*International Journal of Scientific Engineering and Applied Science (IJSEAS) - Volume-1, Issue-7, October 2015*
*ISSN: 2395-3470*
*www.ijseas.com*

# Review of Health Monitoring System Using Zigbee Based Variable Devices

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## Abstract

These systems use wireless technologies to transmit vital signs for medical evaluation. In a multihop ZigBee network, the existing systems usually use broadcast or multicast schemes to increase the reliability of signals transmission; however, both the schemes lead to significantly higher network traffic and end-to-end transmission delay. In this paper, we present a reliable transmission protocol based on anycast routing for wireless pa- tient monitoring. Our scheme automatically selects the closest data receiver in an anycast group as a destination to reduce the trans- mission latency as well as the control overhead. The new protocol also shortens the latency of path recovery by initiating route recov- ery from the intermediate routers of the original path. On the basis of a reliable transmission scheme, we implement a ZigBee device for fall monitoring, which integrates fall detection, indoor position- ing, and ECG monitoring. When the triaxial accelerometer of the device detects a fall, the current position of the patient is transmit- ted to an emergency center through a ZigBee network. In order to clarify the situation of the fallen patient, 4-s ECG signals are also transmitted. Our transmission scheme ensures the successful transmission of these critical messages. The experimental results show that our scheme is fast and reliable. We also demonstrate that our devices can seamlessly integrate with the next generation tech- nology of wireless wide area network, worldwide interoperability for microwave access, to achieve real-time patient monitoring.

*Index Terms*—Anycast, broadcast, ECG, multicast, patient monitoring, vital sign sensor, worldwide interoperability for mi- crowave access (WiMAX), ZigBee.

## I. INTRODUCTION

The aging society is bringing its impact on many de- veloping countries and presents a stark contrast with the low fertility rate of these countries. The changes brought about by the aging society include an increasing demand for caretaking; thus, patient monitoring systems are gaining their importance in reducing the need for human resources. Caretaking homes and hospitals have been planning on the use of biological sen- sors to effectively minister to their patients. Vital signs, such as body temperature, blood pressure, and sugar level, can be regularly collected and remotely monitored by medical profes- sionals, achieving a comprehensive caretaking system.

The transmission of vital signs in nursing homes and hos- pitals is usually carried out wirelessly. The vital signs can be categorized into emergency messages and regularly collected information. While the regularly collected information can be stored and transmitted in a given time period, the emergency messages must be transmitted immediately. The transmission path of vital signs can be divided into outdoor and indoor. The technology of wireless wide area networks (WWANs) is used for outdoor transmission, and that of wireless mesh network (WMN) is responsible for indoor transmission.

Long term evolution (LTE) and worldwide interoperability for microwave access (WiMAX) are the next generation technolo- gies for WWAN. Both technologies aim at providing wireless broadband access service and have the same core wireless tech- nologies, but in different manner. While the technology of LTE considers incumbent deployments, which pursue compatibility with the existing devices, WiMAX is primarily used in fixed to mobile deployments. These technologies will greatly improve the quality of patient monitoring since the vital signs can be transmitted with better bandwidth management.

For the indoor transmission of vital signs, WMN is a conve- nient technology, which can dynamically establish a multihop network topology without prior configuration. The WMN de- vices could change locations and configure itself on the fly. They are also widely adopted for indoor positioning [2]–[5]. These devices have advantages of power efficiency, low cost, and small volume and size. ZigBee [6] is an open standard technology to address the demands of low-cost, low-power WMNs via short- range radio. ZigBee is targeted at RF applications that require a low data rate, long battery life, and secure networking. Its mesh networking also provides high reliability and more extensive range. The ZigBee devices can be combined with WWANs to achieve a seamless platform of wireless patient monitoring. Yet, the current standards of ZigBee do not consider the reliability of transmitted messages in a multihop network topology. Zig- Bee may not be suitable for transmitting vital signs, especially for emergency messages, since these messages are critical for diagnosing the illness of patients as well as providing important clues to the urgency level.

In this paper, we present a reliable protocol of packet for- warding that transmits emergency messages with vital signs on a multihop ZigBee network. We deploy multiple data sinks in a ZigBee network. Our protocol uses anycast to find the near- est available data sink. When the path to the original data sink fails, our protocol automatically selects another data sink as the destination. The transmission path is rebuilt from the last node before the failure link; hence, the latency of path recov- ery is shorter than that for the unicast-based approaches that must rebuild a path from source node. As compared with mul- ticast/broadcast approaches, our protocol significantly reduces the traffic overhead while maintaining the reliability at the same level. With our reliable transmission protocol, we implement a ZigBee device for fall monitoring, which integrates fall detec- tion, indoor positioning, and ECG monitoring. When the triaxial accelerometer of our device detects a fall, the current position of the patient is generated and transmitted to a data sink through a ZigBee network. In order to clarify the situation of the fallen pa- tient, 4-s ECG signals are transmitted along with the emergency message. The new protocol ensures that these critical messages can be transmitted successfully. In our simulations, we consider the traffic overhead, the latencies of the transmitted messages, and path recovery. We also show the prototypes of our Zig- Bee devices and demonstrate the feasibility of our scheme by integrating our protocol with WiMAX.

Our paper is organized as follows. Section II provides a brief discussion of previous work on mobile healthcare systems. Section III describes the reliable transmission protocol, followed by the fall monitoring system

## II. RELATED WORK

### *A. Communication Modes*

Data transmission can be categorized into four modes, namely, unicast, multicast, broadcast, and anycast. Both multi- cast and broadcast are one-to-many transmission, but multicast communication must specify the address of the multicast group to identify the potential receivers. Since multicast and broadcast can deliver messages to multiple receivers, they are suitable for the applications demanding stringent data integrity. Neverthe- less, their weakness stems from the large number of packets that may impede the transmission rate. Unicast differs from previous two modes in that it delivers packets only to a single receiver. Unicast transmission has the least traffic overhead; however, when the path to the receiver fails, additional procedure of path recovery must be carried out to find another receiver.

Anycast is a new network routing approach in which mes- sages from a sender are routed to the topologically nearest re-ceiver in a group of potential receivers. The group is called an anycast group, and the receivers in the same anycast group are identified by the same anycast address. Anycast can be treated as a subclass of multicast that finds the nearest receiver. As compared with the previous communication modes, anycast has lower traffic overhead than broadcast and multicast. Anycast also has better reliability than unicast since it is capable of se- lecting a new receiver. However, anycast routing increases the complexity of the network devices. The path recovery latency of anycast is also longer than that of multicast/broadcast. A better balance between the implementation complexity and the path recovery efficiency is thus critical to the successful deployment of an anycast-based protocol.

We list the properties of these transmission modes used in the following applications.

1) *The nearest or best server selection [7]–[9]:* A client can communicate with the nearest server with an anycast ad- dress. This application can be used to support emergency calls (e.g., call for an ambulance).
2) *Service identification [10], [11]:* Anycast addresses can be used to identify unique services, such as domain name system and HTTP proxy in the Internet.

International Journal of Scientific Engineering and Applied Science (IJSEAS) - Volume-1, Issue-7, October 2015
ISSN: 2395-3470
www.ijseas.com

Developing an efficient anycast routing protocol for ad hoc wireless networks is a challenging task [14]. Although many anycast protocols have been deployed in wired networks, these protocols cannot be applied to wireless networks since every node can move arbitrarily. An anycast approach can use mes- sage broadcasting to transmit service request messages [15]. The sender then selects the best receiver from the received re- sponse messages. Such approach usually produces high traffic overhead. Also, when the number of nodes increases in a wire- less network, the possibility of packet collisions increases and the packet delivery ratio decreases [16].

### *B. Wireless Patient Monitoring Systems*

Currently, a number of studies have been proposed to ad- dress the issues of transmitting vital signs in nursing homes and hospitals over wireless transmission. We briefly overview some research of mobile patient monitoring systems

## III. RELIABLE TRANSMISSION PROTOCOL

In our network architecture, we categorize the nodes into three types: sensor, router, and data receiver. The sensor node

### *B. Router Node*

The router node provides the functions of route maintenance and packet relaying; hence, it only has a ZigBee module. When a router node receives an packet, it checks whether it has the route record for the queried destination node. If *yes*, then it replies with an message to the sensor node. Otherwise, the message is rebroadcasted to its neighbors. Each router node uses a counter, *AnycastGate*, to record the number of the received RREP messages. The counter also indicates the number of data receivers, which can be contacted through the router node. The router node also has a *DataReceiver* list for storing the data receivers notified from the received messages

3) *Improving system reliability [12]:* We can assign an any- cast address to multiple servers scattered. If one of the servers fails, packets will be routed to another nearest server without interrupting service.

4) *Policy routing [13]:* Assume that an anycast address is assigned to the network interfaces of a group of routers. By specifying the anycast address in the hop-by-hop routing option, packets are forced to transmit via one of the routers in the group acquires vital signs and encapsulates these data in packets. Then, the sensor node transmits packets to a data receiver through the closest router. We assume that the sensor node is mobile. Thus, the path to the data receiver would consistently change. Router node is responsible for forwarding messages to a data receiver. Since we use an anycast routing protocol, the data receiver is the nearest one. The data receiver node acts as a data sink, which collects physiological information and transmits to the medical or emergency center. As mentioned previously, the data receiver node can be combined with WWAN technologies, such as LTE or WiMAX, to achieve a seamless platform of wireless patient monitoring. [22].

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The operations of a sensor node are described as follows. When a sensor module acquires vital signs, it informs the Zig- Bee module to check whether it has the route information to the data receiver. If *yes*, then the ZigBee module transmits packets to a data receiver. Otherwise, the ZigBee module encapsulates an message into a frame and broadcasts the frame to the neighboring router nodes. When the ZigBee module receives an packet, it adds route record to its routing table for the data receiver. If the ZigBee module receives more than one packet, the data receivers specified in the extra packets are stored in the *DataReceiver* list. With an active route, the sensor module could periodically sample vital signs and store these data in the buffer of the ZigBee module. Once the buffer of the ZigBee module is full, the ZigBee module encapsulates the data into a DATA message for transmission. After sending a DATA message, the ZigBee module periodically checks the ACK message from the data receiver. When the ZigBee module receives an ACK message, it removes the acknowledged data. If the ZigBee module receives an message or the ACK message is not received within a timeout period, it checks its *DataReceiver* list. In the case that the *DataReceiver* list is not empty, the first entry in the *DataReceiver* list is retrieved and inserted into the routing table. The DATA message is then re-transmitted to the new data receiver. If the *DataReceiver* list is empty, then the ZigBee module will retransmit packet to discover a new route. We show the state transition diagram of the sensor node.

## VI. CONCLUSION

This paper presents a reliable anycast routing protocol for ZigBee-based wireless patient monitoring. For a mobile sen- sor node, the new scheme selects the closest data sink as the destination in a WMN. Therefore, the latency of route query and the number of control messages can be reduced simultane- ously. The new protocol also has the capability of fast rerouting. Therefore, a broken path can be recovered in a short latency, and the reliability of the transmitted vital signs can be assured. We implement a ZigBee-based prototype of fall monitoring system based on the new routing protocol. In the system, we integrate a triaxial accelerometer and an ECG sensor to achieve real-time fall detection and physiologic monitoring. When a fall event is detected, the closest router node to the sensor node is calculated.

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