with various services to create a new service market. The u-Health service, a convergence of the traditional health and medical treatment industry and IT, combines the words health and ubiquitous, which originated from the Latin word meaning ‘exists anywhere and everywhere.’ This u-Health service not only solves social problems such as population aging, increasing medical costs and the lack of professional medical personnel but also is an field that is attracting interest from all around the world as it has transformed the paradigm of health management from treatment to prevention/management.

Sensors that collect patient’s biosignals are the key components of the u-Healthcare service. Wireless network technology for communications between sensors include Ultra Wide Band (UWB), Bluetooth and ZigBee. Of the three, ZigBee is a low-power, low-speed technology with defined network and application layers, based on the media access and physical layers of IEEE 802.15.4 WPAN. ZigBee’s greatest advantage is the ability to create simple and low-cost wireless networks. ZigBee defines a simple, layered routing method using a layered address assignment system [1].

The ZigBee standard defines table-based routing similar to Ad-hoc On-Demand Distance Vector Routing (AODV), but this method has the problem of increased complexity, increased hardware costs for memory and having to broadcast Route Request (RREQ) packets to find routes.

It also provides bridge transmission, which, in an environment with many sensor nodes, uses nearby nodes as intermediate nodes to transmit to the Gateway (GW). However, intermediate nodes have a high probability of using great amounts of power, and thus, decreases the viability of the entire sensor network. Methods such as S-MAC and B-MAC can be used to decrease the power consumption from these problems, but unnecessary and redundant tramsission of data can occur in this process, and there is the problem of decreased network viability due to increased power consumption by the intermediate nodes [2, 3].

This study conducted tests by connecting ZigBee modules to 3 PHDs (ECG, pulse, blood pressure) that measure biosignals. We started by working to complete the sensor node routes or network structure by using the fact that it is not necessary to move from fixed positions such as the heart, fingers and wrists. Then, the service structure of the IEEE 802.11p WAVE Basic Service Set (WBSS) was modified for quick connections, so that the sensors could judge and set routes for hop-count information. Each ZigBee module used external batteries, and we confirmed whether normal monitoring was occurring.

2 Related Research

2.1 ZigBee Standard

The overall MAC structure of the IEEE 802.15.4 is shown in (Fig. 1). The MAC header sets the type of the frame transmitted and the format of the address field and controls the confirmation field. The payload data follows the frame type set by the header and a maximum of 128 bytes can be used. Given the nature of sensor networks, there are many devices, and therefore, each device is distinguished by the address field of the MAC frame [4, 5].

ZigBee supports three types of topologies. First, in star topologies, all nodes are connected to one ZigBee coordinator, and transmission occurs. Tree topologies connect router nodes or end-device nodes to ZigBee coordinators or other router nodes in a tree structure. That is, every router or end-device is connected to its parent router or a ZigBee coordinator. In a tree topology, routing is done through the trees. ZigBee has a layered network address system, and a node's location within a tree can be determined by just its address. That is, frames are transmitted to destination nodes by the address of the destination node, transmitting to the appropriate child node if below or to its parent node if not. Finally, mesh topologies introduces table-based routing methods similar to AODV into tree topologies and is formed by the transmission of RREQs and Route Replies (RREP) and the management routing tables [6].

Acknowledgement frame

Octets: 2	1	2
Frame control	Sequence number	FCS
MHR		MFR

Data frame

Octets: 2	1	(see 7.2.2.2.1)	variable	2
Frame control	Sequence number	Addressing fields	Data payload	FCS
MHR			MAC payload	MFR

Beacon frame

Octets: 2	1	4/10	2	variable	variable	variable	2
Frame control	Sequence number	Addressing fields	Superframe specification	GTS fields (Figure 38)	Pending address fields (Figure 39)	Beacon payload	FCS
MHR			MAC payload				MFR

Fig. 1 IEEE 802.15.4 MAC layer

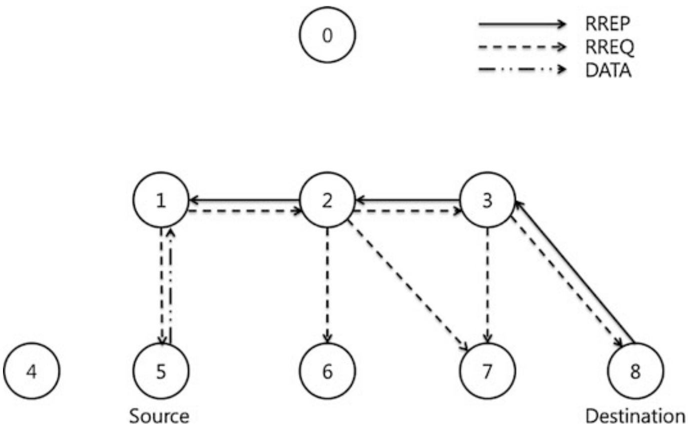

Fig. 2 AODV routing protocol

2.2 Routing Protocol

AODV (Ad-hoc On-Demand Distance Vector).

ZigBee wireless sensor networks use hierarchical routing methods based on logical addresses as its routing algorithm, but AODV only applies to nodes with routing tables and is a request-based routing protocol that can obtain routing information only when data transmission is requested. Therefore, source nodes that need data transmissions set routes through a request-based method by finding the shortest routing route to the destination

Figure 2 shows the AODV routing protocol algorithm. The 1st node, which receives data from the source node, begins route navigation by transmitting RREQ messages to nearby nodes on the routing table and sets routs based on RREP messages. This process is repeated for each data transmission request and unnecessarily consumes energy [7].

Tree. Figure 3 is a tree-based network that supports multi-hopping. It uses preliminary broadcasts to form a network and simultaneously use information from the parent node to set routes. Through this preliminary step of determining data transmission routes, it sets routes from all end-devices to the sink nodes. This structure forms a network system in which data flow concentrates at sink nodes from end-devices [7].

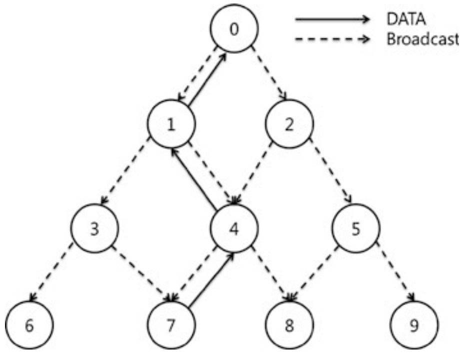

Fig. 3 The routing protocol based on tree

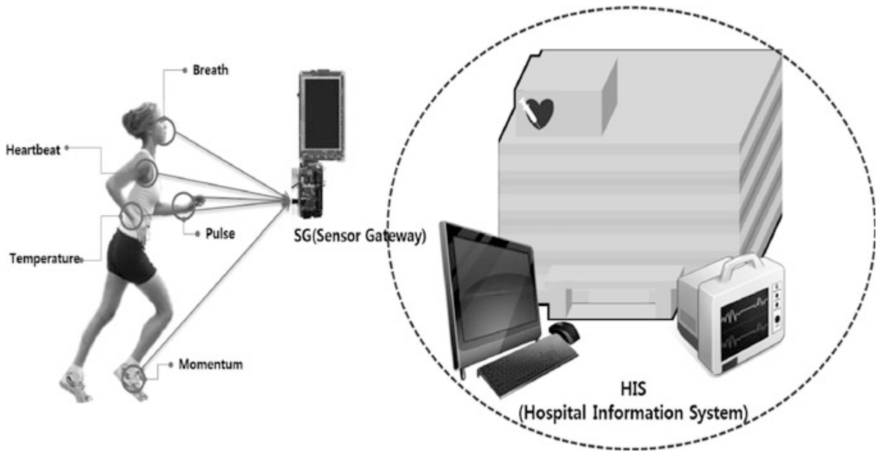

Fig. 4 The overall service structure of remote biosignal monitoring systems

3 Design and Evaluation of Routing Protocol

3.1 Design

Remote biosignal monitoring systems work by attaching various PHD devices such as ECG, pulse and blood monitoring systems on the patient's body and storing the information on smartphones, which are GWs in wireless networks, through connecting sensors. The patient's biosignal data, stored on smartphones, are ultimately saved on remote Hospital Information Systems (HIS) through various wireless communications technologies such as 3G, 4G and Wi-Fi and is used by the medical staff. Figure 4 shows the overall service structure of this remote biosignal monitoring system.

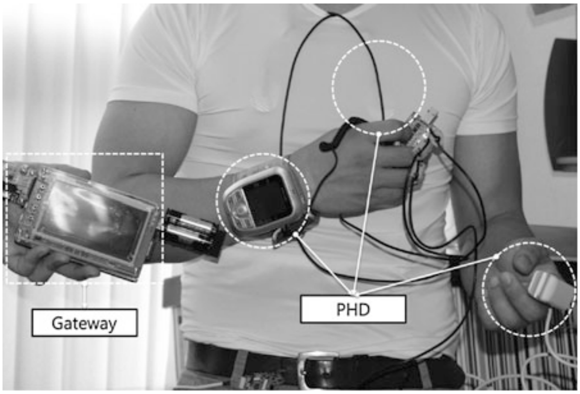

Fig. 5 PHD and GW

This characteristic, as can be seen in (Fig. 5), is the maintenance of fixed routes from fixed positions for PHDs. However, since the GW is a smartphone, a general purpose device, its location changes constantly due to various actions from the ears (calling), hands (holding) and desk (recharging). Therefore, the hop of the sensor to the GW changes for each RREQ request broadcast to set routes, and the proposal of this paper to solve this problem is (Fig. 6).

WBSS reduces the occurrence of unnecessary overhead in data transmission and has a protocol suited for environments where the receiving device constantly changes [8]. If the requesting PHD sends Required Beacons (RB), the receiving node responds with stored information (hop-count number or information on nearby nodes) through Require Response (RR) packets. Using this information, the requesting PHD then determines which sensor node to send the data. To do this, each sensor node must have fixed positions and must remember its hop-count. The requesting PHD remains up-to-date by changing its own settings information (hop distance to GW) through RB messages.

Figure 6 shows the PHD device and sensor node topology used in this study. In (a and b), the requesting PHD is ‘PHD1’ and has the duty to send collected biosignals to the GW. At this moment, PHD1 does not know its own hop-count number. Therefore, it sends RB messages to PHD2 and PHD5, and using RB messages, PHD2 responds with its own hop-count number, 3, and PHD5 responds with its hop-count number, 4. PHD1 decides on a route through PHD2, which had the lower number, and start transmission by setting its own hop-count number to 4. Therefore, (a and c) displays the successful routing process of setting and transmitting the quickest route, and (b and d) is an example of the longest routing process.

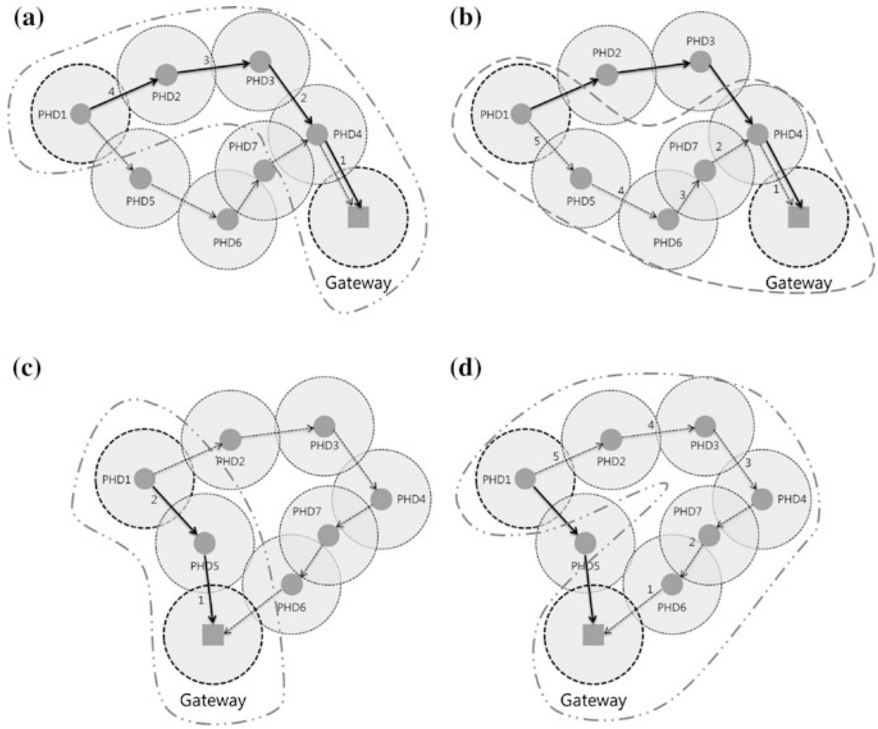

Fig. 6 Modified hop-count routing protocol

4 Conclusion

For this study, we attached PHDs to patients for remote monitoring and designed a protocol for the wireless network system using ZigBee. Previous studies had looked at AODV routing, tree structure routing and modified routing technologies adapted for other various environments. Unlike these existing routing methods, this study proposes an alternate routing protocol that incorporates the characteristics of remote biosignal monitoring systems. The protocol is unique in its modification of the proposed WBSS method as a standard to reduce unnecessary overhead. To do this, sensor nodes must be fixed, and the study focused on solving the problem of having to update in real-time the hop-count to the GW for a GW that moves frequently, confirming that the protocol designed using smart tablets performed normally with a continuously moving GW.

Current research is limited to confirming smooth communication with a continuously moving GW. Future related research plans aims to determine efficiency and battery usage and to research the application of danger detection algorithms that reduce network traffic between GWs and HISs.

Acknowledgments This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (2012-0004574).

References

1. Hwang, J.W., Park, H.H.: ZigBee network formation based on trust model and trustworthiness measurement. J. Korean Inst. Inform. Commun. Eng. **14**(5), 1284–1294 (2010)
2. Lee, B.M., Park, Y.H., Choi, C.H.: A study for transmission protocol for energy-efficiency on a wireless medical sensor node. J. Korean Inst. Inform. Technol. **8**(4), 43–51 (2010)
3. Seo, S.Y., Jung, W.S., Oh, Y.H.: Clustering algorithm for efficient energy management in sensor network. J. Korean Inst. Commun. Sci. **33**(10), 845–854 (2008)
4. ZigBee Alliance.: http://www.zigbee.org
5. IEEE Std. 802.15.4-2003
6. Stevanovic, D.: Technical overview of the Zigbee/IEEE 802.15.4 standard. An informal presentation York University, (2007)
7. Kim, Y.J., Jung, I.G., Yang, Y.H., Kim, B.N., Lee, I.S.: Design and implementation of an real-time bio-signals monitoring system using ZigBee and SIP. Inst. Electron. Eng. Korea Comput. Inf. **45**(1), 62–69 (2008)
8. IEEE std. 802.11p-Part 11: Wireless LAN medium access control and physical player (PHY) specifications: Wireless access in vehicular environments