International Journal of Future Generation Communication and Networking
Vol. 14, No. 1, (2021), pp. 3656–3666

Data Reliability and Packet Routing in Wireless Body Area Networks – A Review

Akande Sheriff Abiodun

Faculty of Informatics and Computing, Universiti Sultan Zainal Abidin (UNISZA), Malaysia
akande.sheriff@unisza.edu.my

Dr. AznidaHayatiBintiZakaria @ Mohamad

Faculty of Informatics and Computing, Universiti Sultan Zainal Abidin (UNISZA), Malaysia

Dr. AzrulAmri bin Jamal

Faculty of Informatics and Computing, Universiti Sultan Zainal Abidin (UNISZA), Malaysia

Dr. Ayman K. Jaradat

Department of computer science and information, College of science in Zulfi, Majmaah University Al-Majmaah 11952, Saudi Arabia
ay.jaradat@mu.edu.sa

Abstract:

The need for remote monitoring system keeps increasing every day especially in healthcare system. There are three categories of people who are greatly benefitting from this healthcareremote monitoring; these are old people who are unable to go for medical checkups every time, the chronic disease patients whose condition is critical and need to be monitored closely and adequately, the third category are the athletes whom body movements and physiological body functions require a close monitoring for optimum performances and analysis. The reliability ofthe transmitted data has played a great role in the fulldeployment of this technology, especially in healthcare monitoring applications. The reliability is treated in terms of power consumption, end-to-end delay, efficient packet routing, and total throughput of the packet delivery ratio. In this paper, we havereviewed the state-of-the-art reliability approaches and categorizedthem into node-to-node, node-to-sink, and node-to-gateway. Likewise, we have theoretically proposed a reliable routing technique between the sensor nodes and gateway deviceswhich guarantee a successful packet delivery even if the coordinator fails. This research is a guideline for the researchers and industries to work on the suggested current issues and shift the paradigm of packet transmissions in WBAN from only intra-sensor to sensor-gateway.

Keywords: WBAN, gateway, reliability, transmission, sensor node

I. INTRODUCTION

Many countries believe the introduction of IoT is a blessing to many fields in life, especially the healthcare domain. In most developed countries, there have been a separate budget for IoT in healthcare to improve the current status quo of health services. In the United State for example, according to IDC in their recent study of 2019 IoT evolution, US is expected to spend up to $194 billion in 2019 on IoT. China is regarded as the second-largest market for IoT, with annual spending of $182 billion, while Japan ($65.4 billion), Germany ($35.5 billion), Korea ($25.7 billion), France ($25.6 billion), and the UK ($25.5 billion) [1]. More so, the ubiquitous computing and the usage of IoT applications to improve the healthcare services in the United State is expected to exceed more than $158.07 billion by 2022 [2].

The recent outbreak of Covid-19 disease across the world and the limited availability of the medical supplies in various countries have justified the need for remote monitoring of the patients. Even the well-developed countries are struggling to cater for their medical supplies as the cases of Covid-19 patients keep increasing, let alone the less developed countries whom have a lesser budget for healthcare.

WBAN has a numerous application ranging from sports, military, healthcare and so on. However, due to the immediate needs of the current healthcare system in terms of monitoring the chronic disease patients remotely, the adoption of WBAN is getting wider in healthcare and attracting more research attention.

The architecture of the state-of-the-arts approaches comprises of a medical sensor, gateway device and medical server. The sensor collects bio-signal readings from a patient and forwards it to a gateway device - usually a smart phone – through establishment of a ZigBee, 6LoWPAN or low power Bluetooth wireless communication.

Copyright ⓒ 2021 SERSC

The data reliability is a key function of a monitoring system. Themanner in which WBAN sensor sends packets continuouslyhas made the QoS metrics practically unachievable except by trade-off. But the data reliability is a least requirement a WBAN system must fulfilled. The reliability is parallelly dependent on power consumption, packet delivery ratio and end-to-end delay and these are all achievable by an efficient routing in the network.

Since WBAN is a subset of WSN, the routing protocols such as AODV, DSDVin WSN are directly implemented for packet routing in WBAN. However, the network requirement of WBAN consists of heterogenous sensor nodes with different requirements and ismore demanding in terms of continuous transmission and gateway communication. The transmission in WBAN beyond an intra-sensor routing, a well reliable communication between the sensor and the gateway should be established as well.

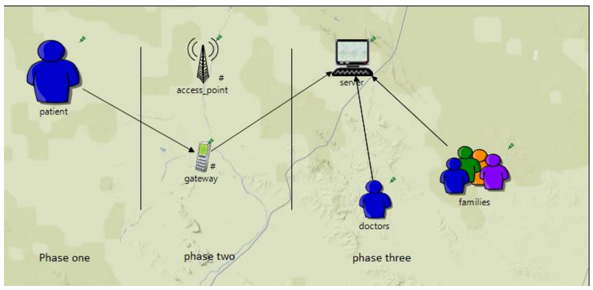

Figure 1 A typical WBAN architecture showing its three phases of communication

In this paper, we have reviewed the state-of-the-arts reliability techniques and make attempt to categorize the routing approaches in WBAN into node-to-node, node-to-sink and node-to-gateway. More so, we have suggested a list of current issues and propose a novel routing solution to one of them.

The rest of thispaperis organized as follows: the section one introduces the overview of the research, the second section explains the typical WBAN architecture and its components, the widely used wireless protocols in WBAN are reviewed in the third section. The WBAN routing protocols are reviewed and classified in the fourth section while the fifth section discusses the proposed gateway failure techniques and the sixth section concludes the paper.

II. WBAN ARCHITECTURE

The architecture of WBAN system can be basically categorized into three (3) phases. Each phase in the network is intelligent enough and capable to provide a form of real-time monitoring analysis and reports. the first phase comprises of WBAN sensors and an established wireless communication network. The second phase contains a gateway device which might be a mobile device or base station stand-alone computer. The medical server is on the top phase which is phase three, it is optimized to serve hundred to thousands of users and can manage huge interconnected networks of medical personnel and healthcare professionals.

Sensor nodes are strategically placed on the body of users and are designed to unobtrusively sample the bio-signal vital signs in the body. These vital signs are transferred to personal server via a wireless personal network such as ZigBee (802.15.4) or low power Bluetooth (802.15.2). The personal server, also refers to as gateway, can be a base station personal computer, handheld, PDA or smart phone where a simple data fusion, data aggregation and segregation and preliminary analysis of physiological data takes place. More so, the gateway transfer captured health to the medical server with the aid of mobile data network, Wi-Fi, and GPRS. The figure 1 shows a typical WBAN architecture with all the three phases of monitoring communication.

A. THE MEDICAL SERVER

The medical server tends to provide a various services and functions to medical professionals and healthcare caregivers. It contains a database which stores electronic patient records. It allows the medical professionals to remotely manage and monitor the patients anytime and anywhere and provide an adequate health response as at when due. The server is capable to authenticate an authorized user to access the system, otherwise the privacy of the

ISSN: 2233-7857 IJFGCN
Copyright ⓒ 2021 SERSC

patient data and security of the whole system would be compromised. More so, the season uploads and summaries of physiological data are taking place inside the server, it worth noting that each of the vital signs has an acceptable metrics of physiological readings and are automatically determined inside the server whether they are within the threshold value or not. The database is updated with a new data session frequently and the care givers can interact with the front-end user interface of the system to assess the readings. A system alert is usually generated whenever there's an abnormal data to keep the medical professionals and emergency team updated of a danger situation without delay. The alert can be an SMS message, email, or a buzzer sound. A delay of few seconds might be dangerous to the health of the patient and it might claim the patient's life. The patient' health summary reports can be interpreted into visual charts and graphs and access through a secure user interface screen. The physician can determine whether a patient is responding to the treatment and prescribe adequate medicines or advices which could be forwarded to the patient electronically via email, SMS, or instant messaging. In addition, due to continuous transmission of bio-signal data and vast amount of data collected and managed by the medical server, a knowledge discovery can benefit from these data through data mining. Likewise, integration of medical database with other research databases along with quantitative analysis of conditions and patterns can help to determine symptom diagnoses of disease and monitor the drug therapy effects.

B. THE GATEWAY INTERFACE

The gateway device, also refers to as personal server, is at the second phase of WBAN communication. It interfaces between the medical server and sensor node with internet connection and wireless communication protocol respectively. It collects data from medical sensor and perfumes a simple data fusion before being forwarded into the server. It also serves as an intuitive graphical and/or audio interface to the user. The application in the gateway can run over multiple platforms with access possibility of wide area network (WAN) internet connection. Platform selection depends on the system specific requirement and should mitigate obtrusiveness for a given user. As the mobility is a great criterion of selecting a gateway device, a stable stationary stand-alone personal computer is an ideal platform for in-home patient monitoring system. Whereas, for high mobility users, smartphones, tablets or handheld computers with internet connection capability could be considered as an ideal platform.

The gateway device requires a ZigBee or low power Bluetooth interfaces to establish a communication between itself and sensor network. Depending on the platform selection, the interface might be integrated within the gateway device or provided as an external plug-in network coordinator (NC). The network coordinator manages the WBAN connection such as timeslot assignment, time synchronization, and channel sharing. Likewise, the sensor configuration such as node registration, initialization, customization and key exchange are all done in the gateway. Once the connection is established between the gateway and sensor node, the former fuses sensor data and creates a personalized session file. The users can get feedback of their health information from the intuitive graphical user interface of the gateway based on the synergy of information from the multiple medical sensors.

The gateway uses its wireless network interface to connect to the wireless wide area network (WWAN) such as GPRS, or wireless local area network (WLAN) such as IEEE 802.11, or mobile network via monthly or weekly subscriptions. For a stand-alone in-home monitoring system, the gateway device can connect to the broadband internet link or local area networks (LAN) via an ethernet cable connection. The gateway is configured with the medical server IP information to access internet services and holds patient authentication information. It schedules upload of health information such as session files at a regular interval or buffer the files in its internal or memory card storage in the event an internet connection is unavailable. In such cases, the gateway may be unable to propagate indicators of serious changes in health status. As such, unavailability of a gateway device is dangerous to patient's life.

C. THE SENSOR NODE

Wireless Sensor Networks (WSN) has been recognized as one of the most important technology which would have a great impact in future. It consists of small batteries which powers motes with minimum computation. It consists of three subsystems: sensor for sensing environment, processor for processing sensed data, and communicator for exchange data with neighboring sensors. The major function of WSN is to sense, process and communicate environmental stimuli such as vibration, humidity, pressure, temperature and so on.

ISSN: 2233-7857 IJFGCN
Copyright ⓒ 2021 SERSC

The advanced form of WSN is WBAN which opens a great opportunity for healthcare providers to manage their patient remotely. Patients can be monitored without being constrained their daily activities and medical doctors are able to monitor as many patients as possible remotely which has tremendously increased the quality of care, quality of life and of course has allowed for a significant reduction in the costs of treatment and monitoring. In addition, WBAN has a potential of early detection of abnormal conditions, and with the help of data mining, if the records of such conditions are kept, it can predict the future condition and possible solutions.

Corventis and CardioNet are one of the top WBAN applications in the market currently to coordinate the vital signs and cardiac abnormalities. They are in form of subscription; patients tend to subscribe for the service. Whenever an arrhythmia is detected in the patient, an electrocardiogram is transmitted (through zLink for Corventis) to the medical server. The subscribers can view their real-time electrocardiogram readings and get advices from the medical practitioners accordingly [7].

Basically, the application of WBAN can be grouped into three categories which are:

- patients monitoring in clinics and hospitals
- home and elderly care centers for chronic diseases patients
- and lastly collection of data for clinical records.

Each of these categories has their peculiar requirements and settings in terms of packet transmission, end-to-end delay and power consumption of the sensor node. For instance, both the category one and two required the abnormal packets to be sent to the medical server immediately at expense of power consumption because delay is given more priority in this scenario, whereas the category three can still tolerate a minimum delay and accumulate the packets before they are being sent to the server since the packets are merely for clinical records. [8].

In the initial applications of WBAN, personal server (or gateway) took a primary role in the packet transmission. The sensor constantly communicates with the main processor of a mobile platform, the entire system was not energy efficient because this type of processor was not design for continuous transmission [9]. This problem was reduced by making the WBAN more self-organizing and carried out itself some basic operations other than sensing, in this manner, the personal server resumed a more secondary role as a simple repository for the information collected from the sensor node instead of coordinating the network.

III. WIRELESS PROTOCOL IN WBAN

In terms of wireless communication protocols, there are few options in the market which are used to equip sensor nodes. These protocols are best defined based on application requirements and functionality.

A. ZIBGEE – 1EEE 802.15.4

The IEEE 802.15.4 standard - otherwise known as ZigBee – defines the physical and MAC layers, while the network, security, and application layers are defined by ZigBee alliance. ZigBee protocol makes use of ISM free frequency bands of 3.1-10.6 GHz, 500 MHz,780 MHz, 868 MHz,915 MHz, 950 MHz, and 2.4GHz. The ZigBee data rate transfer for 2.4 GHz, 915 MHz and 868 MHz are 250Kbps, 40Kbps, and 20Kbps respectively. Although, according to [10] some newly released devices have different data rate transfer for indoor and outdoor. ZigBee behaves like a router which allows all the participating devices in the network to communicate to one another by establishing a mesh network.

B. WI-FI - IEEE 802.11N

This is one of the present day eminent wireless technologies. It provides internet connectivity via ethernet cables for wired connection and radio signals for wireless connection. The IEEE 802.11N standard provides fast connectivity, reliable and secured connection among the participating devices, especially if connected to ethernet technology. It is widely used at home for internet connection nowadays and it operates on ISM radio frequency bands of 2.4GHz – 5GHz with data rates up to 600 Mbps.

ISSN: 2233-7857 IJFGCN
Copyright ⓒ 2021 SERSC

C. BLUETOOTH—IEEE 802.15.1

The Bluetooth also operates on ISM radio frequency band of 2.4 GHz by using a full duplex, spread spectrum signal with a nominal frequency of hopping of 1600 hops. This extra frequency hopping has allowed the transferred data via Bluetooth more protected and shielded against eavesdropping. This protocol is known for its robustness, short range (withing 10m), low latency, support mobile platforms, and relatively high bandwidth. It is widely used in homes, hotspot facilities, offices, and hospitals to establish a short-range connectivity among devices such as laptops, smartphones, PDAs and so on. However, Bluetooth is not widely adopted as ZigBee for healthcare monitoring system due to its limitations in terms of power consumption, inability to connect more than eight (8) devices in personal area network, and start-up connectivity idle [9]. In order to solve these issues, the Bluetooth Low Energy (BLE) has been introduced which is low power consumption by adopting a method of sleep during idle-period and wake during active-period, fast connectivity, and data rate up to 1Mbps [11].

IV. ROUTING PROTOCOLS IN WBAN

The wireless routing protocols in WBAN have played significant roles in the network performance and quality of data transfer. The protocols in WBAN are more heterogeneity in nature than the protocols in WSN due to variety of sensor node parameters and requirements. For instance, each of the medical sensors takes different readings with different thresholds and delay tolerance which requires special transmission process. The authors in [12] has compared the performance of some selected routing protocols in WBAN such as opportunistic protocols, ATTEMPT, DVRPLC, SIMPLE, and PRPLC. They used only three (3) of the performance metrics to determine the best suitable routing protocol for the WBAN application. The chosen parameters are network lifetime which specifies the number of rounds required till the last node in the network runs out of battery, packet delivery ratio (PDR) which denotes the ratio of successful packets against the total number of packets sent, and the last parameter is end-to-end delay which refers to the time interval it takes the packet to transmit from the source to the sink. Their results showed that these protocols are unable to pass the three-performance metrics due to trade-off between the metrics. As such, they suggest a new QoS reliable routing protocol which will not compromise its reliability for other network requirements.

The state-of-the-art routing protocols are not efficient to manage WBAN data [13]. WSN might establish a network with hundreds to thousands sensor nodes of the same type such as temperature or humidity but the same parameter will be taking from all the sensor. This eases the routing protocol tasks since the network is homogenous and it’s easy to implement the same rules over the network. However, in WBAN the network usually contains more than one type of sensor, and each of the medical sensors takes different readings with different thresholds and peculiar delay tolerance. As such, the routing requirement in WBAN is more application specific and complex than WSN.

According to the recent state-of-the-art researches, the routing protocols could be categorized into three (3) main categories:

- Node-to-node routing
- Node-to-sink routing
- Node-to-gateway routing

i. Node-to-node routing protocols

The node-to-node routing can be simply referred to as single-hop communication. In this approach, sensor nodes are used as a relay for each other. The sensor relays its packet to the nearest node based on few criteria such as residual energy, reliability and distance to the sink node as shown in figure 2.

The bio-signal packets in WBAN sensors are more important than each other. Sometimes a sensor can at a time generates a packet which would be regarded as an urgent, warning, or reporting packet. This is purely based on the fluctuation of the physiological readings in the body of the patient. For instance, a diabetic patient wearing both temperature and diabetic medical sensors simultaneously, the glucose levelpackets generated from the glucose sensor might be given higher priority during the transmission than the temperature packets since monitoring of

Copyright ⓒ 2021 SERSC

glucose level in the blood at a regular interval and reporting an unusual reading is crucial to avoid heart stroke as compare to temperature. As such, a priority scheme is needed to filter and prioritize important packets as proposed in [14] where a priority-based routing protocol is introduced toprioritize transmission of some packets over another. Each sensor is assigned to a parent node to forward the readings to the sink. This approach is not scalable as the number of redundant parent nodes increase as the network size increases.

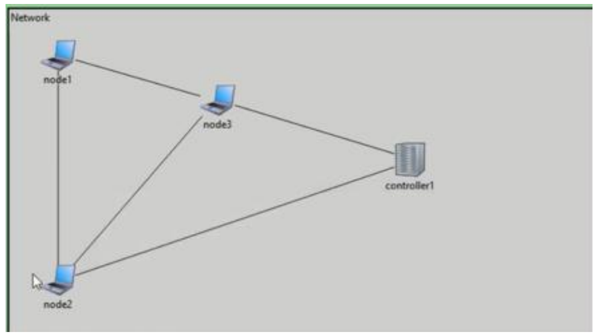

Figure 2 node-to-node routing communication

More so,a clustered-based routing protocol called SEA-BAN is a semi-autonomous adaptive routing which dissipates energy evenly among the sensor nodes and invariably enhanced the network lifetime[15]. The energy status of the sensor node determines its communication pattern whether single-hop or multi-hop transmissions. The sensor nodes are strategically placed in the body based on the sensing data. Sensors such as EMF, EEG, EOG, ECG, cranial pressure, and deep brain simulation sensing are usually required certain number of sensors which are placed consecutively in the body near each other with a definite distance to the *gateway*.

Furthermore, Specific Absorption Rate (SAR) on human body is another issue facing packet transmission in WBAN. This issue happens when a medical sensor involves in continuous transmission and becomes severely hot as a result of Electromagnetic Radio Frequency (EMRF) waves which causes tissue damage. As such, the authors in [16]have proposed a dynamic routing protocol which studies the sources of energy drainage in the sensor network and transmits packets systematically. They gave the sensor nodes three (3) roles: source, relay, and sink. The sink node is one and the rest of the nodes can be either source or relay. When a node has a packet to transmit to the sink, it generates a query to all the nodes in the network to have a knowledge of any load with a direct connectivity to the sink. If the sink itself responds to the query, the transmission established and it's considered as a single-hop transmission because it involves only source node and sink. But, if other nodes respond, the source carries out fitness test - such as energy ratio, link reliability, and SAR condition - for the respondent nodes and selects the most fit to relay its packet to the sink. However, if there's no response to the query, the source node will send its packet itself to the sink.

There have been a few numbers of researcheson opportunistic routing in WBAN. A simple opportunistic routing is an approach in which a source sends a request packet called Request-To-Send/Clear-To-Send to other sensor nodes in the network to relay its packet to the sink. In this manner, any available node randomly can serve as a relay and grant the request of the source, in which sometimes the reliability of the relay node might not be guaranteed. The authors in [17] have proposed an improved opportunistic routing protocol for WBAN in which the source node relays its packet through the sensor with the most residual energy and nearest to the sink. They introduced a timer-based approach which relies on the residual energy and RSSI for relay node selection. Although, the simulated result of their work shows an improved performance over a simple opportunistic approach, but their proposed work lacks considerations of patient movement or postural movement and scalability of a real hospital scenario where the number of sensor node could be tremendously increase and get farer to the sink.

More so, the reliability of WBAN packets during transmission with a minimum energy consumption is one of the top issues in WBAN applications. The approach by [18] has modified the AODV and EADV routing protocols to provide another reliable routing protocol with minimum power consumption of the sensor node. This approach is called Reliable Energy Efficient Adaptive (REEA) which uses energy consumption, hop-count and link quality for reliable route discovery. To achieve a minimized energy network, the concept of piggyback scheme was introduced to send the residual energy of each sensor nodes to their neighbor on demand and the path with a low residual energy is skipped, whereas the paths with a high residual energy are chosen for transmission which solves the issue of energy-hole problem.

One of the earliest researches in this domain is the direct implementation of Ad Hoc On-Demand Distance Vector (AODV) and Destination-Sequenced Distance-Vector (DSDV) routing protocols in WBAN. These two protocols are widely adopted in WSN. AODV and DSDV are the leading on-demand and table-driven routing protocols respectively. The former initializes a request called RREQ (routing request message) to the neighboring nodes in the form of multicast and the node with the shortest distance to the destination responds. While the latter refers back to its routing table and determines the node with the shortest path to the destination. Due to the nature of postural movement in WBAN and packet transmission requirement, AODV is claimed to be more suitable for WBAN transmission and outperformed DSDV in QoS metrics [19].

ii. Node-to-sink routing protocols

The node-to-sink routing involves direct communication between the source and the sink especially in an application where delay is one of the priorities.WBAN has been widely used in sports for player monitoring during live matches and trainings. A WBAN sensor is wear by a player and take readings of current physical parameters and send to his coach for proper performance analysis. The authors in [20] have proposed a routing protocol method using a probabilistic approach to determine current physical parameters such as lactic acid of a player during a live match. The performance of a team depends on the physical and physiological strengths of the players. There are crucial parameters such as respiratory rate, heart rate, body temperature, and blood oxygen which are very important to be monitored during trainings and live matches. There parameters were taken prior live matches and stored in a database to serve as a threshold value for each player since the strength stamina of each player varies and a separate record were created for each player. During the match, players wear a lactic acid sensor which takes readings frequently and generate a warning packet to the sink when the reading below the threshold value. The authors have used a prediction method to remove any coexistence problem – a situation in which a channel is congested with transmitting packets - in the communication channel. Likewise, a Naïve-Bayesian and TDMA methods were introduced to mitigate any possible delay in the channel.

Single-hop communication has been preferred in various researches over multi-hop communication due to direct communication with the sink. No doubt WBAN readings are delay sensitive even if the network has to trade-off its other parameter metrics such as energy efficiency and interference. As such, fuzzy logic approach together with zone-based routing has been introduced by [21] to improve the routing decision in WBAN. They proposed a hybrid routing protocol which combines both proactive and reactive routing methods. The nodes establish a routing table within a zone and transmit packets with in a proactive manner while the transmission outside the zone applies a reactive routing method. The routing metrics such as hop count, link quality, node temperature, node battery status and link suitability are implemented by using a Mamdani fuzzy logic approach which uses an IF-THEN proposition to take decision. These metrics were assigned the values of LOW, MEDIUM and HIGH and form several rules within the network. For instance, if count hope and node temperature are low, and both link quality and node battery status are high, then link suitability is perfect and the transmission can take place.

In addition, hierarchical routing can be used to minimize the power consumption of WBAN sensor by implementing a single-hop packet transmission to the sink. The authors in [22] has used this technique to send the critical data to the sink. The approach involves the division of tasks between the sensor node. At first, all the sensor nodes have the same energy with no cluster head. The transmission is controlled and takes place in several rounds until the sensor nodes runs out of power. In the first round, all the sensor transmits to the sink directly. The cluster head is selected in every subsequent transmission by considering the amount of energy left. The node with the highest energy tends to become the cluster head for that round, and the cluster head keeps changing every in single round. The sensor nodes have a choice of sending their packets to the sink directly or to the cluster head depending on which one is nearer. The cluster head has ability to aggregate data before forwarding them to the sink.

ISSN: 2233-7857 IJFGCN
Copyright ⓒ 2021 SERSC

The genetic approach has also been introduced to improve the selection of a cluster head in the WBAN network. The previous approaches are believed to be centered on a single point and the parallel distribution of energy is needed in order to establish a stable and reliable network in WBAN. The genetic approach technique evaluates a fitness function by using the residual energy and distance to the destination to determine the best node with optimum value which becomes the cluster head [23].

iii. Node-to-gateway routing protocols

The node-to-gateway routing involves the immediate connection of sensor node to the gateway directly and to the server. This is highly applicable in a delay-aware application and ready to trade-off energy efficiency for end-to-end delay.

WBAN sensors are worn only when needed and their requirements are differed from WSN sensor nodes especially in terms of their heterogeneity and execution time. WSN nodes when deployed in an area tend to transmitting for a long period of time especially in a jungle, but WBAN is usually worn by a patient for a certain period of time to take some specific bio-signal readings. As such, end-to-end delay and reliability metrics tend to be trade-off with other parameters such as power consumption in WBAN. The authors in [24] have proposed a priority-based MAC protocol for WBAN which prioritize sensitive and urgent packets over on-demand packets. In their approach, they divided the sensor packets into urgent, normal and on-demand and each were given the priority of high, medium and low respectively.

Dynamic Source Routing (DSR) is an on-demand routing protocol which relies on source routing instead of routing table. It is well adopted in WSN application especially for multiple-hop routing protocol and has various advantages such as: fast reactive service, routing discoveries, routing maintenance, and power efficient. But, its routing cache strategy, the accuracy of routing selection, and packet broadcasting are one of the major drawbacks of this routing protocol especially in WBAN application. As such, the authors in [25] has proposed a time slot and scheduling scheme to improve the efficiencies in DSR protocol. Their main aim is to create an energy efficient network with minimum delay and acceptable packet delivery ratio, they divided the transmission period into serial time slot and assigned each sensor node one or more time slots based on its routing requirement and scheduling. The node is assumed to be in two states: active or sleeping. The active node communicates with the gateway device directly by using its time slot. In other word, the sensor transmission is limited by the allocated time slots and its predetermined. The sleeping mode occurs when a node does not transmit or receive any data package. The sensor goes in hibernate and conserve energy while waiting for next transmission. The drawback of this method is obvious as the WBAN packet transmission is undefined by nature. The bio-signal reading can be taken any moment it happens in the patient's body. As such, time allocation for sensor for optimum transmission is unrealistic in WBAN, but it works well in WSN application.

More so, the researchers in [26] have also proposed a routing protocol which is can handle the heterogeneity of WBAN sensor nodes with acceptable threshold. They had a comprehensive survey of the existing WBAN routing protocols and found out various limitations in the existing protocols such as end-to-end delay, reliability, interference, and packet loss. Their method takes care of periodic and aperiodic data and determined by using an arrival time. The periodic data is believed to be a normal data and can be further categorized into normal and critical. The formal is within the threshold value of medical definition while the latter exceeds the threshold value of sensor node. The aperiodic data is considered as an emergency data and send to the server directly via internet. Each sensor is given an arrival time to the coordinator in case of periodic data, if this arrival time is less or more, then the data is considered as aperiodic and thus it is emergency data.

Load balancing is also crucial in WBAN transmission. The power consumption of the whole network from sensor node to the gateway and medical server has to be balanced to achieve a seamlessly network throughput and packet reliability. Other than the common performance metrics in WBAN, an expected transmission time is introduced as a new metric which takes the fraction of average link load over the transmission rate and use it to calculate the actual time required for continuous load transmission [27].

ISSN: 2233-7857 IJFGCN
Copyright ⓒ 2021 SERSC

Usually, the packet transmission in WBAN is purely intra-routing. The nodes are unaware of their neighbors and the communication between the node and coordinator rarely occurs. In other to solve this issue, another research direction in this domain is focusing on the establishment of a cooperative network within the nearest WBAN sensor nodes by forming an ad-hoc network coordinated by internet. In this approach, a two-way communication is established between the sensor nodes and their coordinators, especially in a big hospital settings, elderly home or athletes training room. The sensor nodes help each other to relay packets when the coordinator reaches a critical energy level due to battery depletion or loss of connection. The network cooperation within the WBAN components exists in phases: node - node, node - coordinator, and coordinator – coordinator. In a situation in which sensor nodes are unable to communicate with their respective coordinators due to unforeseen circumstances, the nodes exchange packets and connects are available coordinator in the network. Likewise, if a coordinator is unable to relay the packet of its sensors, it sends a warning packet to them and the nodes individually looks for alternative route to send their packets. The last phase is coordinator-coordinator which can occur during connection loss or long distance to access point. This principle was implemented in [28] and their simulation shows a better energy efficient network and better throughput.

An energy aware and stable routing protocol (ESR) was also proposed by the authors in [29], their solution chooses a path with stable link and energy efficient. The transmission is categorized into two: node-node and node-coordinator. The former illustrates multi-level transmission among the sensor nodes to minimize the power consumption while the latter communicates directly to the coordinator.

More so, the deployment of a virtual group among the sensor nodes has also being used to improve the real-life data of WBAN. The virtual group can provide an efficient packet transmission with little or no data loss. This alternatively improves the data throughput and end-to-end delay. In this approach, the sensor node connects together as a virtual group to transmit data [30].

V. Gateway routing in WBAN

The gateway usually connects to the internet via Wi-Fi or mobile data subscription and send the packets to the medical server for assessment by the trusted medical personnel. However, due to the nature of smart phone devices in terms of broken, stolen, losing internet connection, battery drainage, its failure is inevitable during the transmission of packets.

In the last few decades, medical sensors are equipped with ZigBee which is a low power wireless communication protocol. However, due to its limited interoperability with other devices in which it can only communicates with other ZigBee devices, a new wireless protocol called 6LowPAN is introduced which is low power and has better interoperability with other devices on internet. The sensors are equipped with both ZigBee and 6LowPAN but uses the former as default mode of sending packets.

The failure of the gateway is divided into two categories: aware and unaware. The failure aware happens when the gateway device communicates with the sensor node prior to its failure time, this happens when the gateway device sends warning packet to the sensor node that it’s about to drain out of battery. The sensor switches to packet buffer mode and searches for any nearest gateway to send its packet to the server with minimum delay. The second category is when the gateway suddenly fails due to stolen, broken, hanging, loss of internet connection and so on. Here, an acknowledgement packet is periodically sent from the sensor node to the gateway at an interval of urgent packet. The sensor sends its packets upon the gateway availability confirmation, otherwise the sensor searches for any secured nearest gateway to send its packet in a broadcasting manner.

More so, consideration of a cost-effective monitoring system is an integral part of total adoption of WBAN by the patients and medical practitioners. The idea of dedicating one gateway device for one sensor node is not cost-effective in terms of price, flexibility, and management. One of the available solutions to this issue is the establishment of a gateway-sharing network between the sensor nodes; a method in which multiple sensors share a single gateway device for data transmission to the server. However, in a big hospital setting where a patient is wearing multiple sensor nodes to take various readings of medical parameters or where multiple patients are sharing the same gateway device to forward data to the medical server, the issue of interference between the wireless

ISSN: 2233-7857 IJFGCN
Copyright ⓒ 2021 SERSC

communication operating under the same free ISM 2.4GHz frequency is one of the current setbacks in such cases which deteriorate the reliability and packet delivery performances. As such, an interference aware scheme for WBAN system which can manage the frequency collision and network congestion is needed which can improve the total throughput of WBAN system. In our future research, these two issues will be implemented and simulated for performance analysis.

VI. Open issues in WBAN routing

The packet routing in WBAN still needs more efficient mechanisms which improves the QoS with minimum tradeoff. In order to produce a cost effective WBAN system, the resources in the surroundings can be adopted to partake in the transmission medium securely. The issue of over-reliance on the gateway device can be simply solved by using the nearest smartphone devices in the surrounding and establish a secure connection to send sensor's packets. This also helps the mobility nature of the patients to move around their vicinity without being attached to a certain position.

On the other hand, the approach of multi-sensor single gateway can be implored to provide a durable WBAN system in hospitals. Multiple patients can share the same gateway device. This requires an efficient routing approach to be implemented in order to avoid packet collision and achieve higher packet delivery ratio.

VII. Conclusion

The routing in WBAN is still in its infancy stage. The second tier of WBAN architecture has received less research attention as compared to the first tier. In this research, we have theoretically proposed a routing algorithm to reduce the over reliance on the gateway device by providing an alternative route for the sensor node to send its packet during the gateway failure. This approach is aimed to be implemented in our subsequent works.

REFERENCES

[1] J. P. Tomás, "US to lead global IoT spending in 2019, with $194 billion: study," 2019. [Online]. Available: https://enterpriseiotinsights.com/20190104/internet-of-things/us-lead-global-iot-spending-2019-194-billion-study. [Accessed: 23-Oct-2019].

[2] M. Watch, "IOT in Healthcare Market Size is Projected to be Around US$ 158 Billion By 2022 - MarketWatch," 2018. [Online]. Available: https://www.marketwatch.com/press-release/iot-in-healthcare-market-size-is-projected-to-be-around-us-158-billion-by-2022-2018-08-17. [Accessed: 23-Oct-2019].

[3] U. Ijaz, U. Ameer, H. Tarar, A. Ilyas, and A. Ijaz, "E-health acquistion, transmission & monitoring system," *Proc. 2017 2nd Work. Recent Trends Telecommun. Res. RTTR 2017*, pp. 1–4, 2017.

[4] M. Doudou, T. Rault, and A. Bouabdallah, "Efficient QoS-Aware heterogeneous architecture for energy-delay constrained connected objects," *2016 9th IFIP Wirel. Mob. Netw. Conf. WMNC 2016*, pp. 9–16, 2016.

[5] J. Vora, S. Tanwar, S. Tyagi, N. Kumar, and J. J. P. C. Rodrigues, "FAAL: Fog computing-based patient monitoring system for ambient assisted living," *2017 IEEE 19th Int. Conf. e-Health Networking, Appl. Serv. Heal. 2017*, vol. 2017-Decem, pp. 1–6, 2017.

[6] D. K. Arvind, C. A. Bates, D. J. Fischer, and J. Mann, "A sensor data collection environment for clinical trials investigating health effects of airborne pollution," *2018 IEEE EMBS Int. Conf. Biomed. Heal. Informatics, BHI 2018*, vol. 2018-Janua, no. March, pp. 88–91, 2018.

[7] C. H. Vallejos De Schatz, H. P. Medeiros, F. K. Schneider, and P. J. Abatti, "Wireless medical sensor networks: Design requirements and enabling technologies," *Telemed. e-Health*, vol. 18, no. 5, pp. 394–399, 2012.

[8] A. Minaie, A. Sanati-Mehrizy, P. Sanati-Mehrizy, and R. Sanati-Mehrizy, "Application ofwireless sensor networks in health care system," *ASEE Annu. Conf. Expo. Conf. Proc.*, 2013.

[9] E. Jovanov and A. Milenkovic, "Body area networks for ubiquitous healthcare applications: Opportunities and challenges," *J. Med. Syst.*, vol. 35, no. 5, pp. 1245–1254, 2011.

[10] "Vibration Monitoring," *memsic*, 2019. [Online]. Available: http://www.memsic.com/applications/Vibration_Monitoring.cfm. [Accessed: 08-Nov-2019].

ISSN: 2233-7857 IJFGCN
Copyright ⓒ 2021 SERSC

[11] H. Cao, V. Leung, C. Chow, and H. Chan, "Enabling technologies for wireless body area networks: A survey and outlook," *IEEE Commun. Mag.*, vol. 47, no. 12, pp. 84–93, 2009.

[12] A. Anwar and D. Sridharan, "A performance comparison of routing protocols designed for body area networks," *2017 Int. Conf. Nextgen Electron. Technol. Silicon to Software, ICNETS2 2017*, pp. 108–111, 2017.

[13] R. Kumari and P. Nand, "Performance comparison of various routing protocols in WSN and WBAN," *Proceeding - IEEE Int. Conf. Comput. Commun. Autom. ICCCA 2016*, pp. 427–431, 2017.

[14] S. Talha, R. Ahmad, and A. K. Kiani, "Priority based energy aware (PEA) routing protocol for WBANs," *IEEE Veh. Technol. Conf.*, no. VOL, pp. 1–5, 2015.

[15] M. T. I. Ul Huque, K. S. Munasinghe, M. Abolhasan, and A. Jamalipour, "SEA-BAN: Semi-autonomous adaptive routing in wireless body area networks," *2013, 7th Int. Conf. Signal Process. Commun. Syst. ICSPCS 2013 - Proc.*, pp. 1–7, 2013.

[16] M. Roy, C. Chowdhury, and N. Aslam, "Designing an energy efficient WBAN routing protocol," *2017 9th Int. Conf. Commun. Syst. Networks, COMSNETS 2017*, pp. 298–305, 2017.

[17] U. F. Abbasi, A. Awang, and N. H. Hamid, "A Cross-Layer Opportunistic MAC/routing Protocol to improve reliability in WBAN," *Proc. 20th Asia-Pacific Conf. Commun. APCC 2014*, pp. 36–41, 2015.

[18] R. Kumari and P. Nand, "'An optimized routing algorithm for BAN by considering hop-count, residual energy and link quality for route discovery,'" *Proceeding - IEEE Int. Conf. Comput. Commun. Autom. ICCCA 2017*, vol. 2017-Janua, pp. 664–668, 2017.

[19] P. He, X. Li, L. Yan, S. Yang, and B. Zhang, "Performance analysis of wban based on aodv and dsdv routing protocols," *2015 2nd Int. Symp. Futur. Inf. Commun. Technol. Ubiquitous Heal. Ubi-HealthTech 2015*, no. 61202399, pp. 36–39, 2015.

[20] A. M. Waghmare and P. H. Ghare, "Performance Improvement for Multi-BAN Routing Protocol for Soccer Player Monitoring and Study of Factors Contributing Towards Efficiency of the Protocol," *2018 9th Int. Conf. Comput. Commun. Netw. Technol. ICCCNT 2018*, pp. 1–6, 2018.

[21] H. Viittala, M. Hämäläinen, and J. Iinatti, "Zone-based fuzzy routing for WBANs," *Int. Symp. Med. Inf. Commun. Technol. ISMICT*, vol. 2015-May, pp. 93–97, 2015.

[22] D. Sethi and P. P. Bhattacharya, "A study on energy efficient and reliable data transfer (EERDT) protocol for WBAN," *Proc. - 2016 2nd Int. Conf. Comput. Intell. Commun. Technol. CICT 2016*, pp. 254–258, 2016.

[23] A. Umare and P. Ghare, "Optimization of Routing Algorithm for WBAN Using Genetic Approach," *2018 9th Int. Conf. Comput. Commun. Netw. Technol. ICCCNT 2018*, pp. 1–6, 2018.

[24] N. Bradai, H. Ben Elhadj, S. Boudjit, L. Chaari, and L. Kamoun, "QoS architecture over WBANs for remote vital signs monitoring applications," *2015 12th Annu. IEEE Consum. Commun. Netw. Conf. CCNC 2015*, pp. 1–6, 2015.

[25] Z. Wei, S. Gang, and C. Yong, "An improved WBAN route protocol based on DSR," *Proc. 2015 IEEE Adv. Inf. Technol. Electron. Autom. Control Conf. IAEAC 2015*, pp. 1142–1145, 2016.

[26] R. Saha, S. Biswas, and G. Pradhan, "A priority based routing protocol with extensive survey and comparison of related works for healthcare applications using WBAN," *Proc. 2017 Int. Conf. Wirel. Commun. Signal Process. Networking, WiSPNET 2017*, vol. 2018-Janua, pp. 1424–1430, 2018.

[27] S. Yang, H. Lee, J. Yun, K. Han, and J. Yun, "Analysis and proposal of wireless mesh network's routing metric for WBAN," *1st Int. Conf. Networks Commun. NetCoM 2009*, pp. 400–403, 2009.

[28] A. Manirabona, S. Boudjit, and L. C. Fourati, "Energy aware routing protocol for inter WBANs cooperative Communication," *2015 Int. Symp. Networks, Comput. Commun. ISNCC 2015*, pp. 1–6, 2015.

[29] O. Smail, A. Kerrar, Y. Zetili, and B. Cousin, "ESR: Energy aware and stable routing protocol for WBAN networks," *2016 Int. Wirel. Commun. Mob. Comput. Conf. IWCMC 2016*, pp. 452–457, 2016.

[30] V. Jayaraj and C. Hemanth, "Formation of virtual groups in WBAN for health care monitoring," *2016 8th Int. Conf. Commun. Syst. Networks, COMSNETS 2016*, pp. 1–5, 2016.

ISSN: 2233-7857 IJFGCN
Copyright ⓒ 2021 SERSC