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Quality of Service Position-based Routing Protocol for Wireless Body Area Networks

Submitted By

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The undersigned hereby certify that they have read, examined, and recommended to the Deanship of Graduate Studies and Scientific Research at Palestine Polytechnic University the approval of a thesis entitled: **Quality of Service Position-based Routing Protocol for Wireless Body Area Networks**, submitted by Lubna Salah-Aldeen Hashlamoun in partial fulfillment of the requirements for the degree of Master in Informatics.

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DECLARATION

I declare that the Master Thesis entitled "**Quality of Service Position-based Routing Protocol for Wireless Body Area Networks**" is my original work, and hereby certify that unless stated, all work contained within this thesis is my independent research and has not been submitted for the award of any other degree at any institution, except where due acknowledgment is made in the text.

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DEDICATION

To My Parents, Husband, Children, Sisters,

Brothers and My Husband's Family.

A special dedication to the soul of my sister, the martyr Hadeel Al-Hashlamoun and to the souls of all the martyrs.

ACKNOWLEDGEMENT

I would like to express my deep gratitude and respect to the people who helped me in completing this work. I would like to express thanks to my supervisor, Dr. Liana AL Tamimi, for his valuable guidance, support, and encouragement during my study. I also would like to thank him for his numerous suggestions and remarks that had a major influence on my work. Thanks are also extended to other members of the advisory committee, Dr. Mousa Farajallah and Dr. Ammar Abu Znaid.

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LIST OF NOMENCLATURE

Symbol	Description	Unit
	General	
WBAN	Wireless Body Area Network	
QOS	Quality Of Service	
WSN	Wireless Sensor Network	
IOT	Internet of Things	
ADC	Analog to Digital Converter	
BAN	Body Area Network	
WBSN	Wireless Body Sensor Network	
ECG	Electrocardiography	
EEG	Electroencephalography	
EMG	Electromyography	
SPO2	Peripheral Capillary Oxygen Saturation	
REP	REPly packet	
RERR	Route ERRor	
RREP	Route REPly packet	
ND	Normal Data	
CD	Critical Data	
MAC	Media Access Control	
SNR	Signal to Noise Ratio	
	Routing Protocols	
MHRP	Mobility Handling Routing Protocol	
QPR	Quality Of Service Position-based Routing Protocol	
AODV	Ad-Hoc On-demand Distance Vector	
MPRR	Multi Path Ring Routing	
OPOT	Optimum Path Optimum Temperature	
HTTRP	High Throughput and Thermal Aware	
ENDD	Efficient and Reliable Directed Diffusion	
LRPD	Lightweight Routing Protocol for Dynamically network topology	
HDCR	Hybrid Data-Centric	
WEQ	Weighted Energy and QoS based Multi-hop Transmission	
	Simulators	
OMNeT++	Objective Modular Network Testbed in C++	
NS-2	Network Simulator 2	
MATLAB	Matrix Laboratory	
	Performance Evaluation Parameters	
PDF	Packet Delivery Fraction	
AEC	Average Energy Consumption	MSc
APL	Average Path Length	Hop
ARAL	Average Route Latency	Sec
CPD	Control Packets per Data Packets	

ABSTRACT

Wireless Body Area Networks (WBAN)s are gaining popularity, as real-time diagnosis and electronic therapy of patients are two key components driving the healthcare field. In addition to the digital technologies involved in this diagnosis, such as the Internet of Things (IoT). The importance of this network appeared during the COVID-19 pandemic, in which patients can treated remotely when the risk of infection spread is high. Besides "traditional" applications such as military, and sports training. Routing in WBAN networks remains a key issue since without properly functioning routing protocols. Unfortunately, routing may also be one of the most difficult areas to protect patients in critical situations. This is due to the high probability of delay and link failure, since the nature of the human body movement and thus changing the location of the network parts. With the wide spread of WBANs, the need for quality of serving their routing protocols emerges as a very important issue that is not easy to tackle. Many of the demands of network Quality of Service (QoS) conflict with the demands of mobility nodes in the network due to the nature of the body movement (e.g., low power consumption and low processing load). The concept and structure of WBAN make them highly prone to network failure several techniques that consume more energy, increase delay, and decrease the reliability of data. Our research has focused on the reliability and latency of services provided by static or mobile nodes. Our newly proposed protocol is a hybrid QoS Position-based Routing protocol (QPR) tries to save network bandwidth and nodes memory in WBANs that introducing a classification of data priority and nodes mobility (QPR). QPR classifies the type of data sensed as critical or normal. When data is critical and nodes are static, data directly transmitted to the sink to guarantee low latency. Additionally, it tries to improve network reliability by employing a multipath strategy when the data is critical and the nodes are mobile. The performance of QPR has compared to two other existing routing protocols: we chose the Ad hoc On-demand Distance Vector Routing (AODV), because the researchers used it as a benchmark in research. Another protocol we chose the Multipath Rings Routing (MPRR), because is a new protocol that gives good performance in addition the implementation code is available in our simulator. After studying the previous protocols, we conclude that AODV provides an efficient route in normal traffic without consideration of a dynamic change of position of the node. However, it fails when the data is critical with mobility occurs. The MPRR achieves a reasonable level of mobility, but it needs high overhead and the need for extra delay. This comparison has been conducting using the OMNeT++/Castalia simulator. Simulation results showed that the QPR protocol improves reliability by around 54% and around 19% latency compared with AODV. In addition, improves reliability by around 19%, and around 17% latency compared with MPRR, considering high nodes mobility, a large number of nodes and a large percentage of critical data sent between these nodes.

Chapter 1: Introduction

1.1 Overview

This chapter introduces the focus of our work as well as the inspiration behind the study we are conducting. We introduce this work and provide a general summary of the thesis in Section 1.2. Sections 1.3 through Section 1.4 outline our research's goals, methods, and key contributions. Finally, we provide a quick summary of the thesis' main structure in Section 1.5.

1.2 Thesis Overview

Wireless Wide Area Networks (WWAN), Wireless Metropolitan Networks (WMAN), Wireless Local Area Networks (WLAN), Wireless Personal Area Networks (WPAN), and Wireless Body Area Networks are the different types of wireless networks based on their coverage areas (WBAN). WBAN An incomplete example of a short-range wireless ad hoc network. Radio waves, ultrasonic waves, and diffusion-based molecular communications are all possible in WBAN systems [1].

A constrained wireless sensor network is a WBAN. WBAN and WSN differ from one another in terms of coverage area, number of nodes, dependability, missing data, security, communication, end-to-end latency, replacement node, node lifetime, and wireless technology [2]. Small, inexpensive, and low-power sensing nodes, which make up the WBAN network, interact with one another over relatively short distances. The sensor nodes have components for sensing, data processing, data storage, and communication. The two main categories of monitoring sensors are wearable and implantable devices that function on the surface of the human body, respectively [3].

Applications of WBAN classify into two types: medical and non-medical. First: for medical applications such as telemedicine and chronic disease monitoring, when patients give ongoing health monitoring of their condition without being restricted from going about their usual daily lives, the value of WBAN in the medical industry becomes apparent [4]. Additionally, the patient receives remote care during the COVID-19 pandemic, when there is a high danger of infection transmission [5]. Therefore, two important factors in the development of the healthcare sector are real-time diagnosis and patient electronic therapy. Second: nonmedical as sports training and military. The importance appears of the WBAN in the non-medical field as in the Internet of Things (IoT).The main components of IoT are sensors, devices, connection, data processing, and user interface. Therefore, the development of WSNs is crucial to the IoT [6].

Three layers make up the classification of WBAN's architecture. Sensors affixed to the patient's body's surface or implanted within make up the first layer. The sensor gathers and transmits a variety of physiological data regarding the patient's body. Smartphones, laptops, and other smart electrical gadgets make up the second tier. A wireless method is used to transmit the data that sensors send to the terminal data center. In WBAN's third layer, the terminal data center is mostly made up of remote servers that offer a variety of applications. Its job is to compile and examine the data that has been received to offer a dynamic response. The sensor node will transmit an emergency alert and carry out emergency transmission, which can speed up emergency management and rescue, particularly when it collects abnormal data [7].

A crucial component of WBAN is a reliable routing mechanism. Each node of the network transmits data to the sink. WBAN routing protocols are generally difficult to develop. The biggest obstacles to developing an effective routing protocol. First, there are resource constraints, energy restrictions, real-time data transmission, memory, transmission power limitations, dependability, and mixed sensor nodes. Second, because the human body is mobile, the nodes' locations fluctuate because of the WBAN networks' dynamic character. This there, therefore, fore causes a more serious issue with network construction. As a result, meeting QoS standards in WBANs is a difficult process. As a result, experts are looking at the best ways to offer WBAN customers high-quality services. Reliability and latency are two examples of fundamental demands [8] [9].

According to the following criteria, the study on WBAN routing protocols is primarily divided into subgroups: cross-layer routing, QoS-based routing, cluster-based routing, posture-based routing, and temperature-based routing. In order to create a quick and stable route, posture-based routing uses the network architecture of the patient's body in various dynamic postures. While in temperature-based routing, the primary factor in the approach of route selection is the nodes' temperatures. In order to improve network performance, the cross-layer routing protocol primarily mixes various protocol levels and makes use of the advantages of each protocol stack. The cluster-based routing protocol divides the network's nodes into clusters. A cluster head and a variety of cluster nodes are included in each cluster. Any application technology that uses limited resources, like WBAN, must take into account quality of service (QoS) [10].

The QoS considerations for the WBAN include data priority, energy efficiency, connection dependability, data transmission reliability, reduced transmission delay, node temperature, and data security. As these references noted, we concentrated our research on ensuring dependability and latency in WBAN. The concept of "reliability and latency" describes the prompt and accurate delivery of monitoring data to healthcare professionals. Reliability and latency are crucial for WBAN sensors because they must be able to view and identify the most important active signals of human health [11].

WBAN is overly influenced by mobility. WBAN places sensor nodes on the patient's body. These on-body nodes move normally with the patient's body motion, frequently changing the network architecture. Therefore, creating a mobility-based routing protocol is a difficult challenge because various patient postures must also be taken into account. Standing, walking, running, sitting, and lying down are a few of the patient postures that need to be taken into consideration while building any routing algorithm for WBAN [12].

Given that WBAN deals with vital signs of the human body, different types of data necessitate varying QoS. Each application and data packet has unique needs; hence, the QoS must be adaptable. The routing protocol may take into account and integrate a variety of QoS measures, including delay, energy, and reliability, depending on the application domain. For WBAN, patient data reliability and latency are crucial considerations [13]. Only select QoS measures are well-performed by each protocol, and none is built to simultaneously handle energy efficiency concerns along with all other specified metrics, including latency, dependability, mobility, thermal impacts, and energy consumption [14]. In this study, we examine several WBAN QoS Position-based routing systems and contrast them with relevant reliability and latency specifications.

The vast majority of studies only use the QoS routing protocol while the patients are stationary, not when they are mobile. The other researchers address patient mobility without considering priority; other researchers also discuss patient mobility and data priority.

However, in a particular instance, like in the Mobility Handling Routing Protocol (MHRP) [12]. Therefore, the goal of this study is to develop a QoS Position-based routing protocol that achieves the requirements of high reliability and minimal time. We provide a brand-new WBAN routing protocol that ensures dependability and latency while taking into account the nature of the data being conveyed, the mobility of the patients, and the static location of the sink node.

It has been suggested to use QPR, or QoS Position-Based Routing Protocol. The foundations of this approach are AODV and MPRR. The new protocol's performance has been examined, along with its effectiveness in addressing QoS issues and its performance in comparison to other routing protocols, using the Omnet++/Castalia simulator.

Simulation results showed that the QPR protocol improves reliability by around 54% and around 19% latency compared with AODV. In addition, given significant node mobility, a large number of nodes, and a high percentage of essential data exchanged between these nodes, improves reliability by around 19% and latency by about 17% when compared with MPRR.

1.3 Research Objectives

Our research's major goal is to develop a QoS position-based routing mechanism for WBAN. Hence our main objectives are:

- Reducing average route latency.
- Increasing reliability.

1.4 Research Methodology

Our approach can be summed up as follows:

- Analyzing the benefits and drawbacks of the present position- and QoS-based WBAN routing protocols.
- Researching Mobility Support for Wireless Body Area Networks.
- Outlining a QoS Position-Based Routing Protocol to enhance the functionality of the WBAN network.
- Using a simulator to build the suggested protocol.
- Evaluating the proposed protocol's effectiveness and benchmarking it against alternative routing protocols.

1.5 Research Contributions

This thesis' primary contribution is the QoS Position-Based Routing Protocol it suggests for WBAN, which ensures latency and reliability in this kind of network.

1.6Thesis Organization

The rest of the thesis is organized as follows: Chapter 2 included background information, a review of related literature, a classification of WBANs routing protocols, and a survey of QoS-based WBAN routing protocols. The suggested routing protocol's technique is covered in Chapter 3. The simulation environment, results, and performance evaluation of the suggested technique are all shown in Chapter 4. The results, analysis, and recommendations are all included in Chapter 5.

1.7 Chapter Summary

A summary of the thesis, the issue statement that motivated us to do this research, and the primary goals of this thesis were stated in this chapter. The key contributions were then highlighted.

Chapter 2: Background and Related Work.

2.1 Overview

Researchers from all around the world pay close attention to routing because of its significance in starting an effective path between source and destination. The background and related work for the WBAN routing protocol are introduced in this chapter. In Section 2.2, it is discussed how WBANs came to be, including their background in wireless body area networks, wireless sensor networks, and WBAN architecture. It also discusses how they relate to Covid-19 and the Internet of Things, as well as the role that routing protocols play in WBANs. The WBAN routing protocol is covered in Section 2.3. The benefits and drawbacks of the AODV routing protocol are presented in Section 2.4. Section 2.5 lists the advantages and disadvantages of the MPRR routing protocol. Section 2.6 contains a summary of the chapter.

2.2 Background

In this section, WBAN-related topics are covered, including wireless body area networks, wireless sensor networks, WBAN architecture, applications and the connections between the IoT, Covid-19, and WBNA. We also discuss the categories of routing protocols used by WBANs, the major difficulties in providing QoS in WBANs, and QoS evaluation metrics.

2.2.1 Wireless Sensor Networks

In place of conventional wired networks, Wireless Sensor Networks (WSNs) use radio waves or the internet to convey data. The hardware of the device consists of a structure for determining its location, a sensing unit with a sensor and an analog to digital converter (ADC), a processing unit, a radio transceiver, a microcontroller or flash memory for data storage, and a power source, usually a battery, to support the entire system [2]. Operating systems, sensor drivers, and host middleware with routing and security modules are some examples of the software components. With their smaller size, lower installation and upkeep costs, and simpler design, wireless networks get around many of the problems and drawbacks of wired networks. WSNs can be inserted and removed quickly and easily, allowing for last minute or urgent changes to health monitoring systems to be made [15].

Wireless Body Area Networks (WBANs) are wireless networks made up of a collection of tiny biosensor nodes dispersed throughout the body or on its surface [3]. IEEE 802.15.6, a specific type of Wireless Sensor Network, defines WBAN, additionally referred to as Wireless Body Sensor Network (WBSN) (WSNs). Low-power wearable or implantable wireless medical devices make comprise an MBAN, also known as a medical body area network (BAN) [16].

2.2.2 Wireless Body Area Networks

A wireless sensor network called a WBAN is made up of tiny bio-medical gadgets called nodes that continuously monitor patient parameters. WBAN's low-power modules are used internally or externally to support a range of applications, including medical ones. WBANs and WSNs both face a number of difficulties, such as miniaturization, dependability, security, etc. The two most significant research fields continue to be healthcare and biomedical device tracking. WBAN development should undoubtedly coincide with medical advancement. The key to preventing late diagnosis is ensuring that patients are checked at home. One can continuously monitor their vital signs by using a WBAN, which gives them more freedom and mobility. Doctors will have a wider and more thorough view of their patients' most recent reports [17].

Electromyography (EMG), a type of sensor that measures the electrical activity of muscles, measures the electrical activity of the heart and brain, and electrocardiography (ECG) measures the electrical activity of the heart and brain. The acquired data can then be connected to remote monitoring destinations for diagnostic reasons after being merged and non-aggregated at a control device, such as a sink or gateway/PDA, where the data was originally transmitted [3]. Each sensor is categorized by WBAN into one of the following three categories: physiological, bio-kinetic, or environmental devices. WBANs use physiological sensors, which may assess bodily characteristics including temperature, blood pressure, and glucose levels. Human motion is seen and calculated using bio kinetic sensors, which can calculate rotational angular rate and acceleration. Any sensor that can assess environmental conditions, such as vibration, light, and pressure levels, is considered an ambient sensor [17].

2.2.3 WBAN Architecture

Figure 2.1 shows the three-layer design of the WBAN body network. The patient's body surface or internal implants may have sensors at the Intra BAN level, which also includes sink nodes for the WBAN and wireless body sensor communication. The sensor collects and transmits a variety of physiological data regarding the patient's body. Inter BAN, the second layer, is made up of smart electronic devices such smartphones, laptops, and other personal computers [7]. It is the communication between the sink node and personal devices because sensors at the terminal data center wirelessly transmit the information. Given the volume of applications, layer three of WBAN, Extra BAN: remote servers at the terminal data center generally handle communication between personal devices and the internet. Its responsibility is to gather and analyze the information it receives in order to provide a dynamic response. When the sensor node gathers anomalous data, it will carry out emergency communication and warning, which can expedite handling and rescue operations [18].

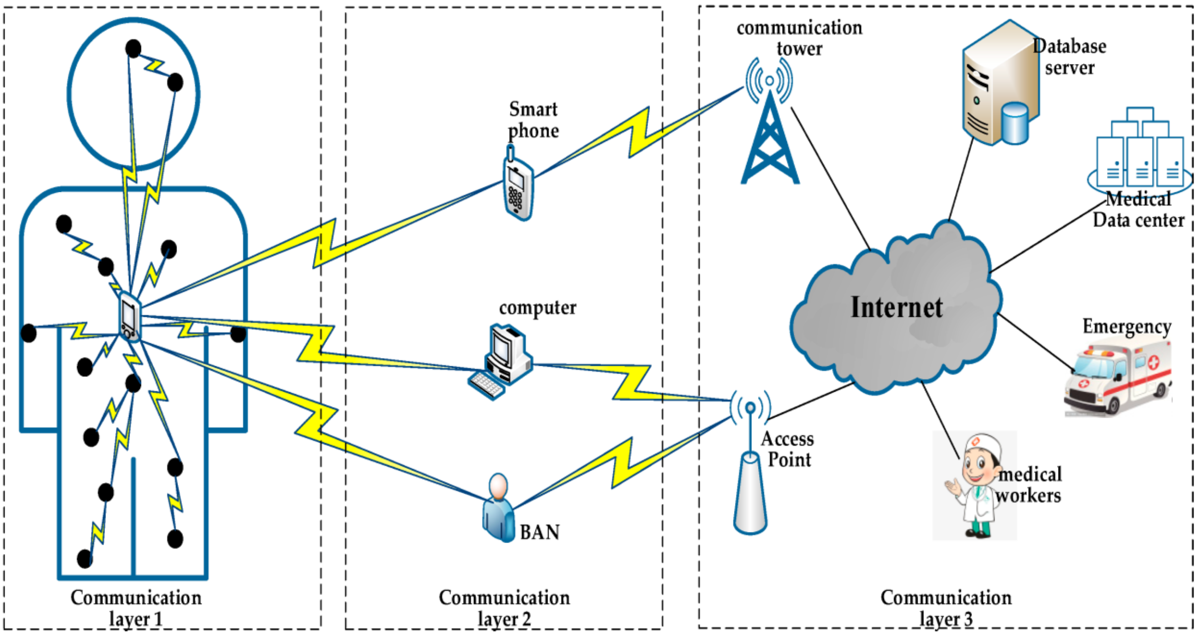


Fig 2.1: Architecture for a WBAN is typically used [7].

2.2.4 Applications of WBAN

Applications for WBAN networks in both the medical and non-medical fields include:

• Military and sports training: Wearable WBAN devices are used to track the health of military personnel participating in various military activities as well as athletes undergoing physical training [4].

• WBAN finds numerous applications in the early detection of cancer cells, diabetes control, tracking the progress of rehabilitation, and decision-making in intensive care units. An evaluation of the health status is possible because to the coordination of biological sensors, data-handling units, and miniature actuators [19].

• WBAN sensors (accelerometers and gyroscopes) are utilized in smart homes for assisted living to monitor elderly individuals' movements and postural changes [20].

• Consumer electronics and entertainment: Playing MP3s on a Bluetooth device, gaming, or connecting and communicating with a smartwatch or portable device utilizing a wearable device to a smart TV, as well as the interaction between WBAN apps and lifestyles [21].

• Security: Traditional security measures, such as passwords, fingerprints, iris scans, and facial recognition, are too complex for the memory of a WBAN device. Since echocardiogram (ECG) traces are thought to be unique from person to person, they have recently become one of the growing biometric patterns that can serve security requirements for WBAN [22].

2.2.5 COVID-19 and WBAN

The development of healthcare technologies is becoming more and more important for the diagnosis and treatment of serious diseases. In the COVID-19 pandemic era, when the danger of infection transmission is relatively high, the patient can be treated remotely. Two important aspects of the development of the healthcare sector are patient e-treatment and real-time diagnosis [5].

2.2.6 Internet of Things and WBAN

Among other digital technologies, the Internet of Things (IoT) contributed to this diagnosis. It is now possible to reorganize healthcare and offer patients omnipresent medical help thanks to WBAN technology. to simplify, secure, and make practical the lives of patients and healthcare professionals [23].

The main components of IoT are sensors, devices, connection, data processing, and user interface. The sensors help acquire information about the environment. Connectivity allows us to send data we have collected to cloud infrastructure over Wi-Fi, cellular networks, satellite networks, and other communication methods. The program first gathers data in the cloud, processes it, and then rests in the user interface section, providing information to the user via an alarm or text notice. WSN development is therefore essential to IoT [6].

2.2.7 Importance of Routing Protocols in WBAN Networks

Sending packets is supported by a routing protocol. It is a crucial component of the network architecture. Implementing routing protocols in WBAN networks is challenging due to the unpredictable nature of links, node mobility, frequently changing topology, absence of a stable infrastructure, and low communication power. Asymmetric linkages are created when part of the links are unidirectional due to variations in transmission capacity [24].

There is no pre-deployed structure available in WBAN networks for end-to-end packet routing. Since nodes communicate with one another without the aid of centralized access points or base stations, each node serves as both a router and a host simultaneously. Due to all of these factors, routing in WBAN networks is an especially challenging operation to complete effectively and powerfully [8].

2.2.8 Routing Protocols for WBAN Networks

For WBAN networks, a number of routing protocols have been suggested. They can generally be split into five major groups: The mobility of patients is taken into consideration through posture-based routing, Temperature-based routing shows the nodes' temperatures, cluster-based routing group’s nodes under a cluster head, QoS-based routing considers reliability and latency, and cross-layer routing sends messages over many layers [25]. According to Figure 2.2. The following section explains these categories in more depth and provides some recent examples of each.

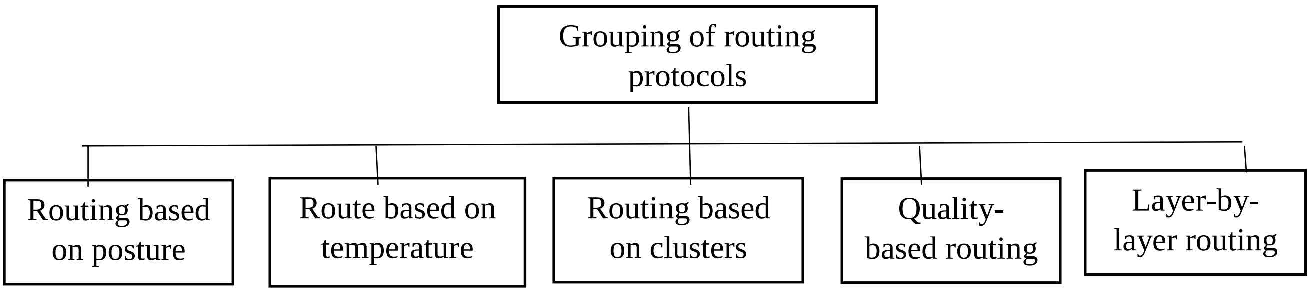


Fig 2.2: WBAN network routing classification [25].

2.2.9 Significant QoS Support Challenges in WBAN

• Resource constraints: The energy, storage, and computing capabilities of WBAN's sensor nodes are constrained. In comparison to wearable sensors making it more difficult to replace or recharge the batteries of implanted sensors [26].

• Unpredictable traffic patterns: The criticality of the patient being monitored determines the real-time data pattern in WBAN [27].

• Network dynamics: Changes in the network topology may be brought on by the body's postural actions and node energy limitations [28].

• Diverse traffic types: Multimedia traffic is obtained from disparate sensors using the same network for transmission but with varying data rates and bandwidth [27].

• Unstable traffic: To prevent the whole energy of any specific node from being depleted and to extend network lifetime, the protocol must be designed to choose alternate nodes from source to destination [26].

2.2.10 QoS Evaluation Metrics

• The percentage of packets sent to the sink and the quantity of packets transferred and retransmitted from the source together make up the packet delivery ratio (PDR). The value ranges from 0 to 1, and a higher PDR value is desired [29].

• End-to-end delay (E2ED) is the sum of handling delay, series delay (depending on packet size), queueing delay (depending on load, among other factors), and other delays. It is a measurement of the typical amount of time needed for a data packet to travel from the source node to the sink. In medical applications, it must be less than 125 milliseconds [30].

• The majority of a node's energy use occurs during data transmission and reception. Additionally, some energy is used for data handling, storage, and retrieval—energy that is typically disregarded or taken for granted. The energy difference between the starting energy and the energy used during the network's operation is referred to as remaining energy [31].

• Network lifetime is the sum of all network operations up until the final node is operational [32].

• Various elements may be included in the Link Utilization function depending on the network's need metric. Here, we evaluate the link utilization function by taking into account the remaining energy, queue size, and link reliability functions. If the link utilization is higher, the network will provide high-quality services in terms of stability, reliability, latency, and delay [33].

2.3 Existing Routing Protocol for WBANs

This section talks about the classifications of routing protocols for WBAN networks in detail.

2.3.1 Posture-Based Routing Protocols

In order to find a quick and reliable path, posture-based routing protocols are utilized to investigate the network topology of the human body under changed dynamic approaches. It is crucial to analyze postural changes. Numerous studies have shown that various human body movements provide regularity. This has the potential to significantly advance the dynamic WBAN in use [34].

A submission for WBAN-based cardiac monitoring that employs a cutting-edge mobility handling routing protocol (MHRP). The WBAN topology that the authors are considering is unique in that it places a backup group of nodes, which consists of one sink, two relays, and one acquisition node, asymmetrically next to another set of nodes that is otherwise similar. When a link fails due to a person moving, the redundant set of nodes will manage the data transmission and guarantee reliability. Aside from the high installation costs of such a double infrastructure, the main disadvantage of this system is the discomfort it causes to the human body [12].

2.3.2 Temperature-Based Routing Protocols

A node's heat is regarded as the primary deciding factor in the path selection process in temperature-based routing. By avoiding high-temperature nodes and designing appropriate pathways, this routing technique aims to prevent node temperature increases or reduce the temperature of high-temperature nodes quickly. In the early stages of WBAN development, temperature-based routing was extensively explored; however, in more recent years, many studies have focused on energy, which has resulted in a modest decrease in temperature-based routing [35].

By selecting two preset threshold margins, the authors of [36] propose an optimum path optimum temperature (OPOT) routing protocol that lowers the temperature that affects the sensor node. This aids in selecting the best routing path and corresponding energy diffusion between sensors in the WBAN network. Data from the neighboring nodes, such as temperature and the separation between the source and destination, are analyzed before establishing the communication channel. If there is a great distance between the source and destination, the relay node is chosen, and data are transferred through it. If the target node is another nearby node, data are sent directly [37].

The authors introduced the High Throughput and Thermal Aware (HTTRP) routing protocol for WBANs, a thermal and energy-aware routing protocol, in [38]. When selecting the next relay node, HTTRP declares the temperature and the remaining energy of the sensor nodes in order to reduce sensor heating and regulate the consumption of their remaining energy. Both temperature-based routing and QoS-based routing are classified by HTTRP. Large throughput progress improves longevity and charges balance while reducing overheating and preventing the formation of hotspots.

2.3.3Cluster-Based Routing Protocols

Clustering routing is a WSN-inspired method. It divides the network's nodes into clusters of nodes. A cluster head and multiple cluster nodes make up each cluster. The algorithm chooses the cluster head, who is in charge of integrating and forwarding information within the cluster [39].

2.3.4Cross Layer-Based Routing Protocols

In order to achieve higher network performance, cross-layer routing protocol essentially combines many protocol levels and incorporates the benefits of each protocol stack. Studies revealed that the cross-layer technique is more compatible with dynamic WBANs and that working together; different layers can provide various priority data more effectively [40].

2.3.5QOS-Based Routing Protocols

In any application technology, QoS-based routing emerges as a key player, but particularly in resource-constrained WBANs. Data priority, energy efficiency, connection and data transmission reliability, low communication delay, node heat, and data security are the QoS that need to be taken into account in WBAN [41].

A Weighted Energy and QoS-based Multi-hop routing algorithm for WBAN was created by the authors of [42].The authors' method ensures that data is sent to the sink by using a single sink node and working both direct transmission and multi-hop transmission. The author's suggested method, which he refers to as a QoS routing protocol, enhances QoS with regard to the longevity and throughput of the WBAN network while lowering energy consumption. In contrast, because loops and iterations are involved in establishing a node's weight value and the node with the highest weight cost is typically thought of as the best next-hop for data transfer, the algorithm's complexity is quadratic, or the square of the nodes in the WBAN network. In wireless body area networks, authors in [43] propose an Efficient and Reliable Directed Diffusion Routing Protocol (ENDD). The gradient is set using directed diffusion as the benchmark, and the perception of the gradient is displayed to show the direction, speed, and hop count of the data transmission. With respect to decreased packet loss rates and power consumption in both stationary and mobile environments, the ENDD algorithm is classified as a QoS-based routing protocol. Life's networks and dependability are improved. Real-time performance is sacrificed to some extent, though.

The authors of [44] for WBANs with dynamically changing network topology suggest a lightweight routing protocol (LRPD). The protocol was developed for intraday WBAN, a network with low-power sensors that is resource-constrained. Numerous real-time WBAN applications require the QoS element of latency to be improved. The modules in the modular LRPD scheme work together closely to achieve purpose optimization. Priority division begins with the data from the aforementioned level being fed into the data classification module. The LRPD algorithm is a QoS-based routing system that gains from enhancing QoS by reducing end-to-end latency and considering priority. However, the energy effectiveness of this regimen is merely medium.

In [45], the authors propose the Wireless Body Area Network (WBAN) Hybrid Data-Centric Routing Protocol (HDCR), which extends network lifetime and satisfies the required minimum class period. A modular technique is HDCR. The HDCR algorithm classifies routing based on temperature and QoS. With this growing advantage, the gaining node uses less energy and the network's lifespan is increased.

As WBAN deals with crucial marks on the patient's body, different sorts of data require varying QoS. Because each application and data packet has specific requirements, the QoS must be adaptable. The routing protocol may take into account and integrate a variety of QoS measures, including delay, energy, and reliability, depending on the application domain. Patient data reliability and latency are important considerations for WBAN. Each protocol works well only for a subset of the defined QoS criteria, such as latency, dependability, mobility, thermal impacts, and energy consumption. None is intended to jointly handle these issues with energy efficiency. In this research, we look at many WBAN QoS routing methods and contrast them with the related reliability and latency specifications.

The vast majority of studies only use the QoS routing protocol while the patients are stationary, not when they are mobile. The other researchers address patient mobility without considering priority; other researchers also discuss patient mobility and data priority. However, in a specific instance like MHRP [12]. In order to satisfy the requirements of high reliability and minimal delay, we generalize the QoS Position-based Routing Protocol in this research. While LRPD work meets QoS standards, reduces end-to-end delays, and takes data priority into account, its medium energy efficiency makes it ideal for important applications [44]. Because WEQ classifies data and selects the best routes depending on a number of characteristics, it reduces reliability, delay, increases network lifetime, and throughput [42]. Table 1 compares the various QoS routing protocols, including OPOT, HTTRP, HDCR, WEQ, ENDD, LRPD, and QPR.

Table 2.1. A comparison of the presented QoS routing protocols.

Protocol	Techniques used	Efficiency Measure	Protocol as a contrast	Simulation Tool	Benefits	Cons
WEQ [42] 2020	-Altered MAC protocol -Classified the information. -WEQ algorithm to select the best path.	Continuity and throughput	IM-SIMPLE, RE-ATTEMP, No Algorithm	OMNeT++ Castalia	Due to its data classification, increases network lifespan and throughput.	The task is quadratic in complexity.
HTTP [38] 2020	When selecting the next relay node, the temperature and remaining energy of the sensor nodes are taken into account.	Network lifetime, charge balancing, temperature, and throughput.	TARP, TARA.	MATLAB	High throughput decreases overheating while extending life, enhancing charge balance, and preventing hotspot development.	Performance for end-to-end delays is average.
OPOT [36] 2020	The optimum routing path is determined, in part, by the temperature of the sensor nodes and the lowest and maximum threshold limits that are specified.	Delay, power, energy, and longevity of the network.	TARA, LTR.	MATLAB	Delay reduction, energy minimization, power reduction, homogeneous temperature distribution, and lengthening sensor node lifetime.	Unless there is a very high packet arrival rate, reduce power usage.
ENDD [43] 2019	-Create the gradient. -Using directed diffusion criteria, residual energy.	Delay from beginning to conclusion, packet loss rate, energy left, and nodes still alive.	FLOOD, DD.	NS-2	Lower power use and packet loss rates in both stationary and mobile settings. The networks are now more dependable and durable.	Some real-time performance is lost.
LRPD [44] 2017	-Daley, optimization. -Modularization strategy.	Delay, reliability, energy, efficiency, priority.	TARA, ALTR, TMQoS, TLQoS.	OMNeT++ Castalia 3.2	Decreases end-to-end latency. Considering importance.	Energy Efficiency is medium
HDCR [45] 2017	- Delay optimization. -Node temperature and reliability. -Modularization.	Temperature, path loss, latency, and link reliability.	CDR, DCR.	NS-2	Reduces node energy usage and lengthens the lifespan of the network.	Static person.

2.4 AODV Routing Protocol

To choose a route to the destination, the source broadcasts a route request packet in ad hoc on-demand distance vector routing (AODV) [46]. This broadcast message travels through the network until it reaches the destination either itself or an intermediary node with the most recent route information for the destination. In their database, intermediary nodes keep track of which node made the request when they forward a packet containing a route request.

The majority of the work done so far has been devoted to optimizing AODV for QoS utilizing Hop count as the parameter, which has improved stability, increased throughput, produced more energy, and decreased delays. The important skill of adapting to different traffic types while paying little to no attention to channel dynamics is missing from the proposed protocols. To meet the stringent demands of MBANs, it is crucial to modify and enhance AODV for QoS. Even while AODV's throughput, latency, and PDR have all been improved, and energy harvesting, quality of service, and delay reduction have all advanced significantly, no single protocol can satisfy MBANs' requirements for adaptability and dependability when handling emergency traffic [47].

The popular AODV protocol has been utilized extensively in research as the fundamental protocol in WBANs and WSNs. It maintains routes online as long as they are needed because it is a responsive protocol. It makes use of RREQ, RREP, and RERR control packets for route finding and management. The connection is broken if a node does not receive a HELLO message from a neighbor. To identify neighbors, send the message HELLO. It is a common protocol for WSNs and WBANs because it is simple, dependable, and has little control overhead [48].Table 2 lists the benefits and drawbacks of AODV.

Table 2.2. AODV advantage and disadvantages.

Advantages for AODV	**Disadvantages for AODV**
The most recent path to the destination was discovered using the destination sequence numbers, and the AODV route was built on demand [49].	Control overhead might increase significantly when numerous responses are sent in response to a single request [51].
The ability of AODV to adapt to highly dynamic networks allows it to respond quickly to topology changes that affect active routes [47].	Periodic beaconing leads to unnecessary Band Width Consumption.
Both unicast and multicast packet transfers are supported by AODV even for nodes that are in motion all the time [50].	Prior to the start of data transmission, there may still be latency.
With AODV, connections may be built up faster and the most recent path to the target can be found more quickly [48].	It is challenging to provide many paths since each node can only retain one next-hop per destination.
Data packets are not subject to any additional overheads thanks to AODV's lack of source routing [49].	When a link breaks, a huge number of control packets are produced. The active route becomes more congested because of these control packets [49].
A flat routing protocol is the AODV protocol. No centralized administrative system is required for it to manage the routing process [50].	A route might no longer be usable, and figuring out when it should expire is challenging [50].

2.5 MPRR Routing Protocol.

A designated parent is absent from nodes in Multipath Rings Routing (MPRR). During topology establishment, a node is only given a level ring number. The ring number shows how many hops there are between the sources and sink nodes. The initial topology structure packet sent from the Sink has a reference to ring number 0. (base station). Any node that gets this topology configuration message will increase the ring number by 1 and rebroadcast it. Once every packet has a ring number, this process is repeated. Up until every packet has a ring number, this process continues. At some point, a ring number will be assigned to each linked node. A source node wants to send data to the sink after the topology configuration stage is finished, but instead of sending it to a specific node, it broadcasts it with its ring number near. Any node with a smaller ring number will be able to receive and broadcast this packet. The process is complete when the packet reaches the Sink [52].

The multipath ring routing protocol is an example of proactive routing because network initialization is finished before data dissemination and route finding is not required before data transfer. The base station is in charge of gathering data from all sensor nodes and sending it to the data gathering station. According to the Multipath Rings Routing Protocol, all nodes are dispersed randomly across the sensor field. Additionally, a unique, non-replaceable, non-rechargeable battery for each sensor node's power supply is expected. The multipath ring routing technique has two crucial phases. Phases one and two of data distribution and topology configuration, respectively [53]. Table 3 lists the benefits and drawbacks of MPRR.

Table 2.3. MPRR advantage and disadvantages.

Advantages for MPRR	**Disadvantages for MPRR**
The rout are always available.	The Control traffic volume usually high.
The delay in route acquisition is minimal.	The need for storage is great.
The mobility-related treatment effects happen at set intervals and change the frequency of periodic updates.	High bandwidth and power requirements were required.
Rapid establishment of routs.	Routing information flooded in whole network [53].
Routing information is updated periodically [52].	Convergence time is low.

2.6 Chapter Summary

An overview, an introduction to background information on WBAN networks, wireless sensor networks, WBAN architecture, applications of WBAN, the connection between WBNA, Covid-19, and the Internet of Things, and the significance of routing protocols on WBANs were the first sections of this chapter. The complexity of five various types of routing protocols—posture-based routing, temperature-based routing, cluster-based routing, QoS-based routing, and cross-layer routing—is then emphasized in this chapter. The basic routing protocol, AODV and MPRR, which will be modified to produce our proposed protocol, is presented in detail (QPR). The advantages and disadvantages of each routing protocol are then listed.

Chapter 3: Proposed Protocol

3.1 Overview

In this manner, the chapter is structured: Some simulation presumptions are described in Section 3.2, and the classification priority process is introduced in Section 3.3. The mobility model is described in Section 3.4; when the data detected is of the typical type, Section 3.5 describes the methods for route finding and setup in AODV. When the data sensed is a critical type with mobile nodes, Section 3.6 covers the methods for topology configuration and data distribution in MPRR; when the data sensed is a critical type with static nodes, Section 3.7 describes the methodology. Finally, the chapter summary was suggested in Section 3.8.

3.2 Assumptions

We consider a person's body to have N nodes. These nodes are arranged at random throughout the (AxB) m2 space. This space is based on the breadth and height of a person and considers the body's mobility. Nodes that interact using regular sensing data do so through the AODV protocol, whereas nodes that communicate using critical sensing data do so via the communication method covered in section 3.5. Each sensor node in Figure 3.1 serves a unique purpose. The real-time bounce rate of the body can be collected via nodes n1 and n7. The wrist pulses of nodes n6 and n8 can be collected in real-time, making it easier to monitor the pulse. In order to prevent damage from severe variations in blood pressure, nodes n2 and n9 continuously monitor and send blood pressure changes to the sink node. Node n3 is able to detect the real-time activity of the cerebral cortex by sensing the potential waveform of the cortex and translating it into a useful output signal. As the sink node, Node n0 may ensure regular data connection between the sensor network and external network. It is similar to base stations in the world of mobile communication. As previously noted, the Sink node in QPR will be positioned in the center of the human body, with the remaining nodes uniformly scattered randomly throughout the body's boundaries [54].

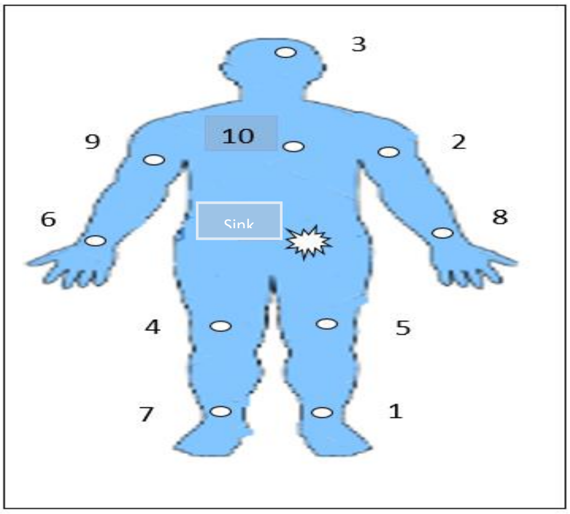


Fig 3.1: System Modeling.

There are two categories for this sensor reading based on the sensor type and the normal measurement for it, such as the SpO2, which detects the oxygenated hemoglobin in the blood and is categorized as critical when the reading is below 90% and normal when it is between 90% and 99% [55]. The AODV routing protocol sends routine reading to the sink node. Every time a network object has to send a message to another node, it uses AODV to determine the next hop. When a request to deliver a message is received, an AODV router checks its routing table to verify if a route already exists. Each item in the routing table is composed of the fields destination address, next hop address, destination sequence number, and hop count. If a route is available, the router simply forwards the message to the next hop. If not, a route request is launched to start looking for a route after the message is saved in a message queue [56]. After receiving the routing information, it updates its routing database and sends the queued message (s). AODV nodes to communicate with one another use four different message types. The messages Route Request (RREQ) and Route Reply (RREP) are used for route finding. Route Error (RERR) and Hello messages are used for route maintenance [49].

Depending on the node's mobility, critical readings are sent to sink nodes in various ways. In the first case, the node is mobile, hence the MPRR routing protocol is utilized to transfer data to sink. Multipath Rings Routing has no defined parent for the nodes. A node is only given a level ring number when a topology is created. The ring number represents the hop separation between the sources and sink nodes. The first topology setup packet sent from the

Sink contains ring number 0 (base station). The ring number of the received packet will be increased by 1 by each node that gets this topology configuration message before it is broadcast once more. Up until every packet has a ring number, this process continues. A ring number will eventually be assigned to each of the connected nodes [52].

After the topology configuration stage is complete, a source node wishes to transmit data to the sink, but rather than sending it to a specific node, it broadcasts it with its ring number attached. Any node with a smaller ring number will be able to receive and broadcast this packet. The process is complete when the packet reaches the Sink.

In a static case, when transmitting a critical reading to the sink node, the message is directly transmitted to the sink by increasing the transmission power on this node to minimize any traffic delay.

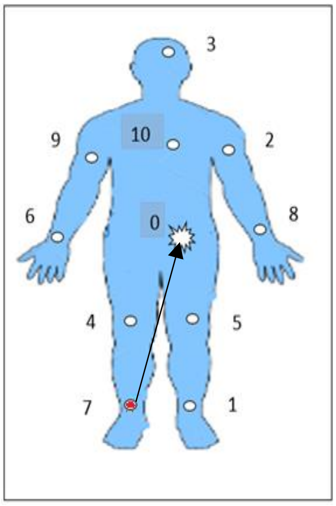


Fig 3.2: Static Patient Critical Data Sending.

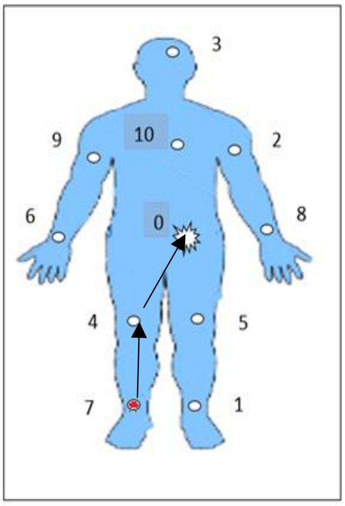


Fig 3.3: Normal Data Sending.

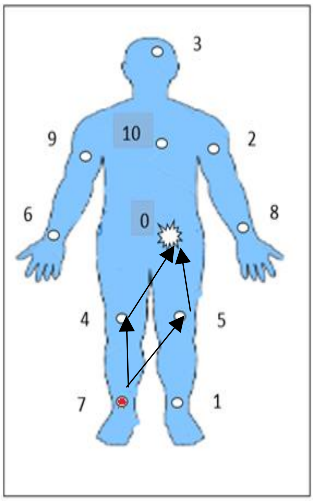


Fig 3.4: Mobile Patient Critical Data Sending.

As seen in Figure 3.2, Node 7 seeks to convey static patient-critical data directly to the sink by boosting the power transfer. By doing this, it minimizes data delay in the event of an emergence. However, when the patient is mobile so we need to guarantee the data access to the sink by sending data by using MPRR as in Figure 3.4, node 7 sends data to the node, which has a smaller ring number by one, as nodes 4 and 5 until reaches to sink. In Figure 3.3, node 7 wants to send normal data so the AODV is used by sending to the next hop which is node 4 until reaches the sink.

Algorithm of the proposed OPR protocol

```
Packet Classifier
Input Packet p, Node n
for each receive p do
    Determine p.Priority
    if (p.Priority==NP) then
        send p by AODV
    else if(p.Priority==CP) then
        Determine n Position
    if (n.Position==SN) then
        send p by direct mechanism
    else if(n Position==MN) then
        send p by MPRR
    end if
    end if
end for
```

3.3 Classification priority

We shall discuss the categorization priority in this section. First, let us define the terms for the variables and notations that will be used in this section and the ones that follow.

Table 3.1: Data type field for QPR.

Symbolization	Data Type	Binary Formula
ND	Normal	0
CD	Critical	1

The MAC frame is composed of the frame check sequence (FCS), which is composed of 2 octets, a 7-byte MAC header, and a variable-length MAC frame body. Four fields are present in the MAC header. The frame control field is the first field, which has four octets. The recipient ID and sender ID, which make up the second and third fields, each have one octet.

The BAN ID is the name of the one-octet field in the last field. The categorization approach adds a new field called "data type" to the frame control field, while the MAC header retains its original seven bytes [57].

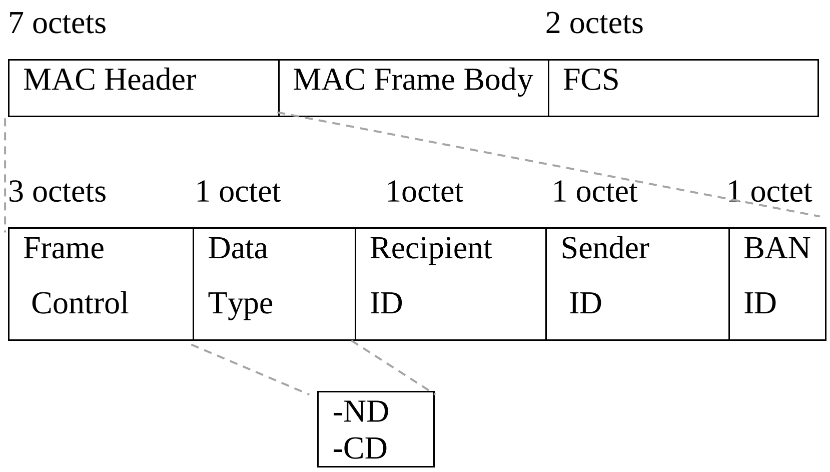


Fig 3.5: MAC Frame Fields.

For instance, if a blood pressure sensor is used and a measurement of more than 120 mmHg and less than 90 mmHg is acquired, a CD is detected. The ND ranges from 90 to 120 mmHg [58]. To save on overhead, the data types are shown in binary format, as specified in table 1. If the Datatype is 1, it indicates that the data is urgent and has to be communicated right away. In this case, direct transmission is used after analyzing the node's mobility to choose the best choice. If the Datatype is 0, the AODV method is being used to transfer regular data.

3.4 Node Mobility

Each node (with the exception of Sink) may modify its position in response to human movement, making our model very similar to, if not exactly matching, the implemented real-life practical systems. Send readings using the straight to sink approach if the node is static. Send a reading to the sink using MPRR if the node is mobile.

3.5 Normal Data Using AODV Route Discovery and Setup

The methods for route setup and discovery are described in this section.

3.5.1 Route Discovery Mechanism of AODV Protocol for Normal Data

Under the flooding mechanism, when a node starts or passes a route request message to its neighbors, the neighbors are expected to return the identical route request message back to the node. To prevent nodes from broadcasting the same RREQs again, each node stores a route request buffer with a list of recently aired route requests (resulting in infinite cycles). Before passing an RREQ message, a node always makes sure to check the buffer to make sure it has not already passed the request. RREQ messages are also stored in the buffer by the same node that sends RREP messages. A sequence number that grows monotonically at each destination (node) represents the logical time at each destination (node) [54].

Every route item additionally contains the destination sequence number, which records the "time" at the destination node when the route was constructed. The protocol employs sequence numbers to ensure that nodes only update routes with "fresher" ones. This also ensures that there are no loops on any of the pathways leading to a destination. Links in an ad hoc network are prone to failure because of the mobility of the nodes and the fleeting nature of the wireless channel. Therefore, it is necessary to have a mechanism in place to restore routes when a connection within active routes breaks. An active route is one that has recently been utilized for the transmission of data packets. Any destinations that become inaccessible as a result of the link breakdown are invalidated in the routing database of the node upstream of the break when it happens (i.e., the node closest to the source node). The list of all of these inaccurate locations is then included in a Route Error (RERR) message [59].

3.5.2 Route Maintenance Mechanism of AODV Protocol for Normal Data

The upstream node sends an RERR, which the source node accepts. If more than one prior hop utilized this joining, the node broadcasts the RERR; otherwise, it is unicast. A node must first establish whether the node that transmitted the RERR is its next hop before it may reach any of the destinations listed in the RERR. As the next hop to any of these destinations, the node invalidates these routes in its route table before propagating the RERR back to the transmitting node's source. The RERR is sent using this way up until the source receives it. After getting the RERR, the source may restart the route discovery procedure if it still requires the route [48]. Each node now has a unique queue that serves as a cache for the routes in addition to the queue that AODV utilizes to store routing information. For this reason, we adopted the same queue design that AODV employs to store its routes. In order to mitigate the problem of hard caching, a cache timer is introduced, and an appropriate cache timeout value is found to maximize the cache's effectiveness even under conditions of high mobility (low pause time). The latest current sequence numbers and node addresses should be carried by RREQ (it is the same sequence number as used by AODV to check the freshness of a route). The target node has already crossed the intermediate nodes. Any route that is added to the cache but does not update during the cache timeout duration is removed [59].

To do this, a new data structure that creates a link list of the nodes' addresses and sequence numbers has been added to the AODV RREQ packet header. In addition to performing the responsibilities previously allocated to them, all nodes that receive a route request packet should read the node addresses and sequence numbers contained in the packet and add any nodes that may be accessed from the most recent node via which the packet originated to their caches. The nodes with their address and the most recent unused sequence number should then add the packet before being broadcast to the nearby nodes [54].

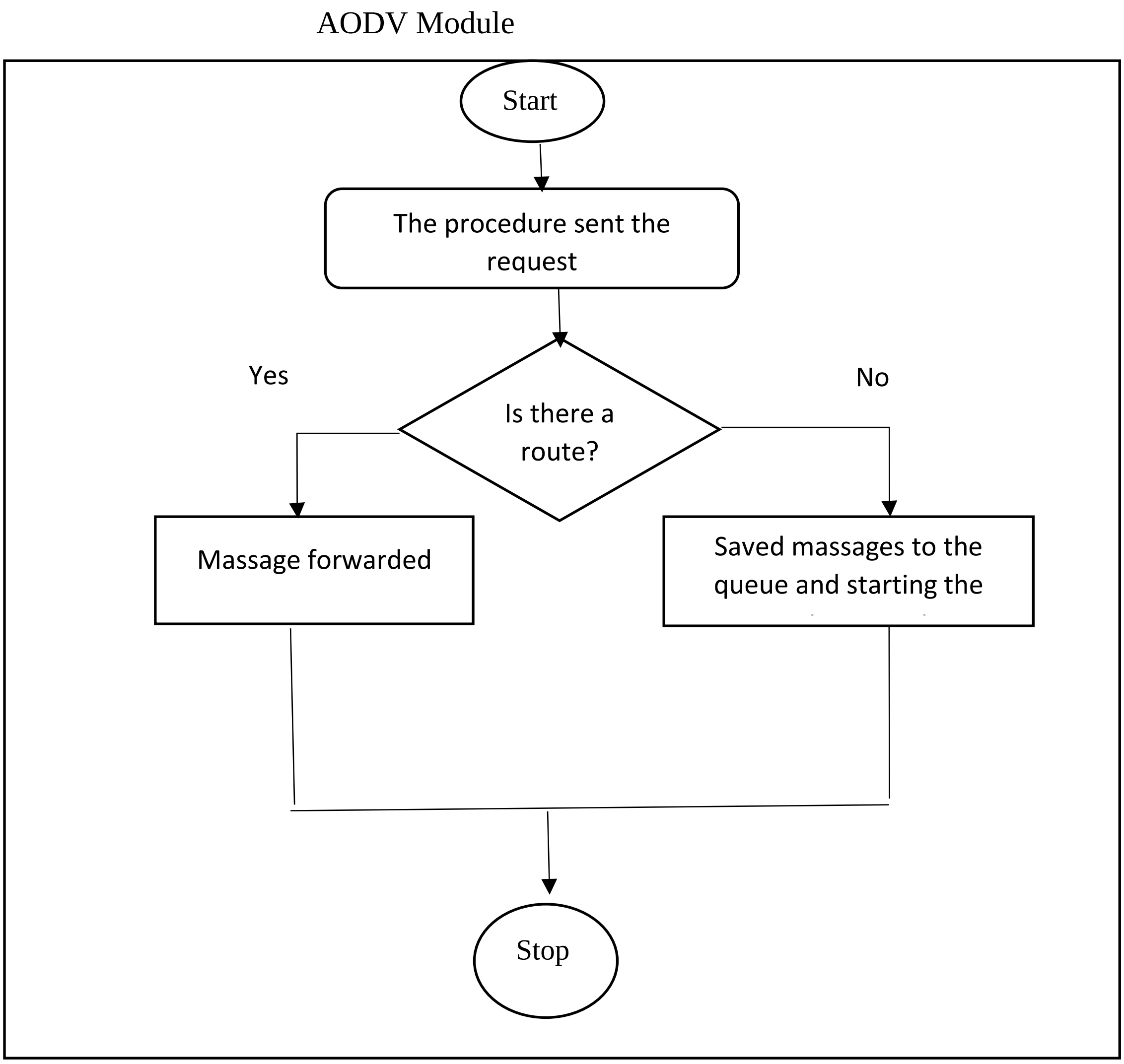


Fig 3.6: AODV_Normal DataModule [59].

3.6 Critical Data Mobile Node Using MPRR of Topology Configuration and Data Dissemination

The topology setup and data distribution mechanisms are explained in this section.

3.6.1 Topology Configuration Mechanism of MPRR Protocol for Critical Data Mobile Node

The main objective of the topological structure phase is to construct the network so that by the time the phase is complete, each node can choose the number of hops that separate it from the sink node. During the topology construction phase, the base station transmits a network setup packet with the current ring number set to 0. Hop distance is determined by a variable known as ring number. Nodes that are nearby the base station in terms of distance can receive this topology setup packet. The receiver node increases the packet's ring number by one and rebroadcasts it after receiving this packet. Additionally, it adjusts its ring number to the ring number of the received packet plus one. As a result, ring one will cover all nodes that are next to the sink node on a straight line, ring 2 will cover all nodes in ring 1, etc. In general, if a node is n hops away from the Sink node, it will fall below ring n [60].

There are five basic fields in the topology configuration packet format. The node ID that is transmitting the packet is the first element. The target node's ID, which is frequently a broadcast address for the topological construction phase, is provided in the second portion. When a network includes several Sink nodes, the third field—the current Sink ID—is useful. The MPRR's fourth field, which also serves as a flag to specify the sort of packet, may contain values for a multipath rings routing topology setup packet, a multipath rings routing control packet, or a multipath rings routing data packet value. The fifth field [52] contains the ring number that is currently in use.

The base station will send topology setup packets with the current ring number values set to zero during the topology configuration phase. Each node will then receive its unique ring number after the procedure is finished. The network is divided into numerous rings when this stage is complete. Each ring shows the hop distance from the base station. There is a chance that one or more nodes will join the network after the topology building stage is complete, enabling them to broadcast link network requests. The sender node can adjust their current ring number to be one higher than the ring number of the received packet by obtaining the receiver node's current ring number in response to this request [53].

3.6.2 Data Dissemination Mechanism of MPRR Protocol for Critical Data Mobile Node

During this phase, a node will broadcast information with its most recent ring number when it needs to communicate with a sink node. Each of the source node's neighbors may thus hear the packet and determine its ring level. Only the receiving node will continue processing a packet if it has a greater ring number than it; else, it will be roughly discarded. The receiving node will acquire and process the packet if it is a sink node. It will rebroadcast the packet by changing the ring number of the packet to its own ring number if it is not a sink node. The process will continue until the packet arrives at the base station. Nodes of ring n-1 will only process that packet; nodes of rings n and n+1 will reject it [60].

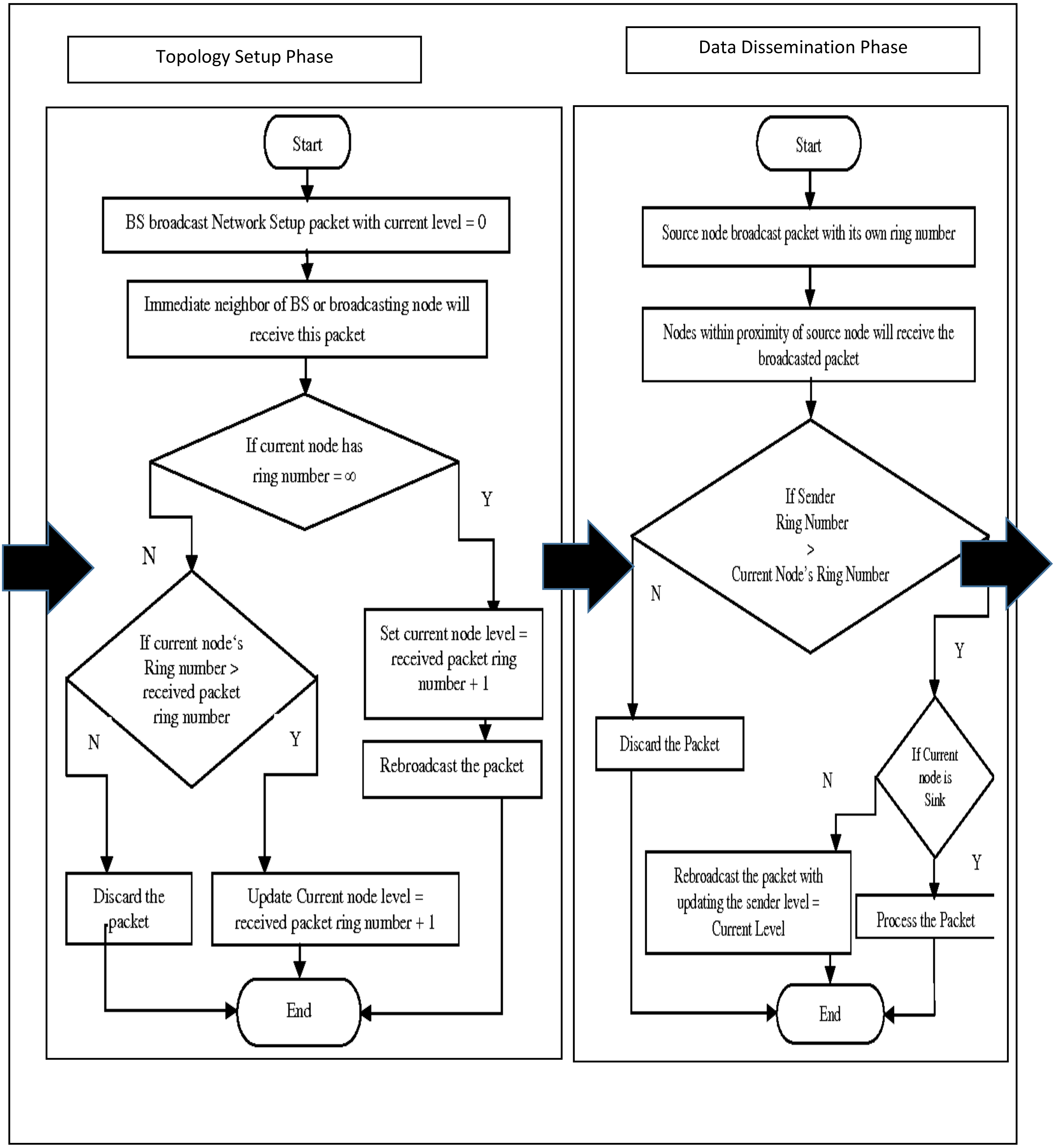


Fig 3.7: MPRR_Critical Data Mobile Node Module [60].

3.7 Critical Data Static Node.

The crucial information is when nodes are mobile and the direct-to-sink technique is used to ensure that the sink, which serves as the purpose node, is reached by raising the transfer power on the source node. The crucial route of active networks is always known as the sink.

3.8 Qualitative Comparison of AODV, MPRR and QPR

The properties of the provided procedures are compiled in Table 3.2. These protocols' specifics and practices differ in various significant ways, which most appropriately leads to noticeable performance variations.

Table 3.2: Studied protocols characteristics.

Performance parameter	**AODV**	**MPRR**	**QPR**
Reliability	Low	Medium	High
Latency	High	High	Low
Energy	High	Medium	Low
Hop count	High	High	Low
Control packet	High	High	Low

The performance of the protocol with more mobile nodes in the network is referred to as reliability. Since AODV may operate in networks with a single path, its dependability is regarded as low. In contrast, MPRR may perform as well as AODV in networks with considerable mobility. MPRR assumes several pathways, which ensures a dependable transmission of data to the sink. Additionally, because AODV and MPRR do not take data priority into account, acting on all data in the same way will result in an increase in packet overhead. Finally, because QPR considers the patient's movement and multipath, it may have great dependability. These factors contribute to the great dependability of QPR.

Due to the broadcasting of RREQ packets, especially in mobility nodes, AODV is thought to have a high latency. In networks with strong mobility, MPRR may also have a high latency. The broadcasting packets will increase since MPRR anticipates many pathways. Finally, QPR may have low latency because it considers the priority of data and the mobility of patients, transmitting data straight to the sink node with the least amount of latency when the data is crucial and the patient is stationary.

Due to the growing number of nodes and increased movement of patient nodes caused by rising broadcasting REQ, AODV is regarded to have a high energy consumption. MPRR may have a similar energy consumption as AODV when it comes to patient mobility. Because it considers data priority, QPR may have a low energy consumption. However, when data is crucial, it transmits data straight to the sink node by raising transmission power, which results in a higher energy consumption.

Due to the growing number of nodes, particularly in key nodes, the hop count of AODV is thought to be high. In networks with growing numbers of critical nodes, MPRR may also have a high hop count. Because QPR considers data priority and transmits data straight to the sink node with a minimum hop count when necessary, it may have a low hop count.

The control packets of AODV are regarded as high owing to an increase in nodes and the mobility of patients' nodes as a result of an increase in broadcasting REQ; MPRR may have a high control packet as AODV in terms of enhancing patient mobility. Because QPR considers the importance of the data and transmits it straight to the sink node with a low hop count when necessary, it may have a low control packet.

3.9 Chapter Summary

The third chapter is the most crucial. All simulation-related difficulties have been detailed, including crucial suppositions, the classification priority model, and the mobility model. The specifics of the techniques for route finding and setup in AODV when the sensed data is of the usual type are then covered in this chapter. Finally, this chapter discusses the method when the data sensed is a critical type with static nodes. The next section describes the strategies for topology creation and data distribution in MPRR when the data sensed is a critical type with mobile nodes.

Chapter 4: Simulations, Results and Performance Analysis

4.1 Overview

The overview of several simulation systems and the justification for choosing the Omnet++/Castalia simulator are presented in the first section of this chapter. Then, we went over the methodology and scenarios for our simulations. The results of our experiments are then reviewed.

4.2 Simulation Platforms Overview

There are several simulation platforms available. These systems differ in terms of mobility, playability, environment, and simulation capabilities. This section will cover The Matrix Laboratory (Matlab), Network Simulator 2 (NS-2), and Objective Modular Network Testbed in C++ (OMNeT++).

4.2.1 Matlab

Matlab- Matrix Laboratory- [61] Math Works Inc. created a computation and visualization tool with hundreds of structures that is extremely effective and feature-rich. The most significant aspect of Matlab is its ability to quickly program and give a platform for users to create their own special routines. In Matlab, a variety of toolboxes are accessible, including those for communication, statistics, fuzzy logic, controller system design, aerospace, and many more [62].

The backbone of Matlab is Simulink, a piece of software that is essential. Linear and nonlinear systems can be represented using Simulink in continuous time, sampled time, or a combination of the two. Designing block diagrams and each of its individual components may be done using drag-and-drop in Simulink [61].

The greatest disadvantage, though, is how hard it is to represent a specific system. Understanding and modeling a system might take a very long period, especially for more recent innovations. The memory requirements of the Matlab simulator and the difficulty of changing library models were also noted. Last but not least, purchasing the software and model libraries for Matlab is expensive because it is a commercial product [62].

4.2.2 Network Simulator 2 (NS-2)

The Network Simulator's second iteration is known as NS-2 [63]. (NS). A unique event simulator geared on networking research is called NS. TCP, routing, and multicast protocol emulation across wired and wireless networks has strong support from NS. NS has consistently included significant assistance from other scholars. Different MAC layers for local area networks are among the approved protocols that are included in the NS package [62]. Systems are modelled by Ns-2 as a collection of occurrences. The simulator has already specified these occurrences. The next event is started, and it is allowed to run all the way through to construct the process. Each event happens in a specific amount of virtual (simulated) time, but it also happens in a specific amount of actual time. The simulator's design separates the data from the control; the data is handled by C++ (per packet processing, the nucleus of NS, fast execution, detailed, complete control), and the control is handled by OTcl (scenario structures, periodic or triggered action, manipulation of existing C++ objects, quick writing and change). It takes a while to become used to using NS-2, and its source code is poorly documented [63].

4.2.3 OMNeT++ (Objective Modular Network Testbed in C++)

A powerful object-oriented discrete event network simulator, OMNeT++ [64] simulates wireless sensor networks. It is recognized as a flexible, modular, and component-based C++ simulation library framework for simulating wireless networks. Although OMNeT++ is not a simulator, it does provide frameworks and tools for creating simulation situations. Operating systems like Windows, Linux, and MAC OS X may all support it. Version 6.0 of OMNeT++, the most current release, focused on using Python-based Analysis Tools in the IDE [65] and became available in April 2022.

To improve user interaction with and utilization of the simulator, the TKenv GUI has been reshaped for single-window mode. The key function of TKenv is to exhibit network animation, node movement, display results, and change visualization. The simple elements that makeup OMNeT++ are modules. Modules come in three different types: (A): Simple Module: It was created using C++; (B): A module that links to additional modules is a compound module; Network Module: The phrase "network module" refers to the compound module at the top level. NED file graphical and text editing, C++ programming, and module debugging are all supported by OMNeT++'s Eclipse-based IDE environment [61] [64].

In NED (Network Description), basic modules may be declared by the user and then connected to create compound modules. The Simulator in OMNeT++ designed exclusively for WSN is called CASTALIA. A well-known BAN simulator made specifically for implanted low-power devices is called Castalia. Researchers frequently use the simulator to practice interpretation in real-time wireless channels and radio models, see the results of real-time nodes, and replicate procedures and protocols [64].

Castalia is not designed as a sensor-specific platform, but rather to offer real-time results of the algorithm developed by the researcher on any given sensor platform. The most recent version of Castalia, 3.3, became released in March 2016.

Castalia offers several things:

• To investigate nodes, the signal strength of the path between nodes, and any levels of interference, use the channel model.

• A radio model can be used to understand SINR, packet size, module type, and carrier sensing, among other things.

• MAC and routing protocol research on nodes.

• Calculating the CPU's energy consumption [65].

4.2.4 Discussion and Simulator Choice

Matlab is a for-profit technology, therefore buying the software and model libraries is expensive. It has other flaws as well, including complexity, the time needed to understand it, memory use, and the difficulty in modifying the library models [64]. The OMNeT++ and NS-2 tools are the most complex. The latter as well as the academic research version of the former are both widely accessible online. However, we may draw the following conclusions from the final two paragraphs:

• OMNeT++ was created specifically for wireless mobile networks. Although NS-2 was initially designed for wired networks before being expanded to include wireless networks, the implementation of wireless simulation in NS-2 is substantially different from wired simulation [62].

• OMNeT++ was developed as a collection of libraries. Libraries are created using PARSEC (a C-based discrete event simulation language). Although NS-2 employs two languages—C++ for data and OTcl for control—the majority of programmers are more familiar with C than OTcl [65].

• Stable protocol layers and a five-layer network architecture are features of OMNeT++/Castalia. At every level, a built-in measures collection is simple to plug in [64].

• It is difficult to learn and operate NS-2 [62].

• Although it may be used to simulate networks with hundreds of nodes or less, NS-2 does not perform well for large topologies [63].

• For obtaining statistics for lower-level protocols, NS-2 is preferable [62].

We chose to utilize OMNeT++/Castalia as a simulation tool based on the available capability, strong focus on wireless body area networks, the knowledge of the partners, and its growing usage to simulate wireless body area networks.

4.2.5 Introduction to Castalia*

Castalia's structure, node locations, mobility models, and the addition of a new routing protocol are discussed in this part.

4.2.5.1 Structure of Castalia

Castalia's basic module construction shown in the diagram below:

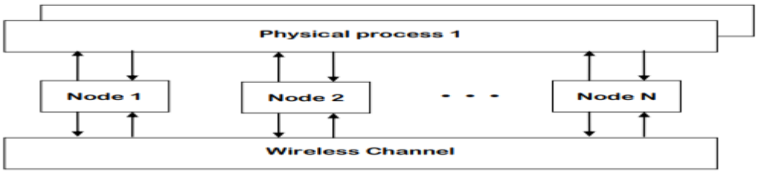


Fig 4.1: The modules and their connections in Castalia.

* Information in this sector and its subcategories obtained by looking Castalia directories and documentation files

Consider the fact that, as opposed to directly, the nodes connect to one another through a wireless channel module (s). The arrows show the message transmission between modules. The wireless channel decides which nodes should accept a packet when a node that has to deliver it directs it to it. The physical processes are connected to them as well by the nodes. The nodes sample the physical process in both space and time to obtain their sensor data (by sending a message to the suitable module).

4.2.5.2 Structure of the Node Composite Module

Application, Routing, MAC, and Mobility are the four main sorts of modules that may be created using Castalia. The directory's correct location for the module's code must be specified. A new application's source code, for instance, must be located in the directory src/node/application, and a new routing protocol's source code must be located in src/node/communication/routing.

It is a composite node module. The node composite module's internal structure is seen in Figure 4.2. For message transients, the arrows are solid, while for simple function calling, they are dashed. As an illustration, the common module connects a resource management function to demonstrate the consumption of energy. The application module will most frequently be changed by the user, generally by developing a new module to implement a new algorithm. By creating a new module to implement a new protocol or mobility pattern, the user may automatically make changes to the communications MAC and Routing modules, as well as the Mobility Manager module. By specifying the necessary abstract classes, Castalia provides aid in creating unique protocols or applications.

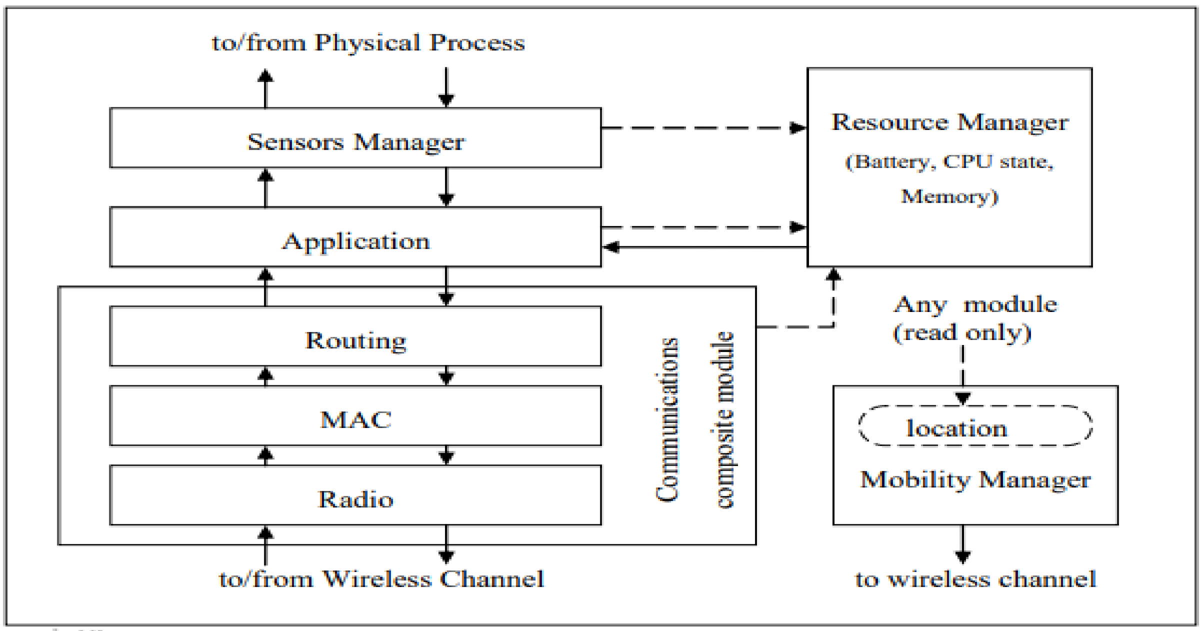


Fig 4.2: The node composite module

4.3 Simulation Methodology and Scenarios

A simulation program called OMNeT++/Castalia is used to evaluate the MPRR, QPR, and AODV protocols' performance. Castalia features two new models called "AODV" and "QPR" that replicate the AODV protocol and our new protocol, respectively. MPRR has already been implemented in Castalia.

We assume that each node can be uniquely identified and that its ID cannot be modified while the WBAN is in operation in order to simulate QPR and AODV. In the identifying process, the ID is utilized. The "node address" field, which is a sequence number for each node in OMNeT++/Castalia, is utilized as the node ID.

All nodes in WBAN go to the Sink node, whose position supports conducting more study since it is outside the scope of our work. There have been several solutions suggested. In order for all nods to test the location of the seed packets, we presume that the position of the sink operation is complete. Additionally, it is assumed that the sink will remain in the same location during all phases. The human body's center, or waist, is where the sink node should be placed, according to previous studies [66].

These nodes initially assumed a constant percentage of source node mobility, taking into account a given percentage of vital data, however as the number of nodes grows, this assumption will become less valid. Following that, node mobility is enhanced while the number of nodes is fixed and the proportion of vital data is fixed. The percentages of nodes and nodes moving were fixed in the previous example as the percentage of vital data grew.

Table 4.1 Simulation parameters

Simulation time	200 s
Simulation field size	3 m×2.5 m
Communication radio-RSSI	8
Communication radio-Power	- 10 dBm
Application	Throughput test
Packet rate	1000
Wireless channel	Path loss map file, temporal mode parameters file, sigma, bidirectional sigma= 0
Communication radio-mode	High
Configuration MAC	Baseline BANMAC, MAC Phy data rate =1024 Mac BUFFER size = 48 Node0= Hub
Number of nodes	4, 8, 12, 16, 20.
Percentage mobility nodes	0%, 25%, 50%, 75%, 100%
Percentage critical data	20%, 40%, 60%, 80%, 100%

In this work, we will investigate how each of these scenarios affects network performance and contrast the suggested protocol with the MPRR and AODV standards already in use. We have utilized CBR traffic via UDP and an 802.15.6 MAC layer for the three protocols.

We have confirmed the impact of the network's three key parameters. These variables are the percentage of mobile nodes, the percentage of essential data, and the total number of nodes. The results of earlier studies demonstrate the substantial impact of this parameter. Five performance measures have been assessed for each parameter:

(a) Packet Delivery Fraction (PDF): The percentage of data packets generated by CBR sources that the destination actually receives. This evaluates the protocol's ability to create and preserve routes.

(b)Avg Energy consumption (AEC): The simulation will be utilized to look at the trade-off between the reliability and energy effectiveness of the provided protocols as WBAN nodes are resource restricted. By calculating the total energy used by the entire network, energy efficiency is evaluated. According to (1), the four activities of transmitting (Etx), receiving (Erx), being idle (Eidle), and sleeping (E total) are the four processes that make up the total energy (E total) utilized by an RF energy model (Esleep) [67].

$$E\text{total} = E\text{tx} + E\text{rx} + E\text{idle} + E\text{sleep} \quad (1)$$

(c) Number of control packets sent for each delivered data packet (CPD): To assess how effectively control packets are used in delivering data to intended recipients, we choose to employ a ratio of control packets broadcast to data packets delivered as opposed to a pure control overhead. When computing this statistic, packets consumed for route instantiation and maintenance are measured. Also taken into account are packets that are delivered in order to build and maintain the network's structure, update node locations, and maintain membership. This metric's computation takes into account the transmission at each hop along the pathways.

(d) Average Path Length (APL): The typical length of the pathways that the protocol exposes it is taken into account by averaging the quantity of hops required for each data packet to arrive to its destination.

(e) Average Route latency (ARL): The typical amount of time required to plan a route to the goal. It is described as the typical time interval between a source's route request/discovery packet and the first matched route reply packet. The sending time of the initial transmission is used to calculate the delay if a request timed out and needs to be resent.

Each data point in the following graphs representing performance parameters is an average over five simulations carried out using the same configuration but various randomly generated numbers.

4.4 Results and Performance Analysis

We examined the impact of three crucial network factors in this section. These variables are the percentage of mobile nodes, the percentage of essential data, and the total number of nodes. Five performance metrics—PDF, AEC, CPD, APL, and ARL—have been examined for each parameter.

4.4.1 Number of Nodes Effect

A 3mx2m network has been taken into consideration to examine how the number of nodes affects the result. Simulations have been done with different node counts (4, 8, 12, 16, and 20). 25% of the nodes across all tests are mobile. Additionally, 40% of the stationary and mobile nodes detected important data. Table 4.2 provides an example with more specifics.

Table 4.2 Simulation Number of Nodes Effect

Test Number	Number of Nodes	Number of Mobile Nodes	Number of Static Nodes	Number of Critical-Mobile Nodes	Number of Critical-Static Nodes
Test 1	4 nodes	1	3	0	1
Test 2	8 nodes	2	6	1	2
Test 3	12 nodes	3	9	1	4
Test4	16 node	4	12	2	5
Test5	20 node	5	15	2	6

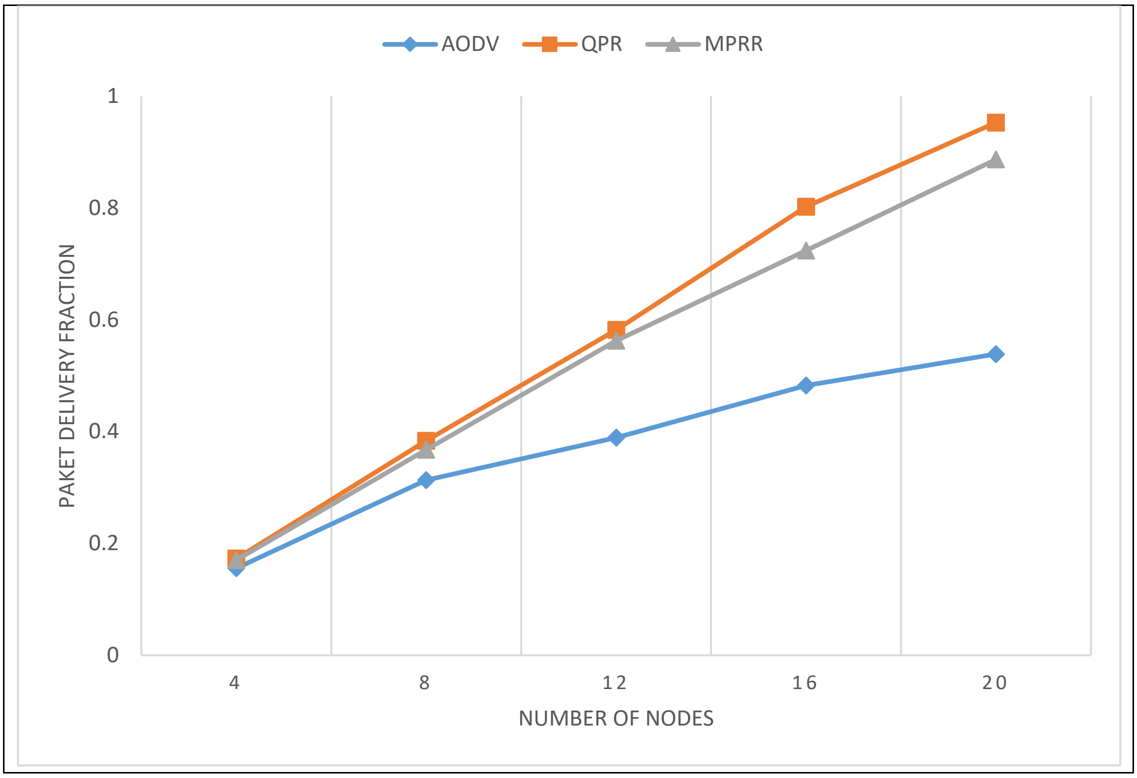
The PDF obtained using either methodology marginally rises as the number of nodes grows, as seen in Figure 4.3(a). QPR is more reliable than other protocols, in addition. In every case, the PDF obtained using QPR is greater than 97%. This suggests that QPR is far more efficient than MPRR and AODV at finding and maintaining routes for the delivery of data packets. The least amount of packets are delivered via AODV.

Figure 4.3(b) illustrates how the three protocols' energy usage rises with the quantity of nodes owing to lengthy pathways. Long pathways increase the likelihood that a link may fail, which in turn increases the requirement to restart the trip. However, QPR uses the least amount of energy since, as the number of nods increases, it does not broadcast the packet to the entire region. Additionally, AODV consumes more energy than MPRR. This is due to two factors. The first is that AODV processes packets more quickly, increasing the likelihood of a connection break and the need to start a new route. Second, an intermediate node in AODV will instantly transmit an RREP to the source if it has a path to the destination.

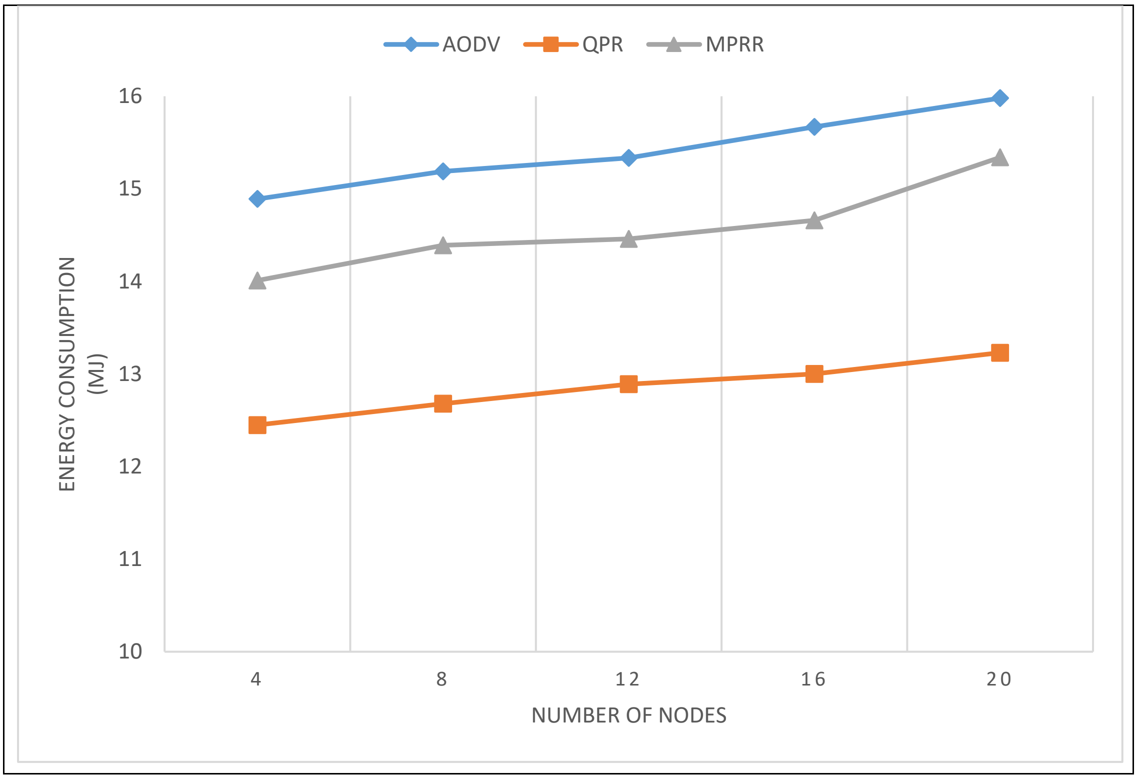
QPR has a lower Latency than other protocols, as was to be expected. According to Figure 4.3(c), ARL is around 45% of QPR, 47% of MPRR, and 49% of AODV. The direct-to-sink process is the reason. Additionally, it is evident from the graph that as the number of nodes rises; lengthy pathways cause Latency for all protocols to rise.

Figure 4.3(d) demonstrates that MPRR, regardless of the fraction of nodes, is just as effective as AODV in finding the shortest pathways. Additionally, the chart shows that when nodes are added, APL rises for all protocols.

Because more data or control packets are sent in all protocols as the number of nodes grows, Figure 4.3(e) demonstrates that CPD modestly rises with node density. However, QPR has the lowest CPD because, as the number of nodes increases, it does not broadcast the packet to the whole region. Additionally, AODV and MPRR have different CPDs.

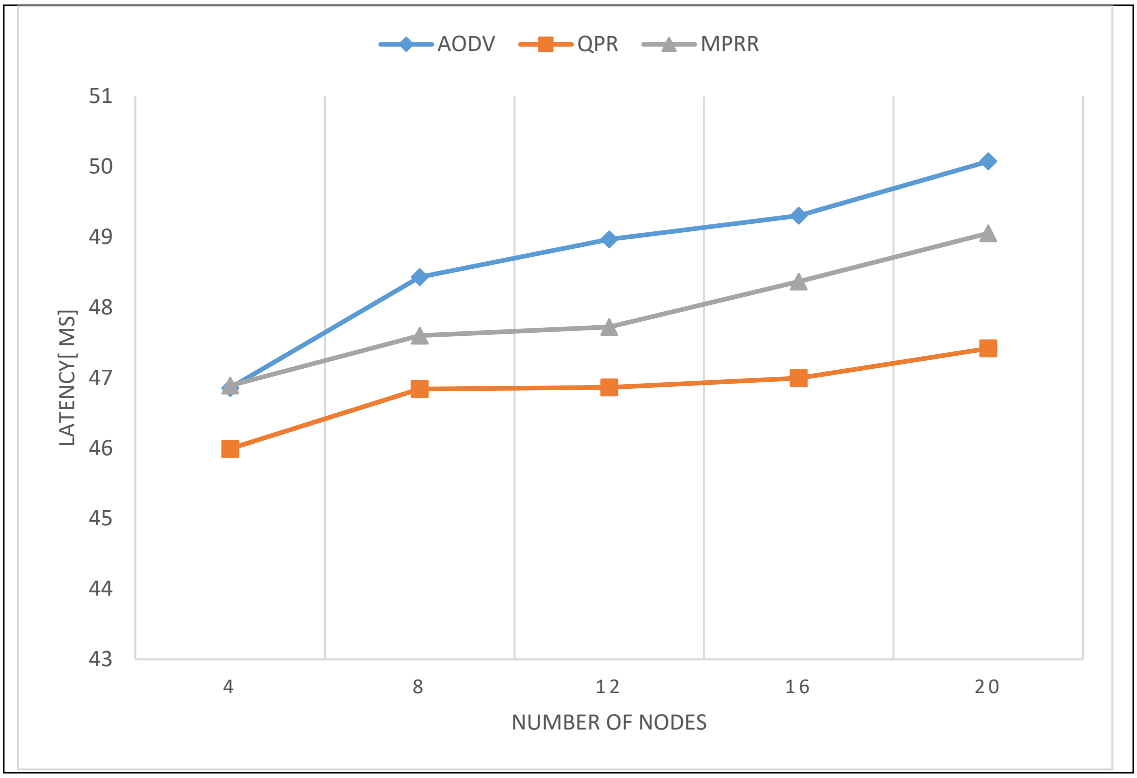


(a)Packet Delivery Fraction (PDF).

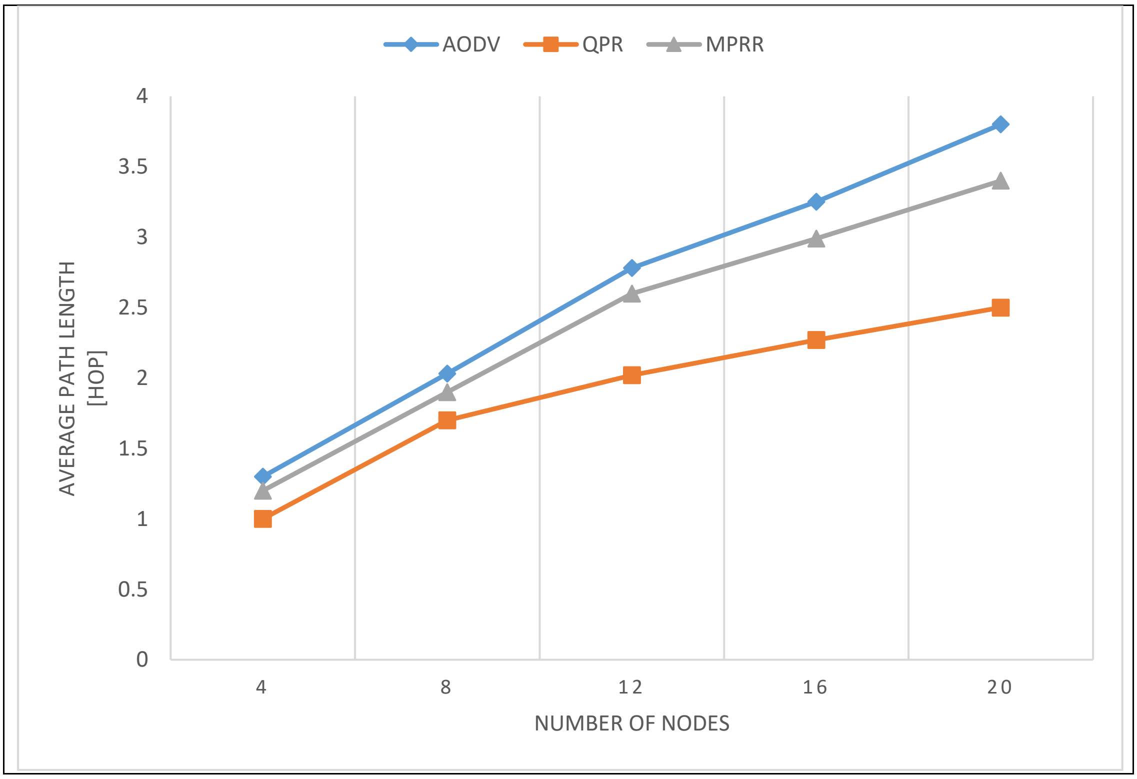


(b)Avg Energy Consumption (AEC).

Fig 4.3: Number of Nodes Effect.

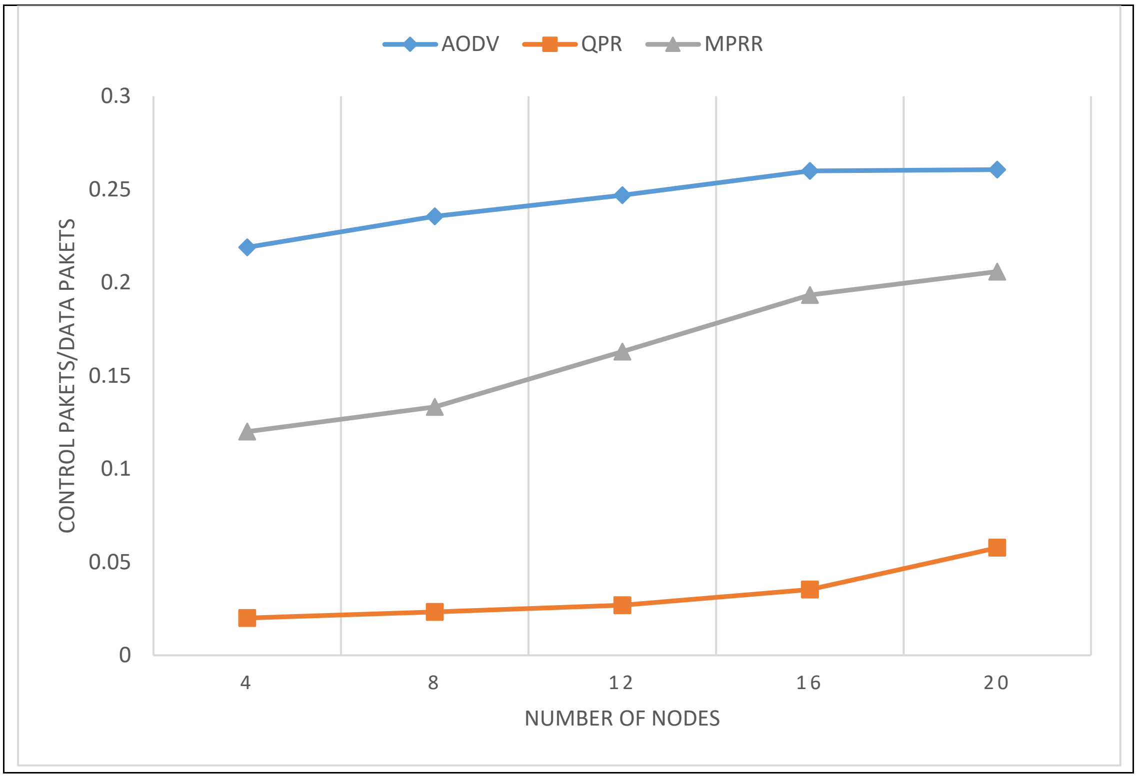


(c)Avg Route Latency (ARL).



(d)Average Path Length (APL).

Fig 4.3: Number of Nodes Effect.



(e)Control Packets per Data (CPD).

Fig 4.3: Number of Nodes Effect.

4.4.2Node Mobility Percentage Effect

A 3mx2m network has been taken into consideration in order to research the impact of the percentage of mobile nodes. There are 20 nodes in this network. 40% of the static and mobile nodes observed important data each time. Simulations have been done with a mobile node percentage of 0%, 25%, 50%, 75%, and 100%. The example in Table 4.3 is shown in greater depth.

Table 4.3 Simulation Node Mobility Percentage Effect

Test Number	Percentage of Mobile Nodes	Number of Mobile Nodes	Number of Static Nodes	Number of Critical-Mobile Nodes	Number of Critical-Static Nodes
Test 1	0%	0	20	0	8
Test 2	25%	5	15	2	6
Test 3	50%	10	10	4	4
Test4	75%	15	5	6	2
Test5	100%	20	0	8	0

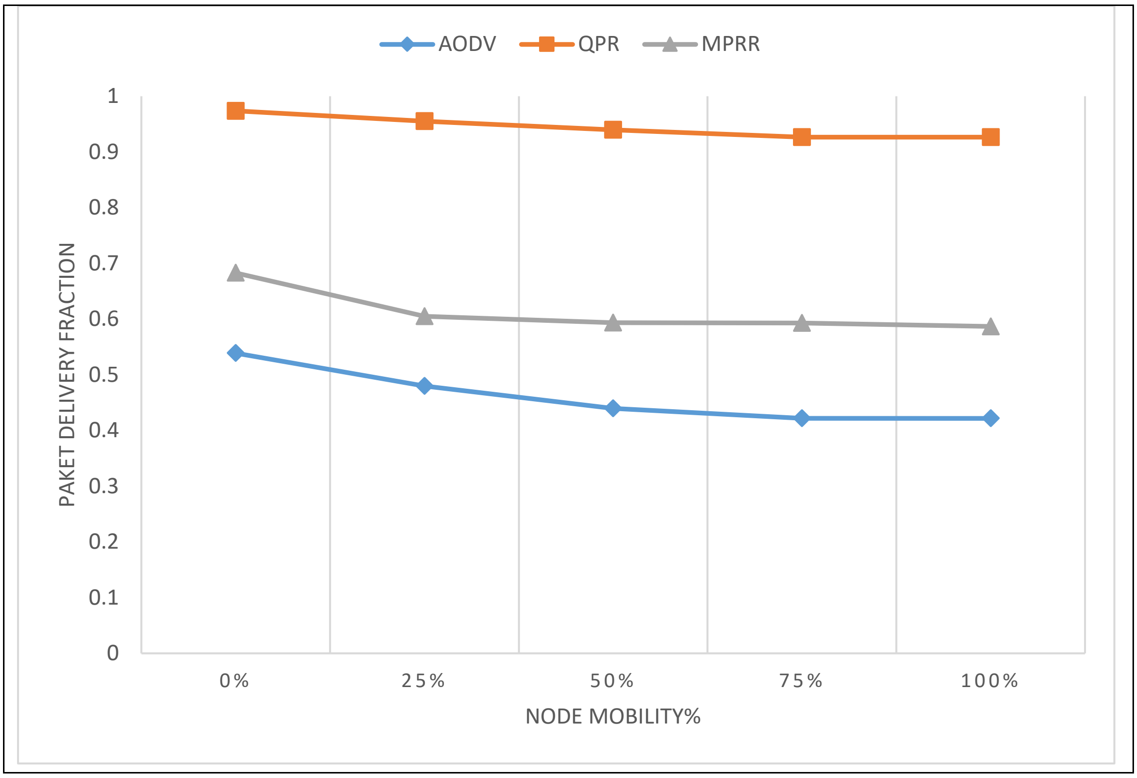
According to Figure 4.4(a), in all cases, the PDF achieved using the QPR procedure is around 93%, the AODV is around 50%, and the MPRR is about 68%. This suggests that even with very significant node mobility, QPR is quite successful in finding and maintaining pathways for the transmission of data packets. In the case of 0% mobility (i.e., all nodes are static), the highest PDF for QPR is 97%, MPRR is 68%, and AODV is 53%, but it decreases as mobility rises. This is because longer pathways take more time and have a larger chance of losing the connection connecting due to node movement, which causes some packets to be dropped.

Figure 4.4(b) illustrates the relationship between node mobility and energy consumption. It is evident from the figure that when node mobility rises, energy consumption for the three protocols also increases. This is due to the likelihood of losing the link connection and reinitiating rising with increased mobility. Even yet, QPR uses less energy than AODV and MPRR do.

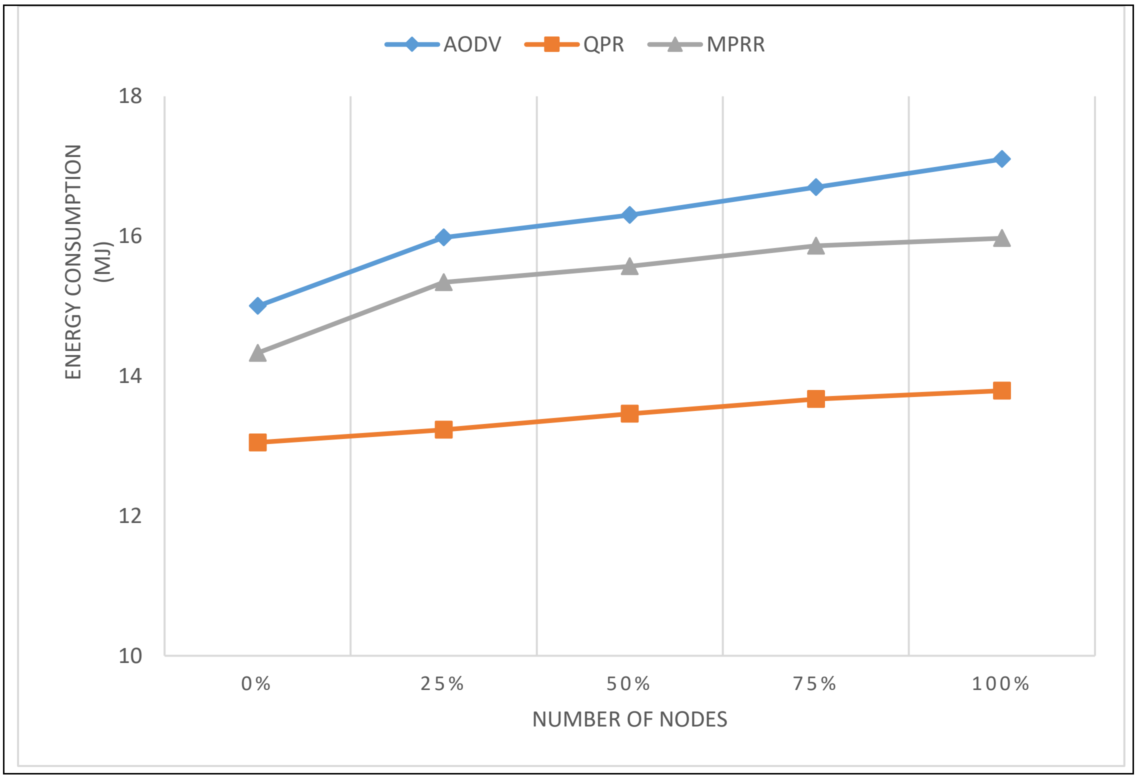
Figure 4.4 illustrates that QPR has lower Latency than other protocols, as would be predicted (c). While AODV is close to 52% and MPRR is close to 49%, QPR's ARL is about 46%. This is as a result of the data-only minimum QPR control packet. Additionally, it is evident from the figure that when node mobility rises, all protocols experience an increase in latency because of a higher likelihood of losing and reestablishing link connections.

Despite the node mobility percentage, MPRR is just as effective as AODV in finding the shortest pathways, as shown in Figure 4.4(d). The chart also shows that as the node mobility percentage is raised, APL rises for all protocols. Furthermore, as predicted, QPR is straight to sink approach results in a lower APL than other protocols.

In all protocols, whether for data or control packets, Figure 4.4(e) demonstrates that CPD increases with increasing node mobility percentage due to the lengthy pathways. However, QPR has the lowest CPD because, as the number of nodes increases, it does not broadcast the packet to the whole region.

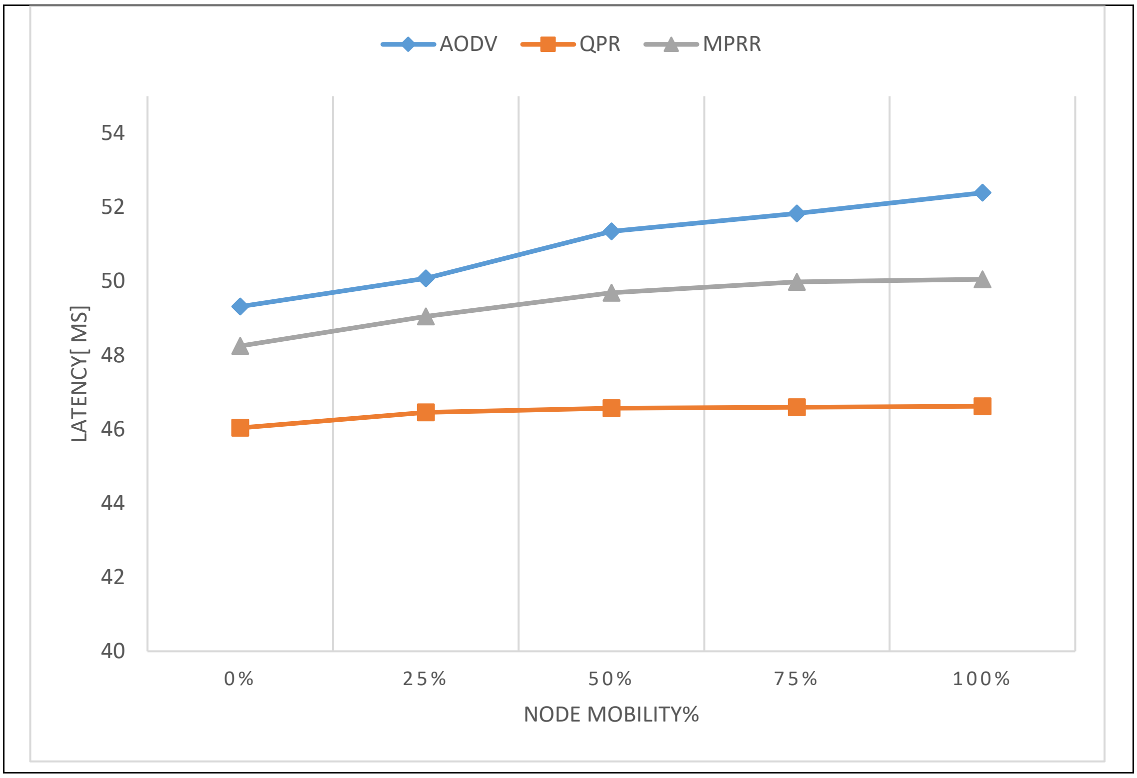


(a)Packet Delivery Fraction (PDF).

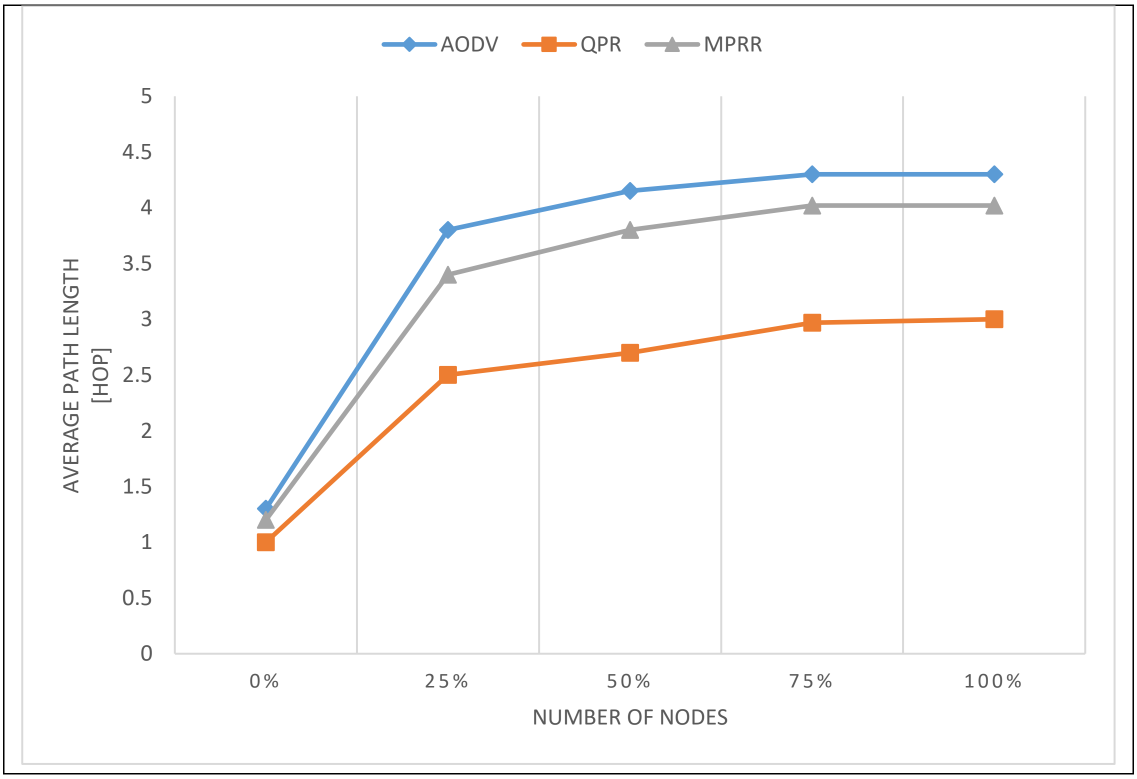


(b)Avg Energy Consumption (AEC).

Fig 4.4: Nodes Mobility Percentage Effect.

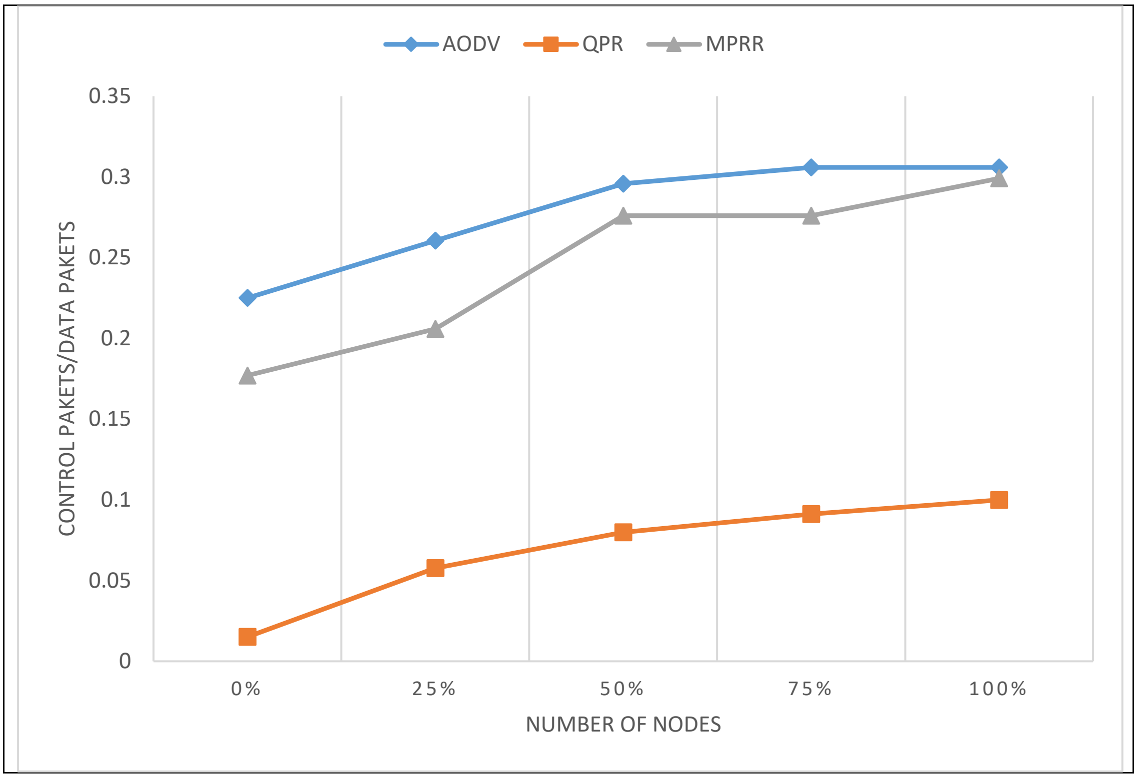


(c)Avg Route Latency (ARL).



(d)Average Path Length (APL).

Fig 4.4: Nodes Mobility Percentage Effect.



(e)Control Packets per Data (CPD).

Fig 4.4: Nodes Mobility Percentage Effect.

4.4.3 Critical Data Percentage Effect

A 3mx2m network has been taken into consideration to investigate the impact of the Critical Data Percentage. Twenty nodes make up this network, and 25 percent of them are mobile (five nodes). The following Critical Data Percentage was used in simulations (0.2, 0.4, 0.6, 0.8, and 1). Table 4.4 provides an example with more specifics.

Table 4.4 Simulation Critical Data Percentage Effect

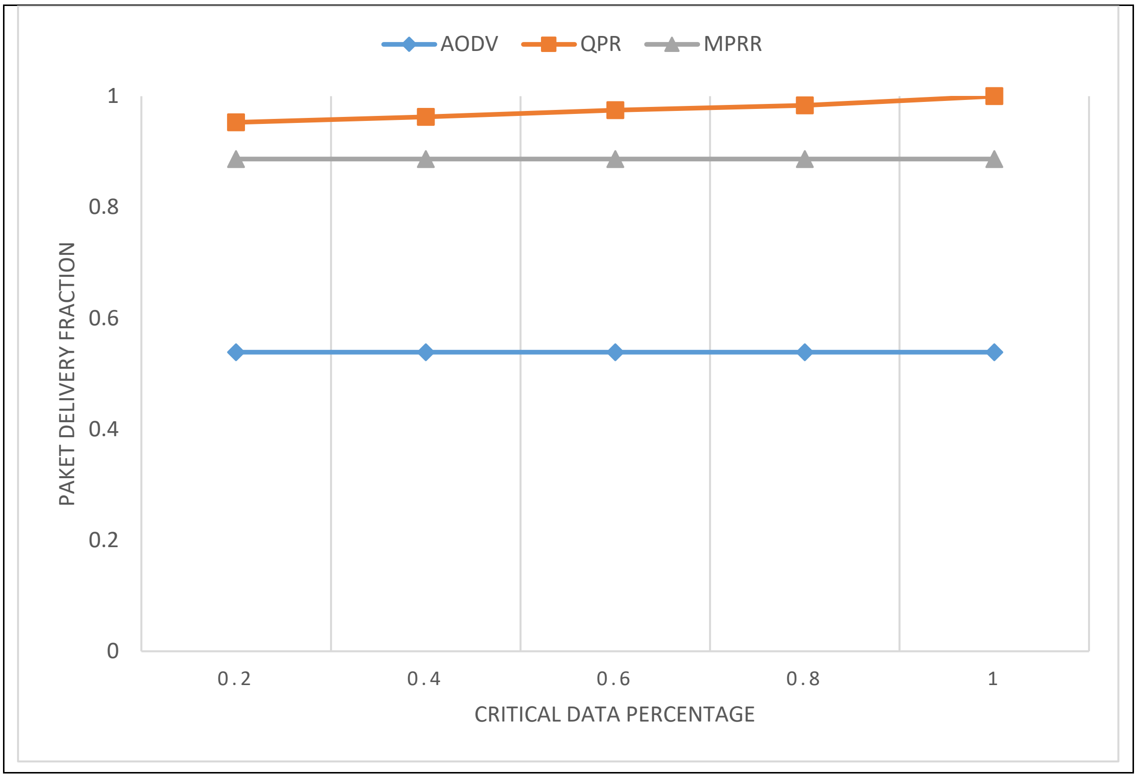
Test Number	Percentage of Critical Data	Number of Mobile Nodes	Number of Static Nodes	Number of Critical-Mobile Nodes	Number of Critical-Static Nodes
Test 1	20%	5	15	1	3
Test 2	40%	5	15	2	6
Test 3	60%	5	15	3	9
Test4	80%	5	15	4	12
Test5	100%	5	15	5	15

Figure 4.5(a) illustrates how the PDF generated using AODV and MPRR remains constant as the essential data percentage rises. As anticipated, the routing technique does not provide data precedence when using these protocols. As the crucial data percentage rises, either QPR procedure marginally increases. Furthermore, it is evident from the graph that the PDF produced with QPR is greater than 98% in virtually all cases, but it approaches 100% when every packet is crucial and sent via the direct-to-sink technique.

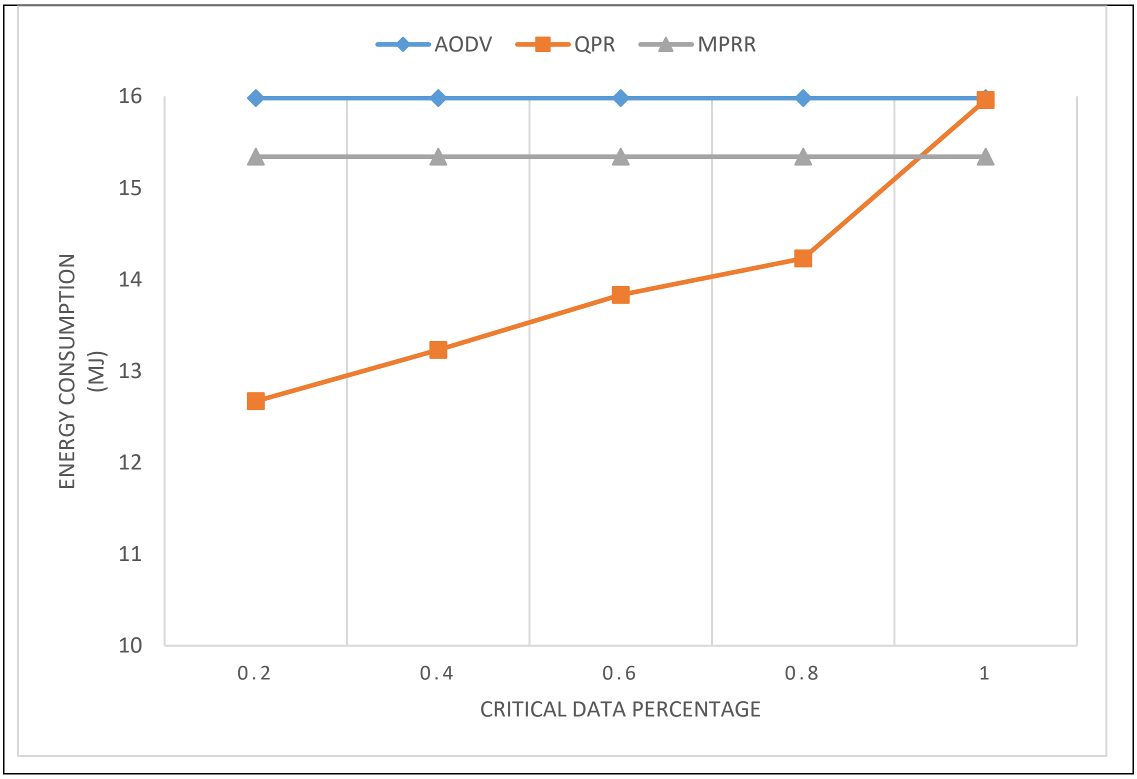
Energy usage for the AODV and MPRR remains constant despite rising in the crucial data percentage, as illustrated in Figure 4.5(b). As may be predicted, these protocols have no impact on the routing algorithm because they do not provide data precedence. However, QPR uses the least energy since it does not broadcast the packet to the entire region in the case of an increasingly important data proportion. The shift in the percentage of critical data also has an effect on QPR since as this percentage increases, so does QPR's direct-to-sink energy consumption. As expected, QPR has 40% of ARL in the critical data percentage under 50%. However, when the critical data percentage is above 50% the ARL decreases exponentially until reaches 10% when all data is critical. This causing of direct to sink mechanisms in one hope so the delay is around 5% in this manner. As a result, QPR has less latency than other protocols, as illustrated in Figure 4.5(c), because some of its hops are only one. Additionally, it is evident from the figure that as the percentage of crucial data rises, QPR latency decreases until it reaches about 5 ms, at which point all data is considered critical and is sent immediately to the sink node.

MPRR and AODV are not impacted by essential data percentage changes, as shown in Figure 4.5(d). The chart also shows that when the crucial data percentage rises over 50% exponentially, APL for the QPR protocol falls from 3 hops to 1 hop because more data is sent directly to the sink in one hop. Additionally, with the direct-to-sink technique, APL for QPR only requires one-step to reach the sink after essential data has reached 100%.

The direct-to-sink method in the QPR protocol causes CPD to slightly drop when the crucial data percentage rises, as seen in Figure 4.5(e). Additionally, because of the direct-to-sink technique, when crucial data reaches 100%, CPD for QPR drops to about 0% of the control packet per data packet. Additionally, changes in the proportion of important data were unaffected by MPRR and AODV.

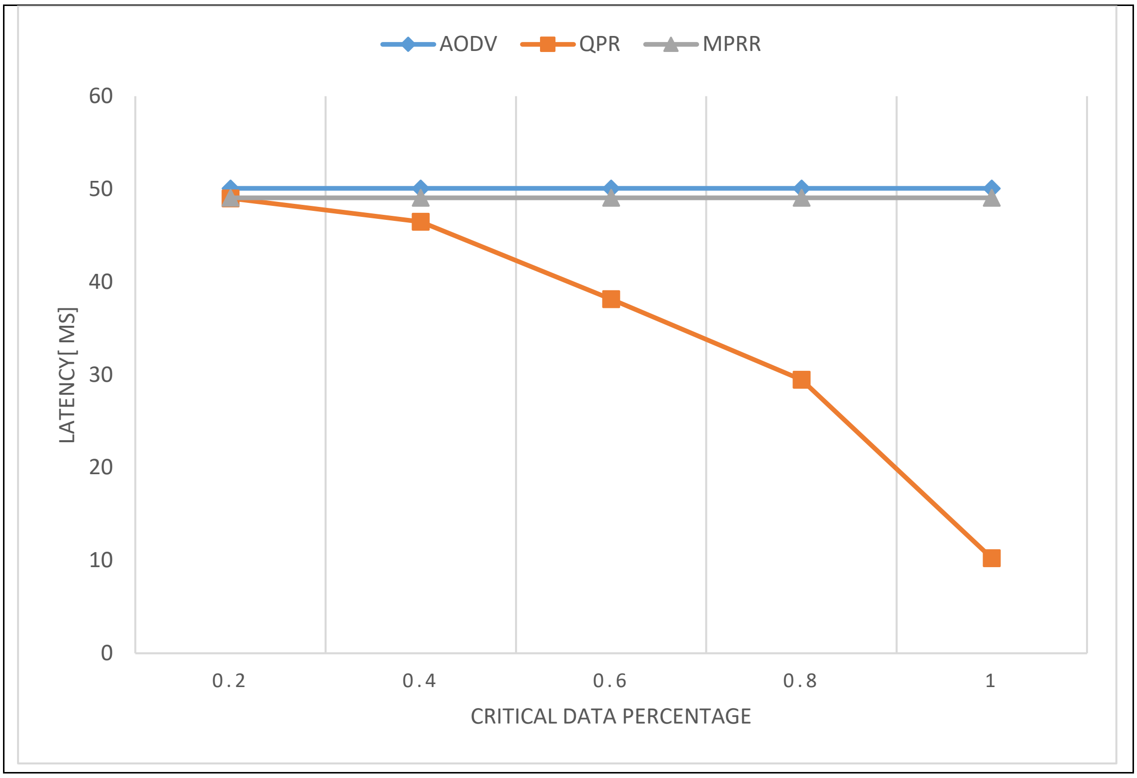


(a)Packet Delivery Fraction (PDF).

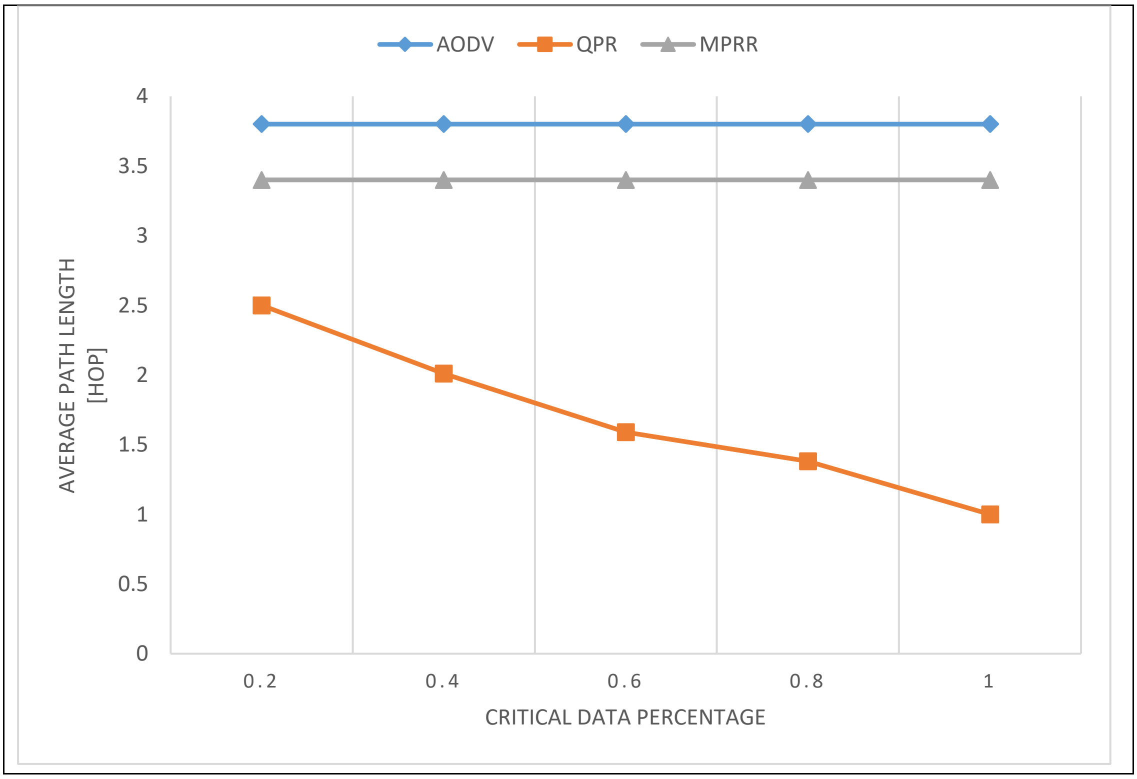


(b)Avg Energy Consumption (AEC).

Fig 4.5: Critical Data Percentage Effect.

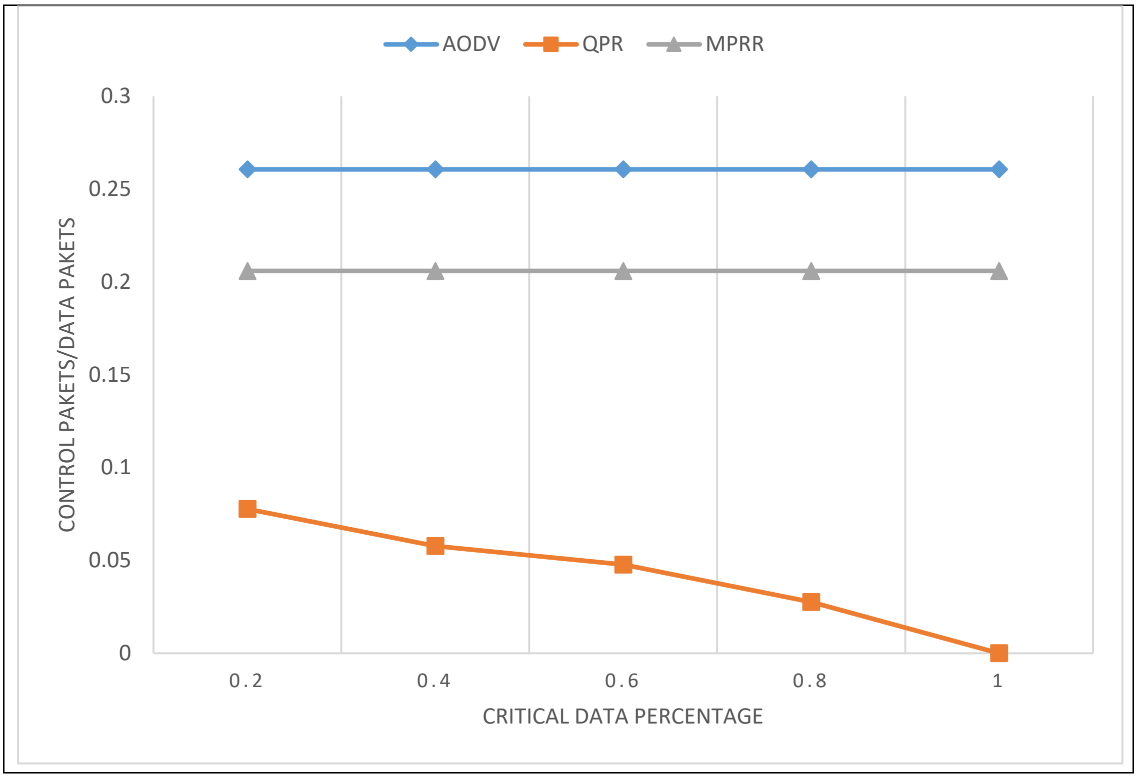


(c)Avg Route Latency (ARL).



(d)Average Path Length (APL).

Fig 4.5: Critical Data Percentage Effect.



(e)Control Packets per Data (CPD).

Fig 4.5: Critical Data Percentage Effect.

4.4.4 Result Summary and Discussion

The outcomes found demonstrate:

• In most cases, the PDF acquired using the QPR procedure is greater than 95%. The influence of the node count demonstrates that as the node count rises, the PDF computed using either approach marginally increases. With several nodes, the PDF generated with QPR is more than 97%. This shows that QPR is far more efficient than MPRR and AODV at finding and maintaining routes for the delivery of data packets. The least amount of packets are delivered via AODV. With a reasonably high node mobility, node mobility percentage indicates that the PDF acquired using the QPR technique is around 93%. In the case of 0% mobility (i.e., all nodes are static), the highest PDF for QPR is 97%, MPRR is 68%, and AODV is 53%, but it decreases as mobility rises. This is because longer pathways take more time and have a larger chance of losing the link connection owing to node movement, which causes some packets to be dropped. The last variable is the percentage influence of key data. The PDF produced with AODV and MPRR remains constant as the crucial data percentage rises. Due to the fact that the routing system does not prioritize data according to these standards. As the crucial data percentage rises, either QPR procedure marginally increases. The PDF generated using QPR has a high proportion of important data and is above 98%. The PDF, however, reaches 100% when every packet is crucial and transmitted using a direct-to-sink approach.

• QPR has minimum Energy consumption compared with AODV and MPRR. The effect of the increasing number of nods increases the energy consumption for the three protocols due to long paths. However, QPR uses the least amount of energy since, as the number of nods increases, it does not broadcast the packet to the entire region. Additionally, AODV consumes more energy than MPRR. This is due to two factors. The first is that AODV processes packets more quickly, increasing the likelihood of a connection break and the need to start a new route. Second, an intermediate node in AODV will instantly send an RREP to the source if it has a path to the destination. After researching how node mobility affects energy consumption, it was discovered that for all three protocols, node mobility rises. This is due to the likelihood of losing the link connection and reinitiating rising with increased mobility. Even yet, QPR uses less energy than AODV and MPRR do. Even as the vital data percentage rises, energy usage for the AODV and MPRR remains constant. These protocols have no impact on the routing system since they do not provide data precedence. However, QPR uses the least amount of energy since, in the event of an increasingly crucial data percentage; QPR does not broadcast the packet to the entire region. Additionally, QPR is the one impacted by the change in essential data percentage; as this percentage rises, so does QPR's direct-to-sink energy usage.

• QPR is less latency-intensive than other protocols. Nearly 45% of QPR, 47% of MPRR, and 49% of AODV make up ARL. The direct-to-sink process is the reason. All protocols have an increase in latency as the number of nodes grows because of the lengthy links. The ARL of QPR is also about 46%, although AODV is about 52% and MPRR is about 49%. This is a result of the data-only minimum QPR control packet. Due to the increased likelihood of losing the link connection and restarting, latency increases for all protocols as node mobility increases. In the essential data percentage under 50%, QPR has 40% of ARL. The ARL, however, declined exponentially until it reached 10% when all data was crucial, or when the critical data proportion was over 50%. In this way, the delay is around 5% due to the direct-to-sink techniques. As a result, QPR has less latency than other protocols, some of which have a fixed percentage of delay in every scenario. When the fraction of crucial data rises, QPR latency decreases until it reaches about 5 ms, at which point all data is considered critical and is sent immediately to the sink node.

• MPRR is just as effective as AODV in finding the shortest pathways. Every protocol experiences an increase in APL as the number of nodes rises. Additionally, despite the node mobility percentage, MPRR is just as effective as AODV in finding the shortest pathways. When the node mobility percentage is increased, APL rises for all protocols. Furthermore, as predicted, QPR's straight-to-sink approach results in a lower APL than other protocols. However, changes in key data percentage have no impact on MPRR and AODV. The chart also shows that when the crucial data percentage rises over 50% exponentially, APL for the QPR protocol falls from 3 hops to 1 hop because more data is sent directly to the sink in one hop. Additionally, with the direct-to-sink technique, APL for QPR only requires one-step to reach the sink after essential data has reached 100%.

• Due to an increase of data or control packets in all protocols, CPD gradually rises as the number of nodes grows. However, QPR has the lowest CPD because, as the number of nodes increases, it does not broadcast the packet to the whole region. Additionally, AODV and MPRR have different CPDs. Additionally, CPD rises as the node mobility percentage rises since all protocols have lengthy routes for both data and control packets. However, QPR has the lowest CPD because, as the number of nodes increases, it does not broadcast the packet to the whole region. However, because of the direct-to-sink method in the QPR protocol, CPD marginally declines as the essential data percentage rises. Additionally, because of the direct-to-sink technique, when crucial data reaches 100%, CPD for QPR drops to about 0% of the control packet per data packet. Additionally, changes in the proportion of important data were unaffected by MPRR and AODV.

In Table 4.5, we summarized the percentage difference between QPR and AODV. In addition, between QPR with MPRR. We calculate the percentage difference depending on this formula Percentage difference = 100 * |a - b| / ((a + b) / 2).

Table 4.5 Percentage Difference between Protocols.

Parameters	Number of nodes		Node mobility percentage		Critical data percentage	
Metrics/Protocols	AODV	MPRR	AODV	MPRR	AODV	MPRR
Reliability (PDF)	35%	5%	69%	43%	58%	9%
Latency (ARL)	4%	2%	9%	6%	44%	42%

4.5 Chapter Summary

Using the OMNeT++/Castalia-3.2 simulator, this chapter simulated the proposed protocol (QPR) with various networking situations (mobility percentage, node number, and essential data percentage) and compared it to the AODV and MPRR routing protocols. The average path length, packet delivery percentage, average route delay, control packets per data and average energy consumption are used to calculate the routing performance. The earlier section provides examples of the outcomes.

Chapter 5: Conclusion and Future Work

5.1 Overview

The outcome of our work on the thesis in Section 5.2 was summarized in this chapter. We completed our work on the thesis in Section 5.3. Section 5.4 identifies areas that might use more research.

5.2 Results

Summary of the outcomes obtained:

• In most cases, the PDF acquired using the QPR procedure is greater than 95%. This demonstrates that QPR is very good in finding and maintaining routes for data packet delivery even when there are many nodes, many nodes, or many vital data.

• All experiments' minimum APL is QPR. Additionally, APL dramatically declines when the proportion of crucial nodes rises because, in the case of critical nodes, the direct-to-sink technique is used to route packets instead of broadcasting them to the entire region.

• In every trial, CPD is the lowest value of QPR. Additionally, when the fraction of important data increases, CPD significantly decreases since critical data are only transmitted via the direct-to-sink approach rather than broadcasting to the entire area.

• Of all the trials, QPR had the least delay. Additionally, since the direct-to-sink strategy is employed rather than broadcasting packets to the entire region, latency is significantly reduced as the number of key nodes rises.

• In the majority of trials, QPR consumes the least energy. However, when the number of important nodes rises, energy consumption rises noticeably because of the direct-to-sink method that forwards packets by boosting power transmission.

• In the case of an increase in the percentage of critical data, there is no change in the values of PDF, Energy, CPD, APL, and Latency for the AODV and MPRR protocols. Due to the fact that these protocols do not consider priority.

• When the node and more are movable in AODV and MPRR, the impact change is almost nonexistent.

5.3 Conclusion

The requirement for an effective, quick, and reliable routing system that takes into account key data and human movement is a crucial problem given the rapidly expanding use of WBAN. The majority of WBAN routing methods in use today presume that patients remain stationary and do not consider patient movement. Other studies disregard the importance of data in favor of the patients' mobility. Additionally, some took into account the mobility and importance of the data when assuming a certain movement.

Our protocol, QPR, offers a way to be dependable and minimize latency while considering node mobility. QPR introduces a number of elements, including mobility criteria and a classification priority of data method. Additionally, it resolves the connection failure with emerging scenarios and the end-to-end latency issue. The new model's performance has been examined, and it has been contrasted with the AODV and MPRR protocols, using the OMNeT++/Castalia emulator. The new suggested protocol, QPR, is very effective when taking into account high node mobility, a big number of nodes, and a substantial percentage of vital data transferred between these nodes, according to simulation findings. Additionally, in all trials, QPR had the lowest Latency.

In the natural condition of low node mobility or low crucial data percentage, QPR performs better than AODV and MPRR in terms of PDF and CPD. Additionally, the Energy for QPR is raised higher in the event of raising the important data percentage than in all other situations, which indicates that data packets follow the direct-to-sink method. Using QPR, the data is divided into critical and normal categories. To reduce latency at this level, the first option is to use a static node with a direct to-sink method when the data is important. The second scenario is when a dynamic node is employing a multipath routing protocol to ensure that vital data reaches the sink up to a connection loss, increasing data dependability.

According to simulation data, the QPR protocol outperforms AODV in terms of dependability by around 54% and latency by about 19%. In addition, given significant node mobility, a large number of nodes, and a high percentage of essential data exchanged between these nodes, increases reliability by around 19% and latency by about 17% when compared with MPRR.

5.4 Future Works

We are now researching the use of our protocol in actual implementation as a continuation of our work. By using our protocol on inter WBANs as well as intra WBANs in our study; we want to increase the adaptability and dependability of our system. Besides researching additional QoS criteria like privacy and security.

REFERENCES

[1] Sanyal, D. K., Kar, U. N., & Roy, M. (2020, February 18). Mobile Communications and Computing: A Broad Review with a Focus on Smart Healthcare | SpringerLink. Mobile Communications and Computing: A Broad Review with a Focus on Smart Healthcare | SpringerLink. https://link.springer.com/chapter/10.1007/978-3-030-37551-5_2.

[2] ShariatmadariSerkani, M. (2018, November 1). A Reliable Routing Algorithm for Delay Sensitive Data in Body Area Networks. Retrieved September 19, 2022, from https://jacet.srbiau.ac.ir/article_13268.html

[3] Banda, L., Sahana, S., Singh, K., & Kumar Singh, B. (2021, November). Optimizing quality of service for sensor enabled Internet of healthcare systems. Neuroscience Informatics, 1(3), 100010. https://doi.org/10.1016/j.neuri.2021.100010

[4] Qu, Y., Zheng, G., Ma, H., Wang, X., Ji, B., & Wu, H. (2019, April 5). Sensors | Free Full-Text | A Survey of Routing Protocols in WBAN for Healthcare Applications. MDPI. https://www.mdpi.com/1424-8220/19/7/1638

[5] Sharma, S., Tripathi, M. M., & Mishra, V. M. (n.d.). Comparative Analysis of Routing Protocols in Wireless Body Area Network (WBAN) | 2nd International Conference on Innovative Practices in Technology and Management, ICIPTM 2022: 703-706, 2022. | Scopus. Retrieved September 19, 2022, from https://search.bvsalud.org/global-literature-on-novel-coronavirus-2019-ncov/resource/en/covidwho-1846111

[6] Jalili Marandi, S., Golsorkhtabaramiri, M., Hosseinzadeh, M., & Jafarali Jassbi, S. (2022). IoT based thermal aware routing protocols in wireless body area networks: Survey: IoT based thermal aware routing in WBAN. IET Communications, 16(15), 1753–1771. https://doi.org/10.1049/cmu2.12438

[7] Arefin, M. T., Ali, M. H., M. Fazlul Haque, A. K., & Publishing, S. R. (2017, May 9). Wireless Body Area Network: An Overview and Various Applications. Wireless Body Area Network: An Overview and Various Applications.

[8] Awan, K., Qureshi, K. N., & Mehwish, M. (2016, December 18). Wireless Body Area Networks Routing Protocols: A Review. Indonesian Journal of Electrical Engineering and Computer Science, 4(3), 594. https://doi.org/10.11591/ijeecs.v4.i3.pp594-604

[9] Sevin, A., Bayilmis, C., & Kirbas, I. (2016, November). Design and implementation of a new quality of service-aware cross-layer medium access protocol for wireless body area networks. Computers &Amp; Electrical Engineering, 56, 145–156. https://doi.org/10.1016/j.compeleceng.2016.02.003

[10] Rodrigues, V. F., Righi, R. D. R., da Costa, C. A., & Antunes, R. S. (2022, July 4). Smart Hospitals and IoT Sensors: Why Is QoS Essential Here? Journal of Sensor and Actuator Networks, 11(3), 33. https://doi.org/10.3390/jsan11030033

[11] Ullah, F., Khan, M. Z., Mehmood, G., Qureshi, M. S., & Fayaz, M. (2022, January 17). Energy Efficiency and Reliability Considerations in Wireless Body Area Networks: A Survey. Computational and Mathematical Methods in Medicine, 2022, 1–15. https://doi.org/10.1155/2022/1090131

[12] Karmakar, K., Biswas, S., & Neogy, S. (2017, March). MHRP: A novel mobility handling routing protocol in Wireless Body Area Network. 2017 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET). https://doi.org/10.1109/wispnet.2017.8300099

[13] Said, O. (2022, May). Design and performance evaluation of QoE/QoS-oriented scheme for reliable data transmission in Internet of Things environments. Computer Communications, 189, 158–174. https://doi.org/10.1016/j.comcom.2022.03.020

[14] Agnihotri, R. B., Pandey, N., & Verma, S. (2017, October 4). Preservation of QoS and Energy Consumption-Based Performance Metrics Routing Protocols in Wireless Sensor Networks. Quality, IT and Business Operations, 313–321. https://doi.org/10.1007/978-981-10-5577-5_25

[15] Sofi, A., Jane Regita, J., Rane, B., & Lau, H. H. (2022, January). Structural health monitoring using wireless smart sensor network – An overview. Mechanical Systems and Signal Processing, 163, 108113. https://doi.org/10.1016/j.ymssp.2021.108113

[16] Hajar, M. S., Al-Kadri, M. O., & Kalutarage, H. K. (2021, May). A survey on wireless body area networks: architecture, security challenges and research opportunities. Computers &Amp; Security, 104, 102211. https://doi.org/10.1016/j.cose.2021.102211

[17] Singh, S., & Prasad, D. (2022). Wireless body area network (WBAN): A review of schemes and protocols. Materials Today: Proceedings, 49, 3488–3496. https://doi.org/10.1016/j.matpr.2021.05.564

[18] Abidi, B., Jilbab, A., & Mohamed, E. H. (2020, March 19). Wireless body area networks: a comprehensive survey. Journal of Medical Engineering &Amp; Technology, 44(3), 97–107. https://doi.org/10.1080/03091902.2020.1729882

[19] Jose, J. M. (2020, August 7). Multi-Biosensor based Wireless Body Area Networks (WBAN) for Critical Health Monitoring of Patients in Mental Health Care Centers: An Interdisciplinary Study. Retrieved September 20, 2022, from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3675030

[20] El-Rashidy, N., El-Sappagh, S., Islam, S. M. R., M. El-Bakry, H., & Abdelrazek, S. (2021, March 29). Mobile Health in Remote Patient Monitoring for Chronic Diseases: Principles, Trends, and Challenges. Diagnostics, 11(4), 607. https://doi.org/10.3390/diagnostics11040607

[21] Taleb, H., Nasser, A., Andrieux, G., Charara, N., & Motta Cruz, E. (2021, September 21). Wireless technologies, medical applications and future challenges in WBAN: a survey. Wireless Networks, 27(8), 5271–5295. https://doi.org/10.1007/s11276-021-02780-2

[22] RecFaces. (2022, January 18). What Is Biometric Security and Why Does It Matter Today? Retrieved September 20, 2022, from https://recfaces.com/articles/biometric-security

[23] Thilakarathne, N. N., Kagita, M. K., & Gadekallu, D. T. R. (2020, August 31). The Role of the Internet of Things in Health Care: A Systematic and Comprehensive Study. International Journal of Engineering and Management Research, 10(4), 145–159. https://doi.org/10.31033/ijemr.10.4.22

[24] Singh, S., Prasad, D., Rani, S., Singh, A., Alharithi, F. S., & Almotiri, J. (2022, June 2). Wireless Body Area Routing Protocols Impact Analysis on Entity Mobility Models with Static Sink Node. Applied Sciences, 12(11), 5655. https://doi.org/10.3390/app12115655

[25] Kaur, R., Pasricha, R., & Kaur, B. (2020, April 27). A Study of Wireless Body Area Networks and its Routing Protocols for Healthcare Environment. Recent Advances in Electrical &Amp; Electronic Engineering (Formerly Recent Patents on Electrical &Amp; Electronic Engineering), 13(2), 136–152. https://doi.org/10.2174/2352096512666190305152857

[26] Zhong, L., He, S., Lin, J., Wu, J., Li, X., Pang, Y., & Li, Z. (2022, May 6). Technological Requirements and Challenges in Wireless Body Area Networks for Health Monitoring: A Comprehensive Survey. Sensors, 22(9), 3539. https://doi.org/10.3390/s22093539

[27] Olatinwo, Abu-Mahfouz, & Hancke. (2019, November 29). A Survey on LPWAN Technologies in WBAN for Remote Health-Care Monitoring. Sensors, 19(23), 5268. https://doi.org/10.3390/s19235268

[28] Marques, D., Senna, C., & Luís, M. (2022, February 13). Forwarding in Energy-Constrained Wireless Information Centric Networks. Sensors, 22(4), 1438. https://doi.org/10.3390/s22041438

[29] Effect on Packet Delivery Ratio (PDR) & Throughput in Wireless Sensor Networks Due to Black Hole Attack. (2019, December 26). International Journal of Innovative Technology and Exploring Engineering, 8(12S), 428–432. https://doi.org/10.35940/ijitee.l1107.10812s19

[30] Arestova, A., Baron, W., Hielscher, K. S. J., & German, R. (2022). ITANS: Incremental Task and Network Scheduling for Time-Sensitive Networks. IEEE Open Journal of Intelligent Transportation Systems, 3, 369–387. https://doi.org/10.1109/ojits.2022.3171072

[31] Raja Basha, A. (2020, August). Energy efficient aggregation technique-based realisable secure aware routing protocol for wireless sensor network. IET Wireless Sensor Systems, 10(4), 166–174. https://doi.org/10.1049/iet-wss.2019.0178

[32] Ayadi, H., Zouinkhi, A., Val, T., van den Bossche, A., & Abdelkrim, M. N. (2018, August 1). Network Lifetime Management in Wireless Sensor Networks. IEEE Sensors Journal, 18(15), 6438–6445. https://doi.org/10.1109/jsen.2018.2840830

[33] Mkongwa, K. G., Liu, Q., & Zhang, C. (2019). Link Reliability and Performance Optimization in Wireless Body Area Networks. IEEE Access, 7, 155392–155404. https://doi.org/10.1109/access.2019.2944573

[34] Kim, B. (n.d.). A Survey on Mobility Support in Wireless Body Area Networks. MDPI. Retrieved September 20, 2022, from https://www.mdpi.com/1424-8220/17/4/797

[35] Bhanumathi, V. (2017, August 10). A guide for the selection of routing protocols in WBAN for healthcare applications - Human-centric Computing and Information Sciences. SpringerOpen. Retrieved September 20, 2022, from https://hcis-journal.springeropen.com/articles/10.1186/s13673-017-0105-6

[36] Banuselvasaraswathy, B., & Rathinasabapathy, V. (2020, March 14). Self-heat controlling energy efficient OPOT routing protocol for WBAN. Wireless Networks, 26(5), 3781–3792. https://doi.org/10.1007/s11276-020-02303-5

[37] Jamil, F., Iqbal, M. A., Amin, R., & Kim, D. (2019, January 1). Adaptive Thermal-Aware Routing Protocol for Wireless Body Area Network. Electronics, 8(1), 47. https://doi.org/10.3390/electronics8010047

[38] Bouldjadj, S., & Aliouat, Z. (2020, February 29). High Throughput and Thermal Aware Routing Protocol (HTTRP) for Wireless Body Area Networks. Ingénierie Des Systèmes D Information, 25(1), 41–48. https://doi.org/10.18280/isi.250106

[39] Hosen, A., & Cho, G. (2018, May 11). An Energy Centric Cluster-Based Routing Protocol for Wireless Sensor Networks. Sensors, 18(5), 1520. https://doi.org/10.3390/s18051520

[40] Jemili, I., Ghrab, D., Belghith, A., & Mosbah, M. (2020, December). Cross-layer adaptive multipath routing for multimedia Wireless Sensor Networks under duty cycle mode. Ad Hoc Networks, 109, 102292. https://doi.org/10.1016/j.adhoc.2020.102292

[41] Yessad, N., Omar, M., Tari, A., & Bouabdallah, A. (2017, September 1). QoS-based routing in Wireless Body Area Networks: a survey and taxonomy. Computing, 100(3), 245–275. https://doi.org/10.1007/s00607-017-0575-4

[42] Ibrahim, A. A., Bayat, O., Ucan, O. N., & Salisu, S. (2020, February). Weighted Energy and QoS based Multi-hop Transmission Routing Algorithm for WBAN. 2020 6th International Engineering Conference "Sustainable Technology and Development" (IEC). https://doi.org/10.1109/iec49899.2020.9122909

[43] Mu, J., Yi, X., Liu, X., & Han, L. (2019). An Efficient and Reliable Directed Diffusion Routing Protocol in Wireless Body Area Networks. IEEE Access, 7, 58883–58892. https://doi.org/10.1109/access.2019.2914241

[44] Kumar M., A., & Raj C., V. (2017, September). On designing lightweight qos routing protocol for delay-sensitive wireless body area networks. 2017 International Conference on Advances in Computing, Communications and Informatics (ICACCI). https://doi.org/10.1109/icacci.2017.8125930

[45] Vetale, S., & Vidhate, A. V. (2017, December). Hybrid data-centric routing protocol of wireless body area network. 2017 International Conference on Advances in Computing, Communication and Control (ICAC3). https://doi.org/10.1109/icac3.2017.8318793

[46] Waheed, T., Aqeel-ur-Rehman, Karim, F., & Ghani, S. (2020, June 23). QoS Enhancement of AODV Routing for MBANs. Wireless Personal Communications, 116(2), 1379–1406. https://doi.org/10.1007/s11277-020-07558-x

[47] Zhang, F., & Yang, G. (2020, November 25). A Stable Backup Routing Protocol for Wireless Ad Hoc Networks. Sensors, 20(23), 6743. https://doi.org/10.3390/s20236743

[48] Abdullah, W. A. N. W., Yaakob, N., Ahmad, R. B., Elobaid, M. E., & Yah, S. A. (2019, February 1). Impact of clustering in AODV routing protocol for wireless body area network in remote health monitoring system. Indonesian Journal of Electrical Engineering and Computer Science, 13(2), 689. https://doi.org/10.11591/ijeecs.v13.i2.pp689-695

[49] RFC 3561: Ad hoc On-Demand Distance Vector (AODV) Routing. (2003, July 7). IETF Datatracker. Retrieved September 20, 2022, from https://datatracker.ietf.org/doc/rfc3561/

[50] Chavan, C. P., & Venkataram, P. (2022, July). Design and implementation of event-based multicast AODV routing protocol for ubiquitous network. Array, 14, 100129. https://doi.org/10.1016/j.array.2022.100129

[51] Biradar, A., & Thool, R. C. (2014, January). Reliable genetic algorithm based intelligent routing for MANET. 2014 World Congress on Computer Applications and Information Systems (WCCAIS). https://doi.org/10.1109/wccais.2014.6916649

[52] Benaddy, M., Habil, B. E., Ouali, M. E., Meslouhi, O. E., & Krit, S. (2017, May). A mutlipath routing algorithm for wireless sensor networks under distance and energy consumption constraints for reliable data transmission. 2017 International Conference on Engineering &Amp; MIS (ICEMIS). https://doi.org/10.1109/icemis.2017.8273076

[53] Pandya, A. (2012, November 27). Performance Evaluation of Multipath Ring Routing Protocol for Wireless Sensor Network. Retrieved September 20, 2022, from http://journals.theired.org/journals/paper/details/504.html

[54] He, P., Li, X., Yan, L., Yang, S., & Zhang, B. (2015, May). Performance analysis of wban based on aodv and dsdv routing protocols. 2015 2nd International Symposium on Future

Information and Communication Technologies for Ubiquitous HealthCare (Ubi-HealthTech). https://doi.org/10.1109/ubi-healthtech.2015.7203326

[55] Alharbi, S., Hu, S., Mulvaney, D., Barrett, L., Yan, L., Blanos, P., Elsahar, Y., & Adema, S. (2018, December 31). Oxygen Saturation Measurements from Green and Orange Illuminations of Multi-Wavelength Optoelectronic Patch Sensors. Sensors, 19(1), 118. https://doi.org/10.3390/s19010118

[56] draft-ietf-manet-aodv-04. (n.d.). Retrieved September 20, 2022, from https://datatracker.ietf.org/doc/html/draft-ietf-manet-aodv-04

[57] Mohammed, I. Y. (2019). [PDF] Comparative analysis of proactive & reactive protocols for cluster based routing algorithms in WSNs | Semantic Scholar. Retrieved September 20, 2022, from https://www.semanticscholar.org/paper/Comparative-analysis-of-proactive-%26-reactive-for-in-Mohammed/8bc4a2703bdc7efc2487fe2e25492212cb473080

[58] Madell, R. (2021, November 17). Blood Pressure Readings Explained. Healthline. Retrieved September 20, 2022, from https://www.healthline.com/health/high-blood-pressure-hypertension/blood-pressure-reading-explained

[59] Singh, M., & Kumar, S. (2017, March 15). A Survey: Ad-hoc on Demand Distance Vector (AODV) Protocol. International Journal of Computer Applications, 161(1), 38–44. https://doi.org/10.5120/ijca2017913109

[60] Huang, G. M., Tao, W. J., Liu, P. S., & Liu, S. Y. (2013, August). Multipath Ring Routing in Wireless Sensor Networks. Applied Mechanics and Materials, 347–350, 701–705. https://doi.org/10.4028/www.scientific.net/amm.347-350.701

[61] Nayyar, A. (2015). A Comprehensive Review of Simulation Tools for Wireless Sensor Networks (WSNs) | Semantic Scholar. Retrieved September 21, 2022, from https://semanticscholar.org/paper/A-Comprehensive-Review-of-Simulation-Tools-for-Nayyar-Singh/9f4fd2f6c446088fac5ce73e3fa0b327a64803b3

[62] Chaudhary, H., & Kumar, V. (2021, December 17). Performance Analysis of LEACH-C and EAMMH protocols in WSN in MATLAB. 2021 3rd International Conference on Advances in Computing, Communication Control and Networking (ICAC3N). https://doi.org/10.1109/icac3n53548.2021.9725400

[63] Bakni, M., Moreno Chacón, L. M., Cardinale, Y., Terrasson, G., & Curea, O. (2019, December 31). WSN Simulators Evaluation: an Approach Focusing on Energy Awareness. International Journal of Wireless &Amp; Mobile Networks, 11(6), 1–20. https://doi.org/10.5121/ijwmn.2019.11601

[64] Varga, A. (n.d.). OMNeT++ - Simulation Manual. OpenSim Ltd. Retrieved September 21, 2022, from https://doc.omnetpp.org/omnetpp/manual/

[65] Castalia - User Manual. (n.d.). UserManual.wiki. Retrieved September 21, 2022, from https://usermanual.wiki/Document/Castalia2020User20Manual.858946124/html

[66] Sharma, R., Singh Ryait, H., & Kumar Gupta, A. (2016, October 27). Analysing the Effect of Posture Mobility and Sink Node Placement on the Performance of Routing Protocols in WBAN. Indian Journal of Science and Technology, 9(40). https://doi.org/10.17485/ijst/2016/v9i40/90182

[67] John, O. T. (2016). Energy Consumption in Wireless Sensor Network | Ogbiti | Computer Engineering and Intelligent Systems. Retrieved September 21, 2022, from https://iiste.org/Journals/index.php/CEIS/article/view/32780

الملخص

تكتسب شبكات منطقة الجسم اللاسلكية شعبية كبيرة، حيث يعد التشخيص في الوقت الفعلي والعلاج الإلكتروني للمرضى عنصرين رئيسيين يقودان مجال الرعاية الصحية. بالإضافة إلى التقنيات الرقمية المتضمنة في هذا التشخيص، مثل إنترنت الأشياء. ظهرت أهمية هذه الشبكة خلال جائحة كوفيد-١٩، حيث يمكن علاج المرضى عن بعد عندما يكون خطر انتشار العدوى مرتفعًا. إلى جانب التطبيقات "التقليدية" مثل التدريب العسكري والرياضي. يتم استخدامها بشكل متزايد في التطبيقات اليومية لجعل حياة المرضى ومقدمي الرعاية الصحية سهلة وآمنة ومريحة. لا يزال التوجيه في شبكات منطقة الجسم اللاسلكية يمثل مشكلة رئيسية لأنه بدون بروتوكولات التوجيه التي تعمل بشكل صحيح، لن تعمل الشبكة ببساطة بالطريقة التي تهدف إليها. لسوء الحظ، قد يكون التوجيه أيضًا أحد أصعب المجالات لحماية المرضى في المواقف الحرجة. ويرجع ذلك إلى الاحتمالية الكبيرة للتأخير وفشل الارتباط، نظرًا لطبيعة حركة جسم الإنسان وبالتالي تغيير موقع أجزاء الشبكة. مع الانتشار الواسع لشبكات منطقة الجسم اللاسلكية، تبرز الحاجة إلى جودة خدمة بروتوكولات التوجيه الخاصة بهم كمسألة مهمة للغاية ليس من السهل معالجتها. تتعارض العديد من متطلبات جودة خدمة الشبكة مع متطلبات عقد التنقل في الشبكة بسبب طبيعة حركة الجسم (على سبيل المثال، انخفاض استهلاك الطاقة وحمل المعالجة المنخفض). إن مفهوم وهيكل شبكة منطقة الجسم اللاسلكية تجعلها عرضة بشكل كبير لفشل الشبكة باستخدام العديد من التقنيات التي تستهلك المزيد من الطاقة وتزيد من التأخير وتقلل من موثوقية البيانات. تظهر مشكلات جودة الخدمة المتعلقة بالتنقل في العديد من المجالات المختلفة، بما في ذلك التوجيه وأولوية البيانات. هذه القضايا حيوية في بعض التطبيقات. لذلك، فقد جذبت مؤخرًا انتباه العديد من الباحثين. ركز بحثنا على موثوقية ووقت استجابة الخدمات التي تقدمها العقد الثابتة أو المتنقلة. البروتوكول المقترح حديثًا هو بروتوكول توجيه لجودة الخدمة مختلط يحاول حفظ عرض النطاق الترددي للشبكة وذاكرة العقد في شبكات منطقة الجسم اللاسلكية من خلال تقديم تصنيف لأولوية البيانات وتنقل العقد. يقدم البروتوكول المقترح تصنيفًا لأولويات البيانات وتنقل العقدة، في محاولة لتحسين الأداء. يصنف البروتوكول نوع البيانات المحسوسة على أنها حرجة أو عادية. عندما تكون البيانات حرجة والعقد ثابتة، يتم إرسال البيانات مباشرة إلى الهدف لضمان زمن انتقال منخفض. بالإضافة إلى ذلك، يحاول تحسين موثوقية الشبكة من خلال استخدام استراتيجية متعددة المسارات عندما تكون البيانات حرجة والعقد متنقلة. تمت مقارنة أداء البروتوكول المقترح مع بروتوكولي توجيه حاليين آخرين: أولاً، اخترنا بروتوكول توجيه المسافة المتجه حسب الطلب، لأن الباحثين استخدموه كمعيار في أبحاثهم. ثانيًا، اخترنا بروتوكول توجيه الحلقات متعددة المسارات، لأنه بروتوكول جديد يوفر أداءً جيدًا بالإضافة إلى أن ملف تنفيذه متاح في جهاز المحاكاة الخاص بنا. تم إجراء هذه المقارنة باستخدام محاكي يدعى (كاستاليا) .أظهرت نتائج المحاكاة أن البروتوكول المقترح فعال للغاية بالنظر إلى أنواع مختلفة من البيانات، وحركة العقدة العالية، وعدد كبير من العقد، ونسبة كبيرة من البيانات الهامة المرسلة بين هذه العقد.