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A Review on Energy Efficient Routing Protocols in Wireless Body Area Networks (WBAN) for Healthcare

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Abstract – Wireless Body Area Networks (WBANs) are increasingly becoming a vital factor in healthcare application and are generating considerable interest to the researchers. Because it is one of the most practical methods to provides a cost-effective tool for remote real time monitoring patients. The design and development of such networks will challenge due to the limited resources of the WBANs. The core and most important problem of this network are that it works on the battery, and it may be the sensors inside the human body and therefore difficult to replace. The very significant drained of energy is communication and routing protocol. The routing protocol in WBANs work under many constraints need to be overcome. The main goal of this review is to discuss the recently proposed routing protocols from the researchers to deal with the energy problem. Also, this research has raised the weak points in each protocol that need further investigation. Moreover, we explain the future research directions in this field.

Index Terms – Wireless Body Area Networks, Network Lifetime, Energy Efficiency, Healthcare, Routing Protocols.

1. INTRODUCTION

Wireless Body Area Networks (WBANs) has many applications but the major use in healthcare for monitoring patients and collect the physiological signal. In recent years, there has been growing interest in WBAN because has become an important field of research due to the increasing need for it in several areas. According to the World Health Organization, over 1.7 million COVID-19 cases around the world [1]. Thus, to be able to monitor this large number of patients, we need WBANs technology. Where this technology provides remote and real time health monitoring system. Through the use of wireless sensors inside or on the human body of a patient for sensing physiological signals and transmit to the sink node and medical servers for more analysis [8][9]. WBANs is defined by IEEE 802.15.6 to refer to low power and short range wireless communication. It should be noted that the bio-sensor nodes are mini size, cost-effective, work on small limited batteries and must be reliable, comfortable, and bearable to the patient. Some of these sensors are ECG sensor, Pressure sensor, Temperature sensor, and a Glucose sensor (especially for the diabetic person).

An even the greater source of concern problem to the WBAN is limited energy and boosting the network lifetime. Where for a more practical explanation of this problem, we cannot replace the sensor battery especially inside the human body, so we need to manage the available energy cautiously and efficiently [2]. WBAN must be able to overcome these challenges to provide a reliable monitor for the patient. Also, each node in the network senses, processes, and communicates with the sink. An even greater source of energy consumption is the transmission power budget [3]. The node will need to be undertaken to find the best path to deliver the data to the sink through the routing protocol. Based on this, to efficiently use the limited available energy we need development an efficient routing algorithm to reduce energy consumption. One of the most important points that must be taken care of when finding the path is the intermediate nodes and how they are carefully selected to reach the sink. Because the wrong choice of these nodes may lead to the death of some nodes quickly and disconnection with the sink. In addition, the size of data transferred greatly affects energy consumption. So, reducing the amount of data sent, or sending only the necessary data leads to saves energy [4, 5, 6].

Figure 1 presents the architecture of WBAN is a three-tier communication model. Data is obtained and collected by distributing the sensors over the entire body. As we can see tire one contains sensors, relay nodes, and the sink node. The sensor nodes monitor the patient's health status and send information through the relay nodes by multi-hop to the sink node. This information thus needs to be interpreted with caution and attention. So, sent through the gateway in tier two to the medical server or the doctor for more analysis [7].

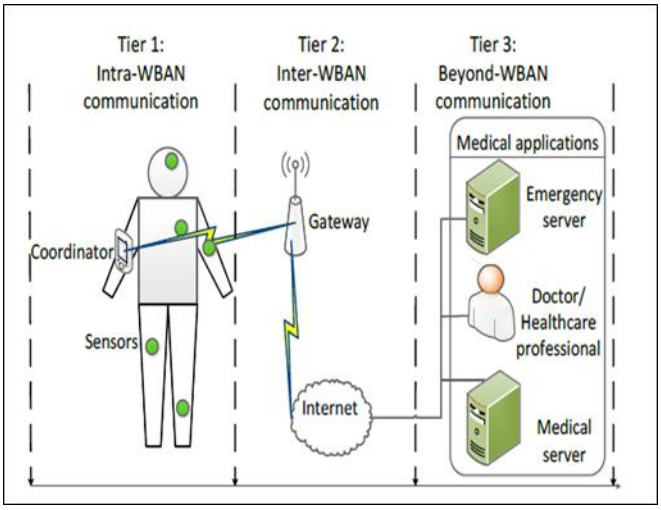

Figure 1 Wireless Body Area Network Architecture [7]

This paper is divided into five sections as follows. In Section 2, outlines the challenge faces the routing protocols in WBAN. In Section 3, categories of routing protocols are presented. In Section 4, we analyze and highlighted recent related work of the literature on energy efficient routing protocol for WBAN in health care applications. Our conclusions are drawn in the final section, section 5.

2. CHALLENGE AND PROBLEM STATEMENTS IN ROUTING PROTOCOLS FOR WBAN

In this section, we limitations highlight and challenges faces the routing protocols in WBAN. Since, this type of network transmits important data and has an impact on patients' lives, therefore choosing the right path must be done carefully. Below is a list of challenges faces routing protocols in WBAN [8, 9]:

2.1. Limited Energy

The nodes in WBAN was set up in small size in order to comfort of the patient. Hence, it is equipped with a small, low power battery. So, the power is limited. At the same time, the sensor nodes may be implanted inside the patient's body, and therefore the battery can only be replaced by surgical intervention. Consequently, the major issue facing the routing protocol in this network is the limited energy.

2.2. Mobility

The principal advantage provided by this network is remote monitoring of the patient, thus allowing freedom of movement for the patient inside the network. But this movement poses a great challenge in choosing a path and transmitting the data to the sink node. Another issue about mobility is changing the network topology. So, the paths to the sink node are variable. Therefore, we need a routing protocol that has the ability to properly handle the patient movement. Few researchers have addressed the movement problem were because many researchers assumed that the patient was lying in bed.

2.3. Quality of Service

As was mentioned earlier, this network transmits critical data, so we need high quality of service. Vital facto is timing and sending data correctly is the most critical in this type of data. Same is exact for other factors like latency, bandwidth, trustworthiness, jitter, robustness, adaptability.

2.4. Security

Security is more difficult in this type of network because it suffers from many limitations. Therefore, there is still a need for Data authenticity, confidentiality, integrity, and availability. So, we need efficient routing protocols that can fulfill all these requirements.

2.5. Real time synchronization

A further important challenge in WBANs is to provide real-time monitoring to the patient. This is critical because of the delay in the arrival of data affects the patient's life, especially when monitoring patients with chronic diseases.

2.6. Data management

The amount of information's that each sensor collects and that needs to be share is significant. WBANs provides two methods to deal with this amount of data, the first method, the sensor sends all the data. And the second method only sends the abnormal data.

3. TYPES AND CLASSIFICATION OF ROUTING PROTOCOLS FOR WBAN

In this section, the types of WBAN routing protocols are outlined. A primary source of energy consumption is the routing protocol, the way of choosing the path from the sensor to the sink node. Protocols are categorized based on the challenge or problem they are solving. Thermal-aware Routing, Cross-layered Aware, Cluster Aware WBAN, and Quality of Service aware are four kinds classes of routing protocols.

3.1. Thermal-aware protocol

This method is based on the temperature of the node for path selection. Based on the approach presented in [10], the purpose of this type of routing protocol is to is to scale down the heat of this type of networks. This is done by ignoring the routes that contain hot spots node. To achieve this, a node whose temperature exceeds a certain threshold is considered a hotspot node.

3.2. Cross-layered Aware

The primary goal of this type of protocol is to improve the performance of WBAN through a cross layered protocol that combines more than one layer. The authors in [11], suggested CLBP, cross layer protocol work on MAC and network layers, using an interaction graph based on body position, which improves node synchronization and channel access.

3.3. Cluster Aware WBAN

In this category, the network makes a group of sensor nodes are called clusters and every cluster includes a boss or head named a cluster head with which to communicate with the sink. So, that helps to reduce the nodes' energy demand. The basic idea of this category is based on the Low Energy Adaptive Clustering Hierarchy (LEACH) routing protocol for Wireless Sensor Network (WSN). Many previous studies have proven that this type of protocol is most appropriate for WBAN because it works on a balance the energy consumption in the network [12].

3.4. Quality of Service aware

We need to pay attention to quality of service quality, because this network transmits important data. The QoS in this type of network that need to be considered are: energy efficiency, delay, data critical, reliability, data security, etc. Many protocols in WBAN depend on reliability and delay because is the most important metric when transmit critical data [13].

4. RELATED WORK

In this section, we reviewing more recent literature in the routing protocol of WBAN and highlighting the limitations of previous studies existing in the field of healthcare monitoring. In the literature there are many research on routing protocols but in this section we focus on most recently energy efficient routing protocols in WBAN for healthcare application.

Naseer Qureshi, et al. [14] proposed a new approach to enhance energy utilization. The main concept of this protocol is to choose the fit next hop by calculating the link quality of sensor network nodes and residual energy by computing Eq. (1) and Eq. (2) respectively. Each sensor needs to send data that it exchanges control messages with its neighbors. The neighbor nodes then calculate the residual energy and link quality of neighbor nodes parameters in the network and return to the source nodes the score function value and acknowledgement. .This handshaking mechanism by using control messages increases network overhead and consumes more energy.

$$SN_{R\_energy} = SN_{A\_energy} - SN_{C\_energy} \quad (1)$$

Where, $SN_{R-energy}$ presents the senor node residual energy, $SN_{A-energy}$ average energy, and $SN_{C\text{-}energy}$ consumed energy.

$$LQ = \begin{cases} 1 & if\ LQA_j > LQA_{Optimal} \\ \frac{LQA_{max} - LQA_j}{LQA_{max}} & if\ LQA_{Worst} < LQA_j < LQA_{Optimal} \\ 0 & if\ LQA_j < LQA_{Worst} \end{cases} \quad (2)$$

Where, $LQA_{Optimal}$ Link Quality Average optimal, LQA_{Worst} and LQA_j are used for connected and disconnected states.

Sagar1, et al. [15] proposed a Critical Data Routing (CDR) for WBANs for data routing. The main aim of this protocol is to reduce energy consumption by sending only critical data to the controller. If any nodes sense critical data directly send that packet to the base station by single hop. Also, each node constructs and updates the routing table periodically. The routing table as shown in Table 1 contains much information that the node needs to calculate periodically, and this constitutes an effort for the node and a complication that you do not need because it only sends data directly to the controller. In the other hand, continuous remote monitoring is really important and all data must be sent to the controller.

Parameter	Explanation
destination	Identification of destination
$LOC_{destination}$	Synchronize body controller
ID_{nk}	The identity of neighbor node nk
$LN_{j,k}$	connection between the node nj and nk
$PD_{j,k}$	delay from node to the sink over node nk
$RC_{j,k}$	Route consistency at back-to-back from node nj to sink over the node nk
$RT_{j,k}$	temperature of the route from node nj to BC over node nk
LOC_{nk}	Coordinates of the adjacent node nk

Table 1 Parameters Description of Outing Table

Al-obaidi, et al. [16] proposed the same idea as mention by the author in [15], by divide the data to critical and non-critical but the variation presented by Al-obaidi, et al. divide the sensor types into critical sensors (CS) send information immediately to sink node and non-critical sensors (NCS) that can enter in sleep mode based on a time schedule. Also, when NCS senses data above the threshold send this data to the sink node and send a receipt acknowledgment request (RAR) to make sure the data arrives successfully to the sink node. Furthermore, Eq. (3) shows the Cost Function (CF) use by NCS nodes to select the route to the sink node.

$$CF(i) = \frac{d(i)}{R.E(i) * P(i)} \quad (3)$$

Where d(i) is the distance between both the sensor i and the sink node, the residual energy of the sensor node i is R.E(i) and P(i) is the number of packets correctly reached per unit time to the sink node. So, the node selected as the forwarder with the minimum CF and all nodes send their data to this node. However, in this protocol all the load on one forwarder node in each period, which causes sensor node depletion earlier.

Zuhra, et al. [17] suggested the Low Latency Traffic Prioritization scheme for QoS-aware routing (LLTP-QoS) for reliable transmission of abnormal data. Use three types of sensors: Biosensor nodes, nodes for relays, and nodes for sinks. Consequently, the main drawback of LLTP-QoS is the use of many sensors on the human body. Moreover, every node uses two different queues, i.e. high-priority (PQhigh) queue for critical data and low-priority (PQlow) for normal data queues.

The LLTP-QoS includes two phases: (i) initialization and traffic prioritization phase and (ii) route discovery phase. In the initialization phase, every node broadcasts the "HELLO" packet and compute Link Delay (LD) and Link Delivery Ratio (LDR) as presented in Eq. (4) and Eq. (5) respectively.

$$LD = \frac{HelloPacket_{ACK} - HelloPacket_{sent}}{2} \quad (4)$$

$$LDR = \frac{Number\ of HelloPacket_{\ ACK}}{Number\ of HelloPacket_{\ sent}} \quad (5)$$

The route discovery phase uses the mechanism of Ad hoc On-Demand Distance Vector (AODV) [18] protocol. The nodes discover the optimized path by using LD and LDR as shown in Equation 4 and 5. To find the path, the source node needs to broadcast a Route Request (RREQ) packet. However, the construction of the discovery phase increases the load on sensor nodes and requires more time for packet routing. It also led to increased network overhead and power consumption in the end. The major weakness in this protocol use of AODV route discovery in WBAN.

Yating Qu, et al. [19] presented protocol takes into consideration many parameters such as remaining energy, quality of transmitting, bandwidth required and also the hop count to the sink when determining the cost function as shown in Eq. (6).

$$M_i = a * \gamma_{i1} + \beta * \gamma_{i2} + \theta * \gamma_{i3} + \lambda * (1 - \gamma_{i4}) \quad (6)$$

Where γ_{i1} represent residual energy, γ_{i2} the transmission efficiency, γ_{i3} the available bandwidth, γ_{i4} hops count, and a, β, θ, λ is the weight factor of each parameter. Furthermore, this protocol's routing process consists of three stages: the initiation stage, the next best selection stage for hop nodes, and the packet forwarding stage as detailed in the flow chart below. This, protocol suffers from complex calculations of routing decisions, which leads to consuming more energy and to nodes depletion.

R. Bhangwar et al. [20], propose a trust and thermal-aware routing protocol by avoiding the hotspot nodes. This protocol uses biomedical sensor and relay nodes, it only transfers data to other biomedical nodes. s. TTRP protocol has three phases; trust estimation phases, routing discovery phases, and routing maintenance phases. In the first phase find the trust relay node. During the second phase determine a Composite Function (CF) to discover a route to sink node as shown in Eq. (7).

$$CF = w1 * Trust + w2 * Temp \quad (7)$$

The route maintenance phase is the last phase of the process, is responsible for link failure, when finding hotspot node during transmission returned to the route discovery phase. A major drawback of this protocol is ignored energy consumption, delay, and use of many nodes that restrict patient comfort.

B. Abidi et al. [21], are suggest a Cluster-based Routing Protocol (CRPBA) aims to resolve WBAN's energy crisis. The network in this protocol is split into clusters. Each cluster contains members and the leader is responsible for gathering physiological data from members. Cluster head selection is done on the basis of Eq. (8) in each iteration.

$$Function\ (d, E) = distance/Energy \quad (8)$$

This protocol chooses the cluster leader in a too simple way. Also, the cluster leader near to sink consumes much energy because it is always chosen as an intermediate for communication with the basin.

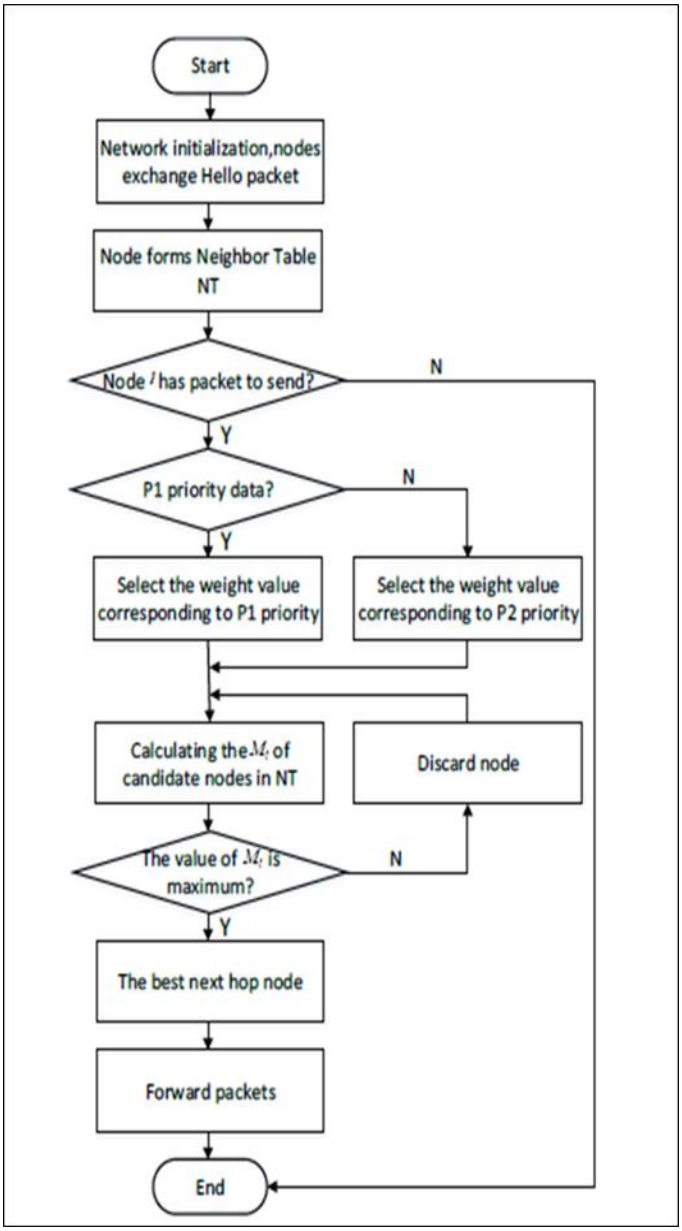

Figure 2 Flow Chart of Yating Qu , et al. Protocol [19]

Table 2 shows a comparison of protocols in terms of energy consumption, complexity and provide continuous monitoring to the patient.

Routing Protocol	Energy	Complexity	Monitoring
Naseer Qureshi, et al. [14]	✓	✓	✓
Sagar1, et al. [15]		✓	
Al-obaidi, et al. [16]	✓		✓
Zuhra, et al. [17]	✓	✓	✓
Yating Qu , et al. [19]		✓	✓
R. Bhangwar et al. [20]	✓	✓	
B. Abidi et al. [21]	✓		

Table 2 Routing Protocols Analysis

In summary, routing protocol plays an important role in the way of energy saving. So, we can observe there is no ideal protocol for dealing with energy and complexity. Researchers focus on enhancing power consumption and reduce data send from nodes to base station based on these topics below. For more details on this issues can be found in [22] and [23].

- Send only critical data.
- Use relay node.
- Enhance monitoring by use machine learning in WBANs.
- Multi hop communication for minimize distance.
- Use energy harvesting technique.
- Take into account the temperature of the nodes.
- Genetic approach routing algorithm.
- Cross layer routing algorithm.

5. CONCLUSION

In this review, a recent energy efficient routing protocols analysis for WBANs on healthcare applications. This study revealed that the energy consumed is highly dependent on the routing protocol. It also depends on the chosen methodology in transmitting the data. Moreover, from the routing protocols comparison was it turns out that we need to tradeoff between energy and complexity. In addition, this paper explains a general concept about WBANs and the challenges they face. In the future, we will propose a routing protocol take into account energy consumption, complexity, and security.

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