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Alternative Priority-based Queuing for WBAN

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Abstract*: Wireless Body Area Network (WBAN) technology enables medical services to expand its scope. It allows medical expert to monitor physiological data of patients using wireless communication. Despite of the numerous advantages it provides, WBAN still incur issues on different metrics on quality of service (QoS) such as end-to-end delay, queuing delay, and reliability. QoS metrics of the WBAN is affected on the efficiency of its queuing system. Previous studies proposed different routing algorithms to address QoS metrics which implement multiple queues to enhance data transmission of different data types. These studies used strict priority logic which serves the highest priority queue first. However, the main problem of this approach is that lower priority data may be totally blocked by a higher priority data. This paper presents an alternative priority-based queuing to address issue on QoS metrics. The results showed that the proposed algorithm decreased the end-to-end delay and queuing delay and increased the reliability of QoS aware routing protocol. Based on the implementation result, it can be seen that the proposed algorithm can be implement on WBAN.

***Index Terms*: Alternative Queuing System, QoS Aware Routing Protocol, Wireless Body Area Sensor Network, Biosensors**

I. INTRODUCTION

Over the past years, wireless communication technologies have taken a major role in healthcare services such as patient real-time monitoring [1]. One of the emerging technologies that allows healthcare application to expand its scope is Wireless Body Area Network (WBAN) [2][3]. It is consisting of medical/biosensors like ECG, EEG, temperature sensor, blood pressure sensor, etc. which gathers patient's physiological data. These data are transmitted wirelessly through a coordinator as shown in Figure 1. It allows medical experts to monitor any abnormal behavior from patients' physiological data. Furthermore, it also enables patient monitoring outside the hospital and provides medical assistance to remote areas. It was asserted in the study of [4] that there are three different types of WBAN which includes managed WBAN, autonomous WBAN, and intelligent WBAN. Managed WBAN is focus on gathering and sending data to a medical expert who analyze and diagnose all the physiological data at the same time; however, the main disadvantage of this type of WBAN is the data will have a bottleneck on the medical expert. Autonomous WBAN includes actuators which respond based on the sensed data from the biosensors. Intelligent WBAN is a combination of managed WBAN and autonomous WBAN. The framework of the WBAN is composed of three tiers of communication, including: (a) intra-body communication network; (b) inter-body communication network; and, (c) extra-body communication [5]. Biosensors in WBAN typically measures different physiological data that involves different sizes of packets including different QoS requirements or metrics. Therefore, WBAN must be able transmit data real-time and reliable considering different types of data priorities. Any packet loss or delays sending data can be dangerous to the patient most especially on critical data. One of the proposed solutions to this type of problem is data prioritization on the sensor nodes [6]. Biosensors have three types; in-body biosensor or implanted biosensors, on-body biosensor or biosensors which surface mounted and off-body biosensor [7]. These biosensor nodes are typically battery operated and have low power [8], thereby replacing the battery of some biosensors especially those are implanted is challenging. One of the proposed mechanisms to achieve high energy efficiency is the use of centralized and cluster-based techniques for cluster tree routing in the biosensor node [9]. Moreover, the study of [10] proposed the reduction of time slots in sending the data which leads to the decrease on the energy consumption of the sensor nodes; however, it may result in the increase of communication delay. Different biosensors have different energy level in sending different sizes of data unlike in the wireless sensor network that has same levels of energy, thus using the different routing algorithm available in WSN in a WBAN is not applicable. Furthermore, due to the heterogeneity of biosensor nodes, different sensor nodes also demand different level of quality of service (QoS) to ensure data quality and reliability, energy consumption and efficiency [11], [12]. Thus, developing an efficient QoS protocol is very challenging considering that different QoS metrics are addressed by different modules [13]. Different routing protocols have been proposed to address QoS metrics such as Routing Service Framework (RSF) [14], Reinforcement Learning based routing protocol with QoS support (RL-QRP) [15], LOCALized Multi-Objective Routing (LOCALMOR) protocol [16], Data-centric Multi-objectives QoS aware routing protocol (DMQoS) [17], Energy aware Peering Routing protocol (EPR)[18], QoS aware Peering Routing for Delay sensitive data (QPRD) [19], and QoS aware Peering Routing for Reliability sensitive data (QPRR) [20]. These protocols handle different types of data using multiple queue system which follows strict priority method. The problem with this method is that the lower priority data is blocked by the higher priority data. From this perspective, the paper would like to enhance the QoS aware queuing of the routing protocol. The assumption of the researcher is that,

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if the queuing algorithm is efficient, the queuing delay will decrease thereby decreasing the end-to-end delay. Thus, an alternative queuing algorithm was formulated to decrease the queuing delay, end-to-end delay, and enhance the reliability of the system.

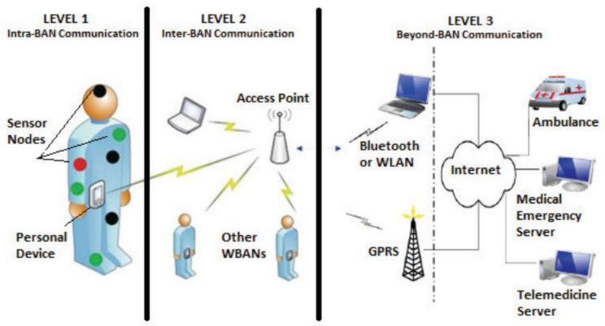

Figure 1: General WBAN Architecture [5]

II. METHODS

A. System Overview

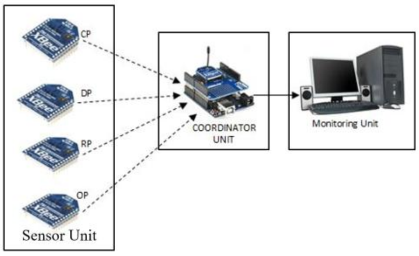

Figure 2: Overview of the system

Figure **2** shows the implementation of the system. It consists of the sensor unit, coordinator unit, and monitoring unit. The sensor unit is responsible for gathering the patient's physiological data.

B. Queuing Delay

The average queuing delay is the time the packet waits in the queue before it can be transmitted to the next node. The average waiting time of the data packets in the queue is computed as shown in equation (1).

$$W\_q = \lambda/\mu(\mu - \lambda) \qquad (1)$$

Where: W_q is the waiting time in the queue, λ is the inter arrival time (Poison distribution), μ is the service time (exponential distribution).

C. End-to-end delay

The end-to-end delay is the time taken for packet to be sent from source to the destination. The end-to-end delay of the system is shown in equation (2)

$$D\_Total = D\_Tx + D\_prop + D\_q + D\_ack \qquad (2)$$

Where: D_Total is the total delay (end-to-end delay), D_Tx is the transmission delay, D_prop is the propagation delay, D_q is the queuing delay, D_ack is the acknowledgement delay.

D. Reliability

WBAN packets are sensitive to packet loss during transmission. To minimize the packet loss on the link, the system uses retransmission on the link. Therefore, the reliability on the on the network increases as the reliability on the link or node increases. The reliability on the node is calculated using exponentially weighted moving average (EWAD) given by equation (3).

$$L\_R = (1 - \gamma)\, L\_R + \gamma\, Tx\_succ/Tx\_total \qquad (3)$$

where: Tx_succ is the number of successful transmitted packets, Tx_total is the total number of transmitted packets, and γ = average weighting factor.

E. Software

A simulation was carried out using the NS3 Simulator. This simulator is developed for the study of proposed protocol for Wireless Sensor Networks (WSN) and Body Area Networks (BAN).

F. Architecture of the alternative queuing

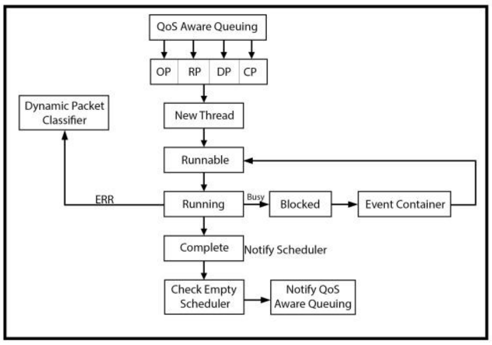

Figure 3: Architecture of the proposed alternative queuing

Figure 3 shows the proposed enhancement on the QoS aware routing algorithm. It focuses on the modification of QoS aware queuing into alternative queuing. The QoS aware queuing classifies the packets as ordinary packets, delay sensitive packets, reliability service packet, and critical packets. The QoS aware queuing module prioritizes the higher priority packets during transmission. The lower priority packet will only be sent if the higher priority queue is empty. The proposed algorithm creates a separate queue that will hold the different classification of packets. The alternative queue will still follow the priority scheduling wherein the CP will still have the highest priority and the OP having the lowest priority. This method will eliminate the issue on starvation on multiple queue system by giving each packet to use the shared resources. The error handling mechanism ensures that the packet will not be dropped immediately even if error occurs. The system checks and notifies the scheduler if the first batch of packets has been completed. If the scheduler is empty then the proposed system will notify the QoS aware queuing to release the next batch of packets.

III. RESULTS AND DISCUSSION

This section presents the simulation results using NS3 Simulator in terms of QoS metrics such as queuing delay, reliability, and end-to-end delay.

The results are compared with the existing QoS aware routing algorithm such as DMQoS [17] and QPRR [21]. Sample implementation result was also shown in this section.

A. Algorithm of the proposed priority-based queue data transmission

Dynamic Packet Classifier
Input Packet p
for each receive *p* **do**
  Determine p.Priority
  if (*p.Priority*==OP) **then**
    opQueue.push(p)
  else if(p.Priority==RP) **then**
    rpQueue.push(p)
  else if(*p.Priority*==DP) **then**
    dpQueue.push(p)
  else if(*p.Priority*==CP) **then**
    cpQueue.push(p)
  end if

create new queue
    nQueue[size=4]
  nQueue(getPacket(opQueue[head]),getPacket(rpQueue[head]), getPacket(dpQueue[head]),getPacket(cpQueue[head]))

Priority transmission
for each *p* **on** *nQueue* **do**
  transmit
    if(transmit==FAILED) then
   send p to dynamic packet classifier
  else
   if(*nQueue.empty*==TRUE) **then**
    create new queue
  end if
end for

The dynamic packet classifier determines the priority of each packet coming in the system. It enqueues packet *p* in its corresponding queue. The system then generates new priority queue by getting the head of each queue (OP, RP, DP, and CP). This priority queue was transmitted based on packets priority accordingly.

B. Implementation Result

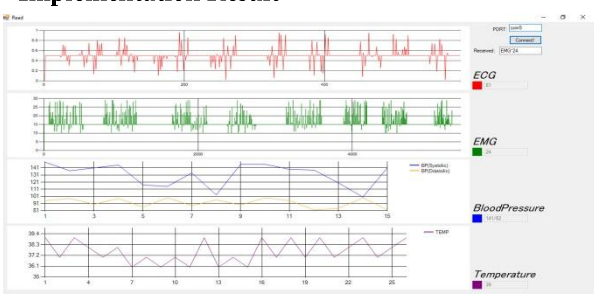

Figure 4: Sample implementation result of system

Figure 4 shows the implementation result of the proposed system. Random data from pressure sensors and temperature sensors with different priority levels was sent from the sensor unit to the coordinator unit. ECG random data having the highest priority (CP) and temperature random data having the lowest priority (OP). It can be seen from the figure that the proposed alternative queuing algorithm is applicable in receiving data with different priorities.

C. Priority order on the coordinator node

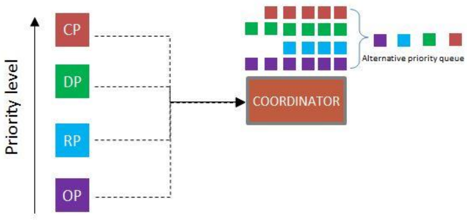

Figure 5: Alternative priority queue order of data on coordinator node.

Figure 5 shows the order of the data on the coordinator based on the priority. The coordinator accepts all the data from the sensor nodes, then classify each data based on priority. Then makes a new queue which consist of the head on each priority queue before sending.

D. Simulation Results

a. End-to-end delay

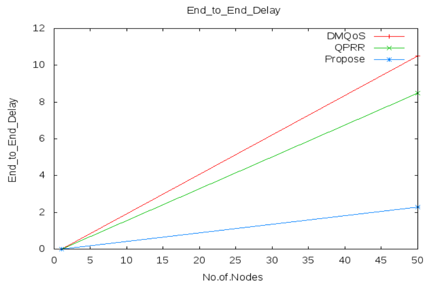

Figure 6: End-to-end delay of the system

Figure 6 show that the use of alternative queuing on WBAN decreases packet's end-to-end delay from the source node to the destination node. This implies that the system transmits the packet from a source to destination faster than DMQoS and QPRR.

b. Queuing delay

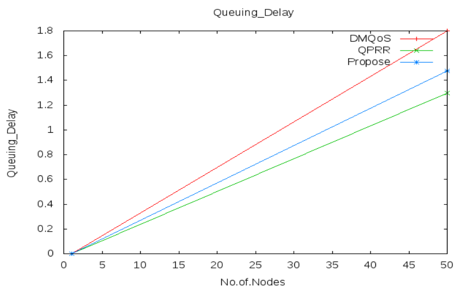

Figure 7: Queuing delay of the system

Figure 7 displays simulation result of the proposed alternative queuing system on the average queuing delay. It shows that the proposed system has lesser queuing delay than DMQoS, however, it also indicates that QPRR has lesser queuing delay than the proposed system because QPRR only consider OP and RP priorities.

c. Reliability

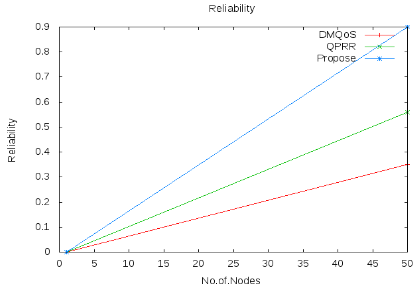

Figure 8: Reliability of the system

Figure 8 shows the result of the simulation for the system's reliability. It is shown on the figure that the proposed architecture sends data more reliable than DMQoS and QPRR. This implies that the data from the sensor nodes reach the destination without loss. The proposed architecture overcomes the issues on data loss and starvation of multiple queues. This is because the proposed architecture has an error mechanism that reconstructs the queue based on the remaining priority if data loss occurs.

IV. CONCLUSION

An alternative priority-based queuing system for WBAN has been proposed to enhance the QoS aware routing protocol in different QoS metrics. NS3 simulator was used to evaluate the proposed enhancement to the QoS aware routing protocol. The output of the simulation shows that the study decreases the end-to-end delay, queuing delay, and increases the reliability of the system. The implementation result also shows that the alternative queuing algorithm can be implemented in WBAN. Due to the limited resources and tools, the study did not compare QoS aware metrics based on the simulation results and the actual implementation.

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