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DECREASING THE POWER CONSUMPTION IN WIRELESS BODY AREA NETWORKS: A TECHNICAL SURVEY

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Abstract—*Chronic health disease such as hypertension, diabetes, high blood pressure, heart attack, cancer and asthma have spread across the world. Health-care wireless body area networks (WBANs) have been widely deployed by medical professionals to manage and monitor the health information of a patient remotely, and various data-management approaches have been used to handle the continuous transmission of WBAN data. The data segregation and classification approach is considered one of the most promising WBAN data-management technique among the extant state-of-the-art approaches. This approach considered promising as it play an important role in avoiding network congestion ,however it will consumes more energy from the sensor while transmitting information which is accumulated in the buffer in the network. This paper gives the research which is intended to solve this problem by a novel classification scheme which segregates the sensor's readings into urgent, semiurgent and nonurgent packets. This article offers an architectural routing approach for a medical that enables transmitting packets during the gateway failures in the network. The survey is made on performance evaluation using OMNET++ simulator with varied performance metrics shows promising results, because verification outperforms the extant state-of-the-art methods in terms of power consumption, packet delivery ratio, and the number of transmitted packets.*

Keywords**:** *WBAN, state-of-art approach, packet delivery ratio.*

1. WBANs AS A TOOL IN CHRONIC DIESEASE MANAGEMENT

Chronic health issues such as hypertension, high blood pressure, diabetes, heart attack, and asthma are causing high death rates among elderly people in our community [1].This is because of the non-proper monitoring of health issues in the patients .The disease is diagnosed at a very late stage causing death. In addition to the above elderly people often do not have the strength to visit Hospitals. WBAN as a technology counters the above mentioned points.

WBAN consists of medical sensors, a processor, a transceiver, and a battery [2]. The Medical sensors are used to determine vital signs such as the heart's electrical activity by using electrocardiogram (ECG) testing, blood pressure, blood oxygen saturation levels and heart attack, and these sensors are placed inside a human body as a small patch for a long period to continuously transmit packets that are being forwarded to the medical server [3]

WBAN sensors continuously transmit bio-signal packets, management of these packets is of paramount importance. The data segregation and classification technique is one of the efficient data- management techniques that have been used to handle the sensor's readings in WBANs

Biosignal packets can be classified into:

- Urgent packets
- Non-Urgent packets

The urgent packets is give more priority and is sent to the gateway immediately, the non-urgent packet is accumulated and is sent to the gateway less frequently.
Since the non-urgent packets are accumulated, the sensor will require more energy to transmit them to the gateway. This needs to be addressed. To increase the reliability of the system, a medical sensor should be equipped such that if the gateway fails, it can still manage to transmit packets to the medical server. To achieve energy efficient WBAN's we classify the non-urgent larger packets to smaller packets. Data segregation and classification technique, we placed the biosignal packets into non-urgent, semi-urgent, and urgent categories. The urgent packets are the biosignal packets that are above a threshold, whereas semi-urgent refers to the biosignal packets close to the specified threshold, and nonurgent depicts the biosignal packets below the threshold. The approach limits the packet transmission over the network and thus minimizes the energy consumption of the sensor.

RELATED WORKS

The existing Techniques that are used to manage the WBAN data are:
Map Reduce, dynamic data selection, hybrid predictive model, query processing optimization, data segregation and classification, cloud resource allocation, fuzzy logic, statistical model technique, convex optimization framework, and data analysis application.
Data segregation and classification technique is an efficient method of managing WBAN data.

The authors in [3] introduce a real-time cloud-supported health-monitoring system for tracking the medical status of non-hospitalized patients by introducing a local cloud for WBAN to extend the present global cloud-based concept .The authors use data segregation and classification to reduce the flow of data traffic. Data are classified into urgent, which is sent immediately to caregivers, and
Non-urgent is accumulated and sent less frequently. However, the segregation algorithm implemented inside the gateway does not solve the power consumption issue of medical sensors; it only reduces the rate of the packet's transfer to the cloud, which only mitigates network congestion

Moreover the interference between the medical devices that are operating under the same medical frequency can lead to high packet loss, in which case sensor nodes need to retransmit the lost packet, using more energy. To solve this issue, the authors in [4] separated the patient data into three categories by using a data aggregation algorithm:

- Red, which means immediate;
- Yellow, which signifies delayed
- Green, which implies minimal.

However,this research was mainly focused on interference prioritization of patient data to achieve a minimum delay. Likewise, the data aggregation algorithm had not yet been developed; it was just assumed during their implementation.

The authors in [5] present an automated data collection technique to ease the acquisition of medical data from patients in a tele-monitoring system. The main objective of the work was to minimize unaffordable human errors when gathering medical data manually. The authors introduced a medical sensor fixed with existing medical equipment to automatically acquire data from a patient. In this article, packets were accumulated and transmitted as a large packet. The transmission rate of the sensor was reduced, but energy consumption increased.

The authors in [6] introduced an anomaly detection algorithm that can divide the sensor's readings into normal and abnormal to determine the complexity state of a patient. Their work consumes much more of the power of amedical sensor as the transmission involves sending all the packets.
In a WBAN system network reliability is important. The tendency for gateway failure to occur is high, since the most useful gateway devices nowadays are smartphones and PDAs, which are generally regarded as power-constraint devices.

There are also gateway failure methods that have been introduced in wireless sensor networks to coordinate the sensor nodes in the field such as [7]. In a WBAN system where a patient is wearing one medical sensor node, previous literaturehas not considered the failure of the gateway devices or provided an adequate routing solution for the medical sensor to transmit its packet to the server.

RESEARCH SCOPE AND MOTIVATION

This research assumes that the patient is wearing only one sensor node, such as a diabetes patient who wears only a diabetes sensor.

The WBAN health-care monitoring system canbe categorized into a monitoring system that records and analyzes all the medical data and a monitoring system that considers only the critical data. The scope of this research covers only the critical data, which means that noncritical data were not treated. The introduced algorithms work under the following assumptions:

- The threshold value of a specific medical sensor is known. For instance, normal blood pressure is 120 mmHg and below. The range for medium high blood pressure is 121– 140 mmHg, while any value greater than 140 mmHg is considered abnormal and needs urgent attention.
- The health-care monitoring application does not support the full medical history of the patient. Some semi-urgent and non-urgent data are dropped at the sensor, while only urgent data are sent to the medical server.
- The adopted wireless communication protocol of the medical sensor is 6LoWPAN and not ZigBee. The 6LoWPAN protocol can communicate with the nearest access point and to the server.

- There is no retransmission of packets in case of packet loss, because data are constantly updated.
- Finally, the gateway can connect to the internet via Wi-Fi or mobile data subscription.

Table 1. Shows the readings of some medical sensors.

Medical Sensor	Function	Readings: Normal Case	Readings: Medium Case	Readings: Serious Case
ECG or EKG	Examines the electrical and muscular functions of the heart	Approximately 60–100 beats per minute (bpm)	Less than 60 bpm	Greater than 100 bpm
Blood pressure	Measures the blood pressure value	Lower than 120/80 mmHg	120–139 mmHg	140 mmHg and greater
SpO_2	Determines the amount of oxygenated hemoglobin in the blood	94–99%	90–93%	Below 90%
Diabetes sensor	Monitors the glucose level in the blood	Lower than 100 mg/dl	Between the range of 101–126 mg/dl	Greater than 126 mg/dl
Heart-failure sensor	Measures the intracardiac pressures in the heart	A brain natriuretic peptide (BNP) less than 100 pg/mL [10]	BNP ranges from 101–400 pg/mL	A BNP greater than 400 pg/mL

DEFINITION OF TERMS

WBAN MEDICAL SENSORS

A WBAN can be regarded as a network of biosensors that is usually located in the clothes, on the body, or under the skin of a person.

GATEWAY DEVICES

The word *gateway* usually refers to a device used as a gate between two or more devices, and it may include a firewall, server, and router.

BIOSIGNAL PACKET TRANSMISSION

A biosignal is usually referred to as any signal in living beings that can be continually monitored and measured. Classification of the sensor's reading used in this research and the components are:

Urgent data: These are defined as the biosignal data above the threshold value of a medical sensor. For instance, any value above 140 mmHg in the case of high blood pressure is considered urgent.

Semiurgent data: These are the biosignal data that are within the range of a specified threshold value. For instance, 121–140 mmHg is considered an intermediate case of high blood pressure. The patient's condition is not as bad as urgent and not as good as nonurgent. This kind of data is sent to the medical server if the reading persists twice consecutively;

Nonurgent data: These are the biosignals that are below the threshold value. Any reading below 120 mmHg can be regarded as nonurgent data. These data are not sent to the medical server.

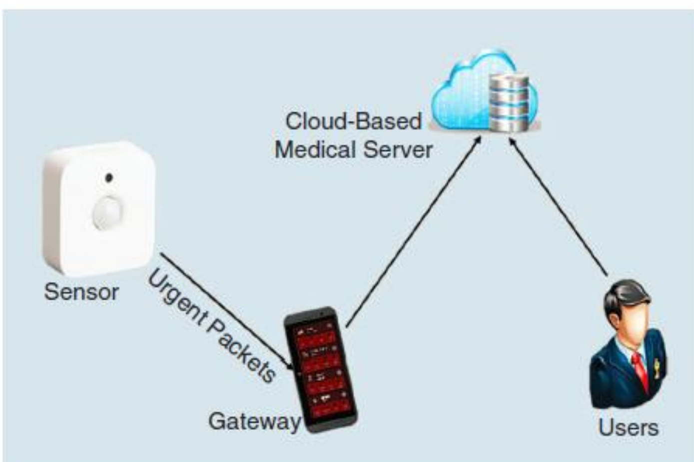

Figure 1:Rouet 1 or transmission.

RESEARCH MODEL:

The three main hardware components in this research are theWBAN sensor, the gateway, and the medical server. The packet transmission stages are as follows:

- Stage 1: Bio-SIGNAL data is collected from the patient and Mathematical computation is performed on it.
- Stage 2: The signal data is classified into urgent, semi-urgent and non-urgent packets.The urgent packet is sent to the gateway immediately. The urgency of a packet varies from one sensor to another, and Table 1 shows different values.The semiurgent packet is buffered temporarily inside the sensor, and the buffered packet waits for the next transmission. If the next transmission is also semi-urgent, the sensor forwards the buffered packet to the gateway or drops the packet if it cannot be forwarded.The nonurgent packet is dropped immediately without being transmitted to the gateway.

Algorithm 1 Data segregation and classification.

```
Start
 Srand (time (0)); energy = par("Energy");
 WATCH (energy);
do {
 ∑(n = 1 − 200)//random number generator
  for
   n ⊳ u {
   show "This is an urgent data";
    p = e − 0.002
  if (e > 0.002) {
   show "energy remaining
   send (msg, "out1");
  else {
   show (this-> getName () <<" is dead.")}}

  else if
   n ⊳ s1 && n < s2 {
   show "This is a semiurgent data";
   send (msg, "out1");}
  else {
show "This is a nonurgent data";
delete msg
end if
end do

for (g = 0; warning packet){
 send (msg, out2);}
 else {g = c;
 send (msg, out1);}
end for
```

Algorithm 1:Data segregation and classification.

- Stage 3: The gateway sends a warning packet to the sensor immediately when it is about tostarts using route two until it receives another welcome packet from the gateway, and then it returns to default. Algorithm 2 shows the code of gateway failure.

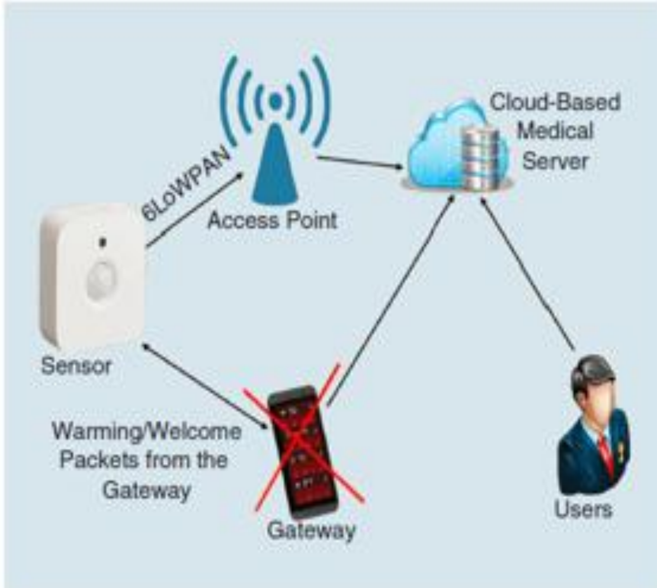

Figure 2: Route 2 for transmission.

Algorithm 2 Gateway failure.

```
Start
  p = e – 0.01; // for each packet
  if (e ≥ 0.01){
      show "energy remaining";
      send (msg, "out2");}
scheduleAt(simTime()+tx_interval,ms);
else {
  g = e – 1
  show "The gateway is about to die";
  send (msg, "out1");}
if (∑charge ≥ 0.002     ){
 g == ς
 send (msg, out1)}
else {
delete msg; }
```

Algorithm 2: Gateway failure.

RESEARCH EVALUATION:

This research was evaluated with an OMNET++ simulator.

EXPERIMENTAL SETUP AND PERFORMANCE METRICS

Table 2 shows the parameter configuration of the network model of this work.

PERFORMANCE METRICS

The metrics involved are:

- the average power consumption of the medical sensor
- the number of transmitted packets during the simulation.

- The packet delivery ratio, which was determined by estimating the difference between the successful packets and lost packets.

Table 2. The configuration of parameters.

Deployment	Area	100 m x 100 m
	Deployment type	Static (transmission always starts from the sensor.
	Sensor loads	1 p/s, 0.2 p/s, and 10 p/s
	Number of sensor nodes	One
	Initial sensor energy	100 mW
	Initial gateway energy	100 W
	Buffer size for introduced work	One packet
	Buffer size for existing work	Five packets
	Transmission cost for urgent packet	0.002 mW
	Transmission cost for buffered packet	0.005 mW
	Transmission cost for gateway	0.01 W
	Random number generator (RNG)	1–200
	Packet size	128 Byte
Media access control	6LoWPAN	–
Simulation	Time	1,000 s, 2,000 s, and 3,000 s
	Sensors	ECG, SpO_2, and blood pressure

Table 2: Configuration of parameters.

RESULTS AND DISCUSSION

THE THROUGHPUT OF TRANSMITTED PACKETS

Table 3 shows the number of packets transmitted in both this work and existing research in terms of simulation time and number of transmitted packets.

We notice the following:

- The number of urgent packets generated was very close in all of the methods. This implies that if most transmitted packets are urgent packets, there would not be differences between this work and other methods.
- The number of nonurgent packets generated was also close in all of the methods.
- The efficiency of this work relies on the amount of semiurgent packets being transmitted. Some of the semiurgent packets were transmitted, but only few were dropped, which shows misleading values from the sensor

Table 3 clearly demonstrates that the introduced data segregation and classification algorithm has significantly reduced the transmitted packets to the gateway.

Table 3. The throughput of transmitted packets.

At simulation time of 1,000 s of an SpO₂ sensor					
	Number of transmitted packets				
Methods	Urgent	Nonurgent	Semiurgent (Transmitted)	Semiurgent (Dropped)	Total Throughput
[3]	358	642	—	—	1,000
[6]	360	640	—	—	1,000
Introduced method	359	465	140	36	499
At simulation time of 2,000 s of a blood pressure sensor					
	Number of transmitted packets				
Methods	Urgent	Nonurgent	Semiurgent (Transmitted)	Semiurgent (Dropped)	Total Throughput
[3]	566	1,434	—	—	2,000
[6]	602	1,398	—	—	2,000
Introduced method	601	1,200	119	80	720
At simulation time of 3,000 s of an ECG sensor					
	Number of transmitted packets				
Methods	Urgent	Nonurgent	Semiurgent (Transmitted)	Semiurgent (Dropped)	Total Throughput
[3]	1,200	1,800	—	—	3,000
[6]	1,198	1,802	—	—	3,000
Introduced method	1,150	1,540	222	88	1,372

Table 3: The throughput of transmitted packets.

PACKET DELIVERY RATIO

Figure 3 indicates that the gateway was continuously transmitting packets until the available power was not sufficient to transmit a packet. It sends a warning packet to the sensor and the latter starts sending the subsequent packets to the medical server. There were two urgent packets lost because the warning packet and the urgent packet collided. Therefore, to improve the packet delivery ratio, an adequate data collision avoidance technique should be implemented inside the sensor and the gateway, although this may also result in more power consumption. Since the packet loss was the same for all of the medical sensors with the same transmission intervals, Figure 3 shows only the packet delivery ratio graph of the blood pressure sensor at a 1-s transmission interval with 1,000-, 2,000-, and 3,000-s transmission times. Figure 3 shows that this work has provided a better reliable routing architecture as an alternative for the medical sensor to transmit its packets when the gateway fails. In this work, the packet delivery ratio is high, whereas in previous works, a higher simulation time indicates a lower packet delivery ratio. This is simply because the gateway cannot transmit packets for a longer time. After the death of the gateway, all the packets forwarded to the gateway were lost. In addition, the simulation also indicates that the packet delivery ratio in [6] is better than [3], because its gateway transmitted packets longer before its death.

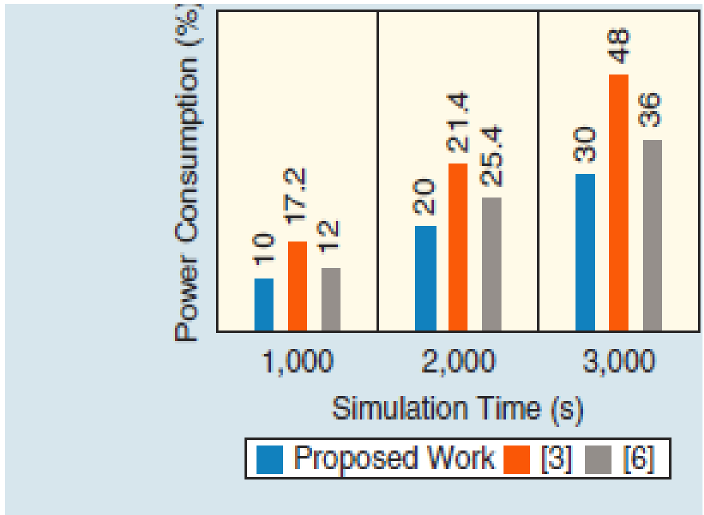

Figure 3: Packet delivery ratio.

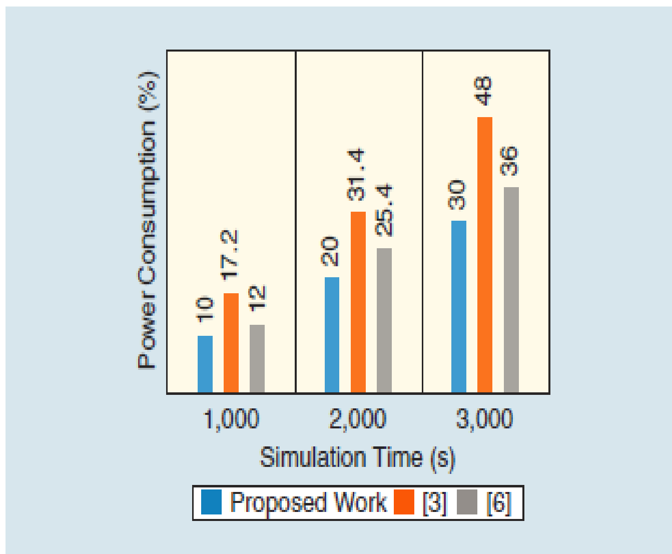

Figure 4: The average power consumption in SpO2 sensor.

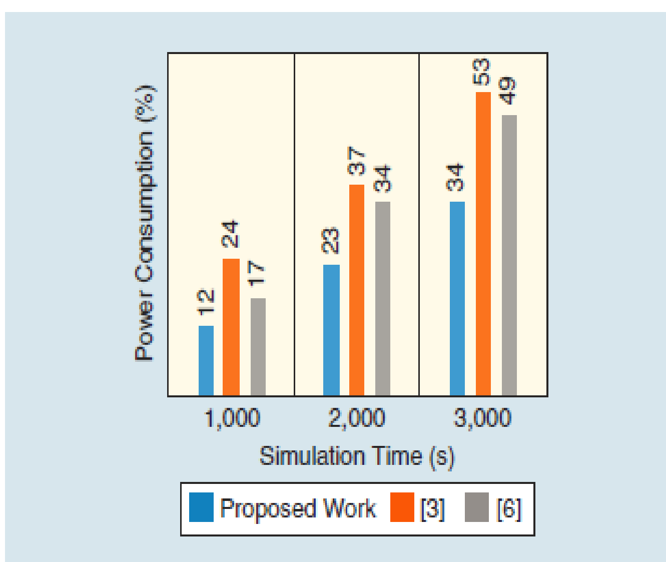

Figure 5: The average power consumption in the blood pressure sensor.

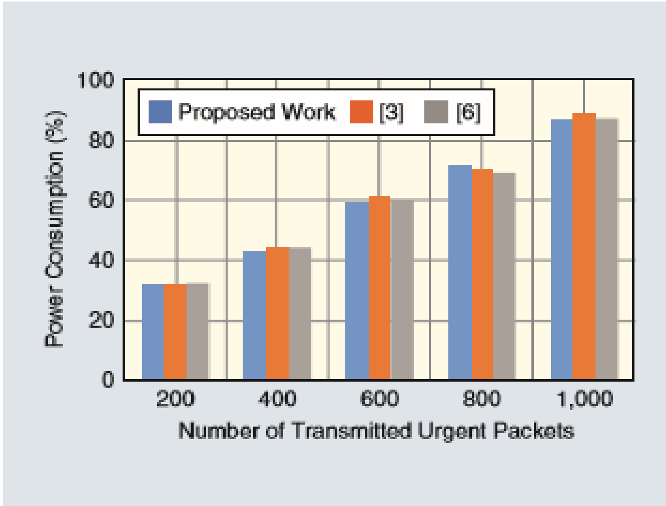

Figure 6: The higher urgent packets in the proposed work.

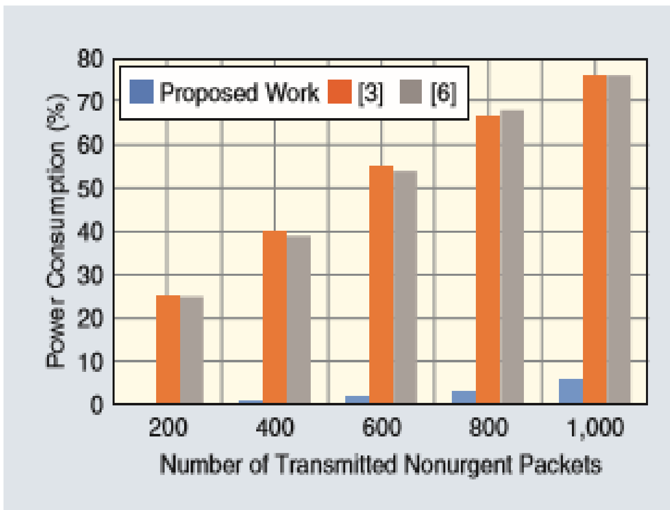

Figure 7: The higher nonurgent packets in the introduced work.

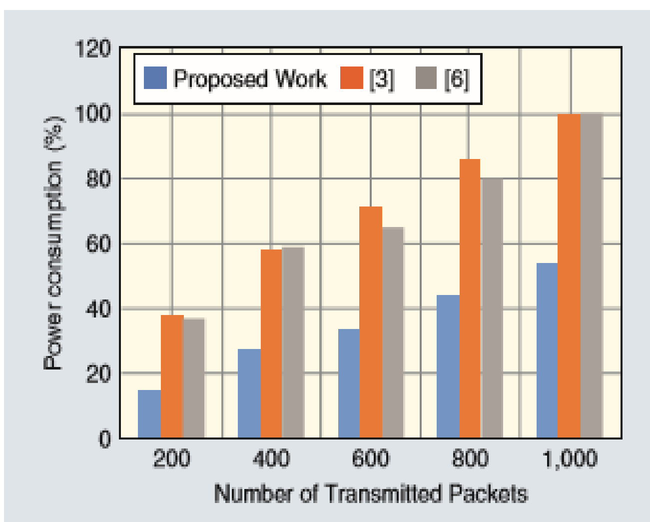

Figure 8: The balanced packets transmission in the introduced work.

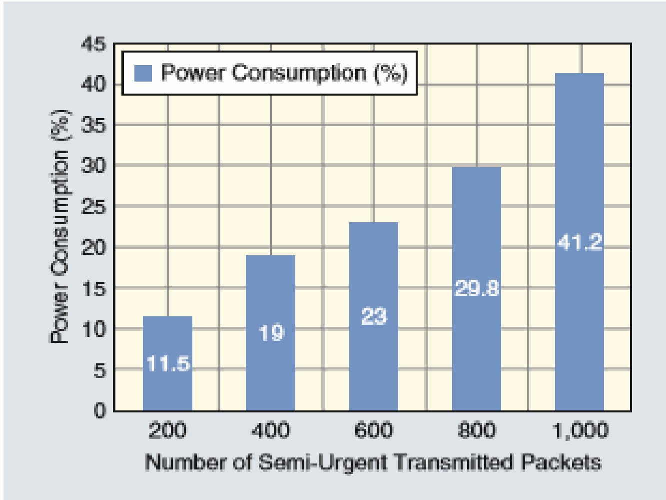

Figure 9: The higher semiurgent packets in the introduced work.

AVERAGE POWER CONSUMPTION

Figures 4 and 5 show the power consumption of each of the SpO2 and blood pressure medical sensors, respectively. The figures show that this work has significantly reduced the
power consumption of the sensor. This work consumes less power followed by [6] and [3], and a higher simulation time indicates more power consumed. However, the type of a packet generated by the sensor may have a significant effect on the power consumption. Here, we modified the algorithm to generate a specific packet more than the other and simulated the result. Figure 6 illustrates the result of transmitting only the urgent packets. This work slightly outperforms previous works in terms of the power consumption.
In the same way, Figure 7 shows when nonurgent packets are the most transmitted packets, and we noticed that introduced work immensely outperforms previous studies. The reason is simply because all of the nonurgent packets in this work were dropped, whereas in the existing work, all of the nonurgent packets were buffered and gradually transmitted. Likewise, in a situation where the transmission is balanced among the packets, the introduced work also outperformed previous work, as shown in Figure 8. Finally, Figure 9 presents the result of a good performance of the introduced work if most transmitted packets are semiurgent packets.

CONCLUSION AND REMARKS

The main contributions of this research are the development of a data segregation and classification technique to improve the power consumption of the WBAN sensor and the introduction of a novel routing architecture introduced to improve the data reliability when a gateway device fails. The introduced data segregation and classification algorithm classifies the sensor's readings into urgent packets that are sent to the gateway immediately; nonurgent packets that are dropped; and semiurgent packets that are sent to the gateway if the readings persist twice, otherwise, they are dropped. The performance of this work is evaluated with an OMNET++ simulator, and the results outperform the existing state of the art in terms of power consumption, data reliability, and packet delivery ratio.

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