Selection of Priority in Wireless Body Area Network Sensors using IoT Technology

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***Abstract*—Wireless Body Area Network(WBAN) is an ongoing technology for continuously monitoring the health conditions of a patient. It is a wireless network consisting of various low-powered physiological sensors and a hub placed strategically on a human body. Each sensor sends physiological data in the form of frames using a medium access control (MAC) protocol to the hub. In turn, the hub relays the physiological data to the physician/doctor's monitoring device through an access point over the Internet. According to the IEEE 802.15.6 standard, the priority of the frame is based on the sensor monitoring a specific health parameter. In this paper, we propose an Internet of Things(IoT) based mechanism for selecting and changing the priority of the sensors of the WBAN as when required. In other words, a physician/doctor can change the priority of a sensor as when they need to change the priority of the sensor from a distant location. Increasing the priority of a node improves its packet transfer rate, end-too-end delay and the bandwidth bandwidth. Our simulation study shows that the average round-trip delays incurred for changing the priority of a sensor which is in a network with 3 hops, 5 hops and 7 hops away from the border router are 192ms, 447ms and 545ms respectively. Further, our study shows that the difference in average delay between case 1 (represents an average delay incurred for changing the priority from highest to lowest) and case 2 (from lowest to highest) is 22% of the average delay of case 1. Also, we show that the difference in the power consumed by the lowest and highest priority node is around 20.3%.**

***Index Terms*—WBAN, IoT, CoAP, Priority**

I. Introduction

IoT is a network of computers, machines and low-powered electronic systems such as sensors and actuators. Its application can mainly be found in smart homes and wearables. But now this technology has has found its way in health care monitoring through an integrated architecture of IoT and WBAN [1]. WBAN provides a very cost effective way to monitor a patient's health [2]. A WBAN is a wireless network consisting of various low-powered physiological sensors such as temperature, heart rate and blood pressure, and a hub placed strategically on different parts of a human body. Each of the sensors send the sensed data to the hub. In turn, the hub relays the physiological data to the physician/doctor's monitoring device through an access point.

In 2015 a report from the World Health Organization showed that over 45% of the WHO member states have less than one physician per 1000 population. Therefore, we would benefit from this promising technology by having deployed WBAN on patients and monitor remotely from a base station through IoT. In Ref. [3], a system was developed to monitor a patient's health without restriction on a patient to visit the hospital. It benefits on cost reduction due to no hospitalization. For example, a system to detect different medical conditions and alert a patient by sending an SMS/e-mail to the doctor was proposed in 2013 [4]. In this system, the physiological data is sent to the base station with the help of a hub placed in a patient's body. In Ref. [5], a health-care system for the elderly was proposed. An alarm goes off in case a stroke is detected. In Ref. [6], a system for monitoring the elderly and chronically ill patients was proposed. It is a network that comprises of sensors and a base station and uses IEEE 802.15.4 and IEEE 802.11 to transmit data.

Our system model can also be focused on patients with comorbidities. If a patient shows some new irregularities in his health condition which was not diagnosed during the initial medical examination, then accurate and constant monitoring is required for this particular parameter until the symptoms/illness subsides or is cured. For example, a doctor can change the priority of the sensor for a hypertensive patient who has a history of the same illness, according to the stage and risk factor in Ref. [7]. In Ref. [8], a WBAN architecture describing the dynamic priority mechanism and how the data sending rate , transmission time gap and allocation of available bandwidth is dependent on it. Though the paper depicts that above metrics are effected based on the priority of the sensors, it talks about sensors having high and low priorities but doesn't show a working implementation to dynamically change the priority.In this paper, we propose a mechanism to change the priority of the WBAN sensors dynamically from a remote location. We propose to study the mechanism by using the performance metrics such as average round-trip delay, power consumption percentage and rate of packet transfer.

The rest of the paper is organized as follows: Section II discusses about the various IoT protocols used to study the priority selection mechanism. Section III contains the metrics used for the study. Additionally the Simulation Settings are given in section III-A. The results are discussed in Section III-B. Finally, the paper is concluded in Section IV.

II. Methodology

The IEEE 802.15.6 standard is the standard for WBAN, it supports a variety of real-time health monitoring systems and different priorities for the sensors. Table I shows the priority mapping to the contention window [9]. The priorities are based on different contention window range. In our work, we implement the CSMA/CA which is a carrier sensing mechanism provided as part of IEEE 802.15.6. The MAC protocol provides differentiated services or priorities to the sensors using their contention window ranges. In the RDC layer, we have also used ContikiMAC which is a radio duty cycling mechanism.

TABLE I
Priority Mapping to the Sensor Nodes

Priority TYpe	Contention Wondow Ranges [CWmin,CWmax]
0	[16,64]
1	[16,32]
2	[8,32]
3	[8,16]
4	[4,16]
5	[4,8]
6	[2,8]
7	[1,4]

The system uses a client server architecture where the sensor nodes act as clients and the base station act as the server. An application and network protocol is mainly used to communicate between the sensor nodes and the base station. In our work primarily the following two important protocols are used in the IoT stack

A. CoAP

The Constrained Application Protocol (CoAP) is a transfer protocol for networks with light nodes, mostly used in the application of Internet of Things. It has similar characteristics to that of HTTP, CoAP depends on REST style architecture. CoAP is based on UDP [10]. It has a two layer architecture, where its first layer is used to handle the exchange of messages using UDP between two points of the constrained network and the second layer handles the request and response type communication using the method and response codes [11]. The internetwork between CoAP and HTTP is created due to the REST architecture which is another unique feature of CoAP as shown in Fig.1. This is due to the intermediaries, in the REST architecture, that performs translation between HTTP and CoAP without any additional requirements on the client side or the server side.

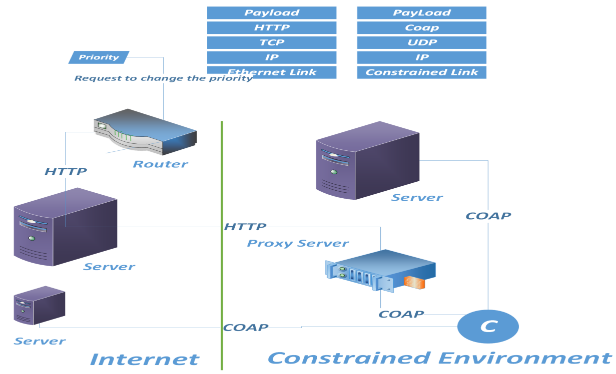

Fig. 1. Internetwork between CoAP and HTTP.

B. RPL Border Router

RPL stands for routing protocol for low-power and lossy networks. RPL transports the concept of routing topology through destination-oriented acyclic graph (DODAG): a directed graph without any cycles, oriented towards a root node [12], a good example would be a border router that we use in our simulation study. An RPL border router connects a given lossy network to an external network i.e. the Internet. Thus, it can be found on the edge of a network. We assume that the data when received by the RPL border router has been successfully transmitted from the sensor to the base station. The part of RPL network which consists of the sensors and a hub is called WBAN as depicted in Fig. 2. The data packets of the WBAN sensors are forwarded over a route which is selected from all available routes to the border router by the routing protocol using hop count as a metric.

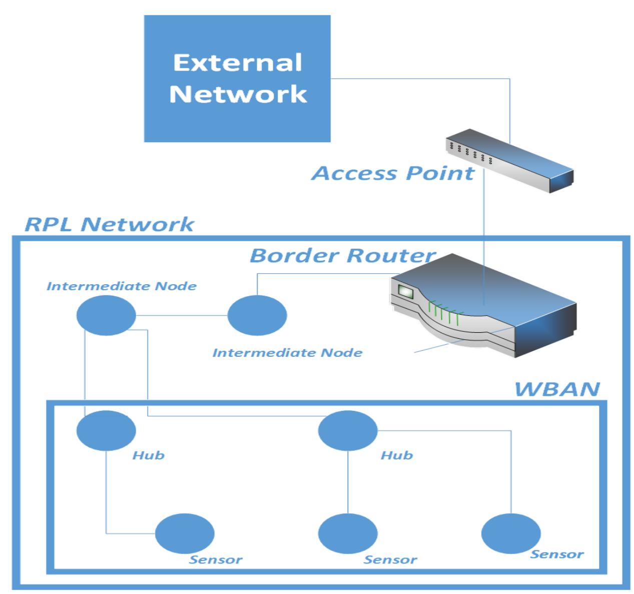

Fig. 2. Control Flow of RPL for WBAN.

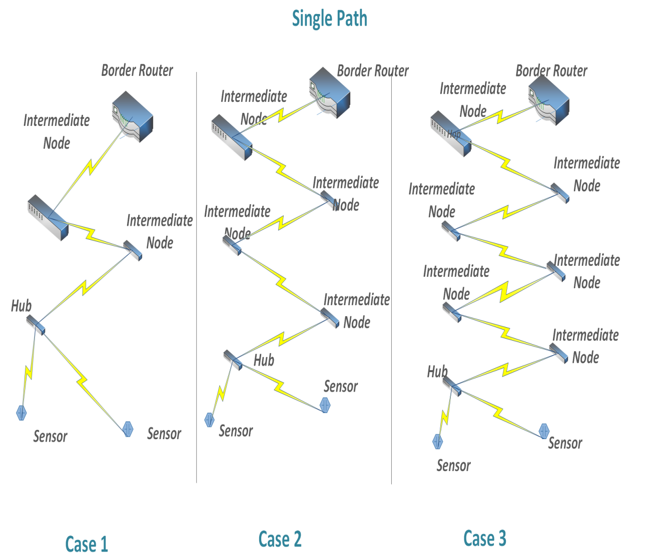

Fig. 3. Networkt topology with a single path from a sensor to the border router

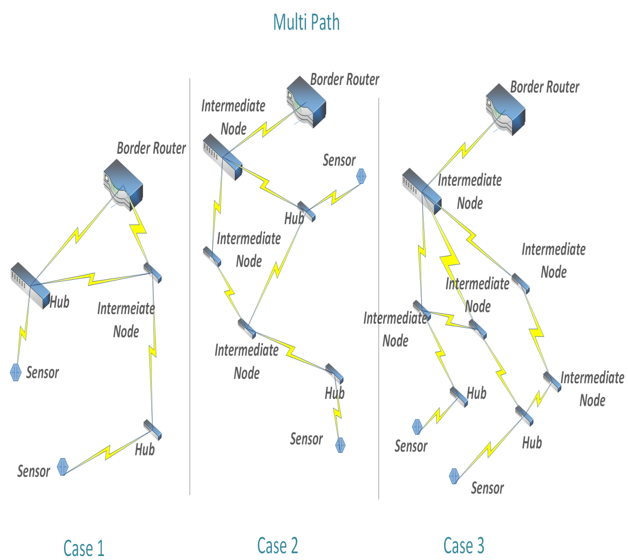

Fig. 4. Networkt topology with multiple paths from a sensor to the border router

III. Analysis

We consider the simulation framework for studying the IoT enabled WBAN. We implement our mechanism for changing the priority of mote over the Internet through CoAP for two different topologies of RPL network as shown in Fig. 3 and Fig. 4. The priority ranges from 0(lowest) to 7(highest). The GET method is used to gather the resources and change of priority can be requested using the POST method of CoAP. The performance of the proposed scheme is studied using the following metrics in Table II.

- Round-Trip Time: Round-trip time(RTT) is defined as total time required for transmitting packets from coordinator to sensor and get the acknowledge from sensors to coordinator.
- Radio On: It is defined as average amount of power consumed by a sensor node to be in an active state.
- Packet Transfer Rate: The rate at which the number of packets are transmitted from a source to destination.

A. Simulation settings

We conduct extensive simulations of the proposed mechanism using the simulation framework consisting of CoAP protocol, a constrained network of Sky motes as sensor nodes and a RPL border router as it is connected to the main access point or the base station.

We use Cooja simulator for network simulation in Contiki Platform. We simulated the network consisting of WBAN motes (representing sensors), border router, and access point deployed within the simulation area of 40m $\times$ 40m. We collected the results after running the simulation for 300 seconds. The size of each packet is 97 bytes. It has been assumed that each sensor node has always a data packet in its buffer for transmission. We study the network performance using the protocols as follows: CoAP for Application Layer, ContikiRPL for Network Layer, WBAN MAC for Data Link Layer, and ContikiMac (RDC) for Physical Layer. Description about the parameters and their values used in the simulation are provided in Table II.

TABLE II
SIMULATION SETTINGS

Parameters	Values
Simulation area	40m $\times$ 40m
CCA threshold	- 45 dB
MAC protocol	802.15.6 CSMA/CA
Mote Type	SKY Mote
Slot Time	20 μs
CCA Time	15 μs
Channel Check Rate	128 Hz
Radio Channel	26
RTS/CTS	Off
Packet Size	97 bytes

B. Result

We consider six different network topologies to analyze the round-trip delay from a router to sensors while considering different number of hops. Each topology has a coordinator/hub, a border router/access point and sensors. A coordinator is a router which relays the data through an access point. An intermediate node is an access point which is responsible for forwarding the data to external network. Sensors send the data to the hub and the hub in turn forwards the data to the border router.

A single path is considered from a router to sensors as shown in Fig. 3. We consider three different topologies with different number of hops to analyse the Round-trip time from router to sensors.

Multiple paths are considered from a router to sensors as shown in Fig.4. We consider three different topologies with different paths to analyze the Round-trip time from router to sensor and also ensuring that it always take the shorter path to send the message. The paths to the border router can be selected based on the metrics such as expected transmission and hop-counts.

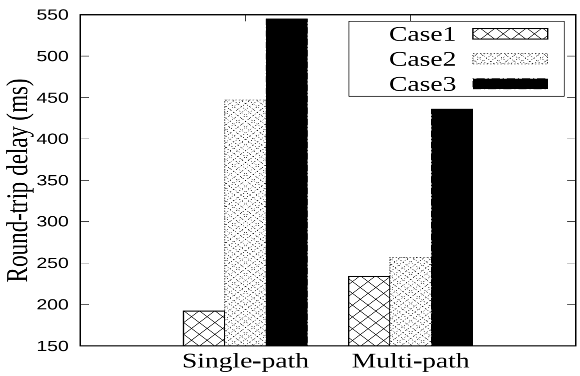

Fig. 5. Round Trip Delay from coordinator to sensor

In Fig. 5, we show the Round-trip time from a router to sensors for each case for Fig. 3 and Fig. 4. For the single path, we analyze from the result that round-trip delay increases with the increase in the number of intermediate nodes, and for the multiple path, if we increase the number of intermediate nodes in the shortest path from the router to the sensors, then an increase in the Round-Trip delay is seen.

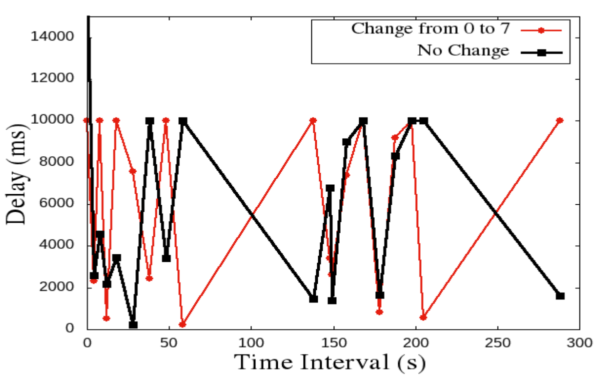

Fig. 6. Comparison of time delay with and without setting the priority

In Fig. 6, we consider two cases to demonstrate the delay time for a certain period of time. In the first case priority of nodes is unchanged and in second case the priority of the node is changed from low to high many times. We observe that the average delay to get channel for first case is 6333.62 millisecond and for the second case is 5562.29 millisecond (as per simulation time). We observe this result by considering the topology as shown in case 2 of Fig. 3.

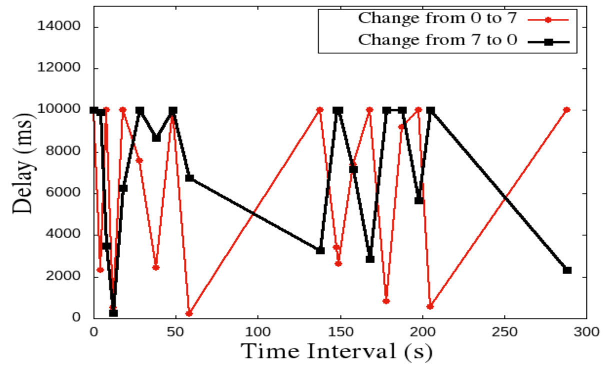

Fig. 7. Comparison of time delay for highest and lowest priority node when the priority is changed multiple times

In Fig. 7, we consider the time delay for certain period of time by considering case 1(represents an average delay incurred for changing the priority from highest to lowest) and case 2 (represents an average delay incurred for changing the priority from lowest to highest). We observer that the average delay to get channel for first case is 7188.57 millisecond and for second case is 5562.29 millisecond (as per simulation time). We observe this result by considering the topology as shown in case 2 of Fig. 3.

Further, our study shows that the difference in average delay between case 1 and case 2 (from lowest to highest) is 22% of the average delay of case 1.

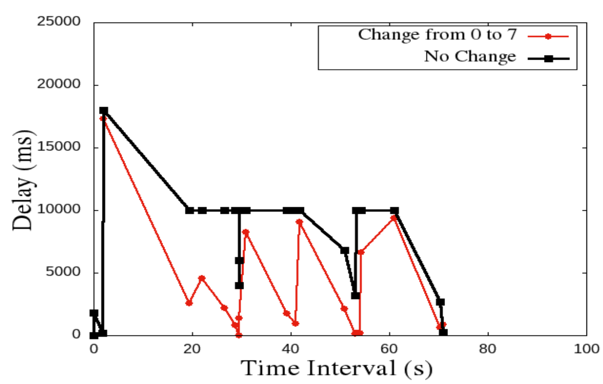

Fig. 8. Comparison of time delay for highest and lowest priority node when the priority is changed only single time

In Fig. 8, we show time delay for certain period of time. In this case we change the priority only once from lowest to highest and observe that the node with the highest priority will have less delay compared to the node with the lowest priority. We also observe that the average time delay for the highest priority node is 4811.92 millisecond and for the lowest priority node is 8677.28 millisecond (as per simulation time). We observe this result by considering the topology as shown in case 2 of Fig. 3.

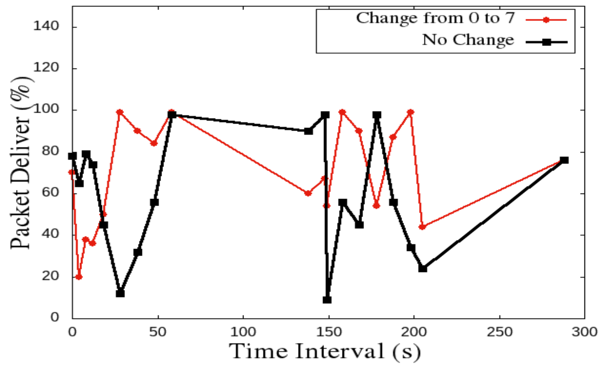

Fig. 9. Comparison of delivery of packet with and without setting the priority

In Fig. 9, we show a number of packet transfer in percentage by considering case 1(the priority of the node is kept unchanged) and case 2 (change the priority from low to high repeatedly). We observe that the average packet deliver in percentage for first case is 60.28 and for the second case is 65.77 (as per simulation). We observe this result by considering the topology as shown in case 2 of Fig. 3.

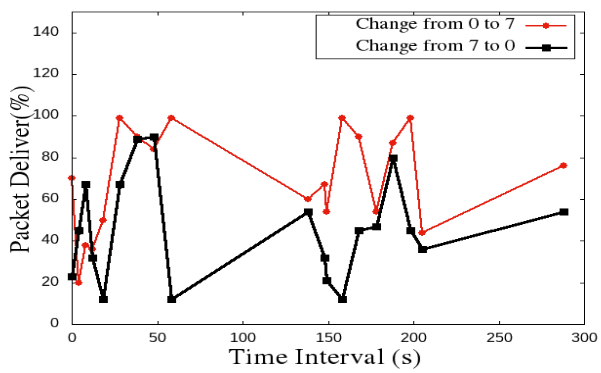

Fig. 10. Comparison of Delivery of Packet for Highest and Lowest Priority Node when the priority is changed multiple times

In Fig. 10, we show a number of packet transfer in percentage for both the cases. First case is when we change the priority of nodes from high to low and in second case we change the priority of node from low to high. We observe that the average packet deliver in percentage for first case is 45.42 and for the second case is 65.77 (as per simulation). We observe this result by considering the topology as shown in case 2 of Fig. 3.

TABLE III
POWER CONSUMPTION OF MOTES AS PER PRIORITY

Priority of Nodes	0	1	2	3	4	5	6	7
Power Consumed (%)	79	80.2	82.3	86.5	87.8	90.5	92.5	99.3

The node whose priority is high consumes more power(in terms of percentage) than the node having low power as given in Table III that.

IV. CONCLUSION

After performing the simulation multiple times, we observe that the request to change the priority of the sensor node has its own delay (round-trip time) which would be added in the overall data transmission delay. But even after adding this delay, the overall time taken to transmit the data is less than the time taken before the priority change. We also change the priority of the same sensor multiple times to get the most accurate result. After repeatedly changing the priority of a sensor node from high to low and low to high we can clearly see that the data packet transmission of the node is increased when the priority is high.

Finally, we conclude that the priority selection mechanism we propose can if incorporated in the existing health care system would improve the time-delay and the field of telemedicine would be benefit from it.

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