

# A Review on Recent Research on Enhancement of AODV Routing for Wireless Body Area Networks (WBANs)

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**Abstract-** Wireless body area networks (WBANs) are attracting considerable and widespread interest owing to their many uses in several applications. Within the next few years, WBANs are likely to become an important component in the medical field. Specifically, with the emergence of epidemic diseases such as COVID-19 and because of the important services it provides in the field of health care. WBANs need to provide a stringent quality of service when monitoring patients. This is critical because WBANs transmit critical data, and any data loss or transmission delay can pose a life-threatening threat to the patient. Researchers and experts have always seen that protocol choice greatly and directly impacts all QoS requirements in WBANs. The AODV protocol gives good performance despite the presence of significant limitations in wireless body networks. Because of the widespread development of the protocol by many researchers, it is necessary to discuss these new advancements serving wireless body networks in this review. This paper explains the advantages of AODV protocol for WBANs. It also discusses the protocol's current evolution in order to improve the performance of WBANs.

**Keywords-** wireless body area networks, energy efficiency, routing protocols, network lifetime, on-demand distance vector routing

## I. INTRODUCTION

WBANs have received much attention over the last two decades owing to their use in remote real-time patient monitoring. However, this is not particularly surprising given the recent spread of corona virus infection and the requirements for isolation and patient monitoring. The characteristics of wireless body networks enable it to be the best solution for monitoring patients in such situations [1]. WBANs are common and useful in the medical field. In addition to medical uses, WBAN shows great potential for entertainment, real-time streaming, lifestyle, and fitness [2].

IEEE 802.15.6 [3] has defined the WBANs "WBAN is a communication standard optimized for low power devices for their operation on, in or around the human body to serve a variety of applications including medical, consumer electronics or personal entertainment and other." Therefore, wireless body networks use small, lightweight, and low-power wearable sensors to monitor and lift people's health. In this case, the small size of the sensors provides flexibility and comfort for patient movement. However, at the same time, the small size and

low power pose a great challenge for this type of network [4]. A great deal of considerable attention must be paid to finding solutions to overcome these challenges. The development of WBANs has been a challenge for years because they have many limitations. In general, attention should be paid to reliability, power, and accurate data communication between nodes, especially when used in the medical field, because it transmits critical data. The previous points are significantly influenced by the choice of path to route data between nodes. Determining the best path to transfer information between the sensors and obtain it to the sink greatly affects the reliability and node energy [5]. See [6],[7],[8] for more information on this topic.

Several authors have proposed several protocols to overcome the problems faced by WBANs. At the same time, we can take advantage of the properties of the Mobile Ad Hoc Network (MANET) protocols, after modifying them, to work with WBANs. The results of many comparisons between MANET protocols show that the AODV protocol is best suited for developing and working with WBANs. Our findings confirm the findings of previous studies [9],[10]. The focus and primary goal of our study is to mention the latest developments in the AODV protocol with regard to WBANs only. As far as we know we believe that no other authors have found a review paper to develop AODV protocol only in the field of WBANs.

The remainder of this paper is organized as follows. Section 2 explains the architecture of WBANs. Section 3 describes the algorithm of the AODV protocol and why we choose this protocol for WBANs. Section 4 presents a review of recent research on the enhancement of AODV enhancement in WBANs. Outlined in the Section 5 trends in AODV research for WBANs Finally, conclusions are presented in Section 6.

### 1.1 APPLICATIONS OF WBAN

WBANs are undergoing a revolution in development and interest owing to their use in many domains. In other words, WBANs are increasingly being set as vital factors in the following areas [11]:

#### A. Medical filed

The medical application of WBANs is widely considered the most important use. For this reason, it is used in health care facilities and for monitoring chronic

diseases. It can be used to limit the spread of coronavirus disease. Real-time remote monitoring of infected patients Comprehensive patient physiological information can be collected, analyzed, and sent to doctors[12][13]. Therefore, future work should focus on enhancing the quality of WBANs in the medical field because of its great benefit in this field.

**B. Entertainment**

WBANs are used in sports to monitor the physiological information of athletes in sports to improve their sporting activities and physical fitness. The temperature, heart rate, and blood pressure were monitored. This information can be utilized to reduce sporting accidents, injuries and future training planning. In addition, WBANs can be used for real-time streaming [14].

**C. Military**

WBANs can protect soldiers from threats by monitoring the environment around them. Information is obtained from a set of sensors worn by soldiers, through which the commander can efficiently coordinate team tasks. In this case, the information in this application for WBANs needs high protection owing to the importance of this type of data [15].

**II. WBAN ARCHITECTURE**

The architecture of WBANs, as shown in Fig. 1 [16],[17], is divided into three layers. The first layer consists of collection sensor nodes (e.g., ECG and EEG) placed inside or on the human body. The level of energy consumption can be reduced by placing a node to collect information from all sensors, called sink nodes. These nodes send the patient's physiological data to the second layer. For further analysis, the second layer contains a coordinator. The coordinator sends information to the doctor or medical server in the third layer via Internet communication. The main problems in WBAN architecture are routing information and communication between sensor nodes. Many researchers give a reason for that because of the limited availability of energy and heterogeneity of nodes [18].As stated in the Introduction, the main target of AODV protocol is to find the best path within the first layer.

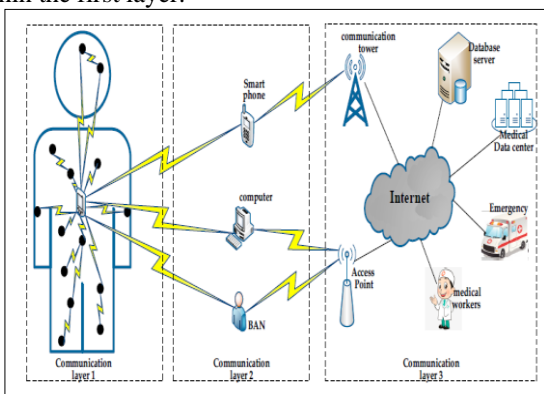


Figure 1. Architecture of WBAN[16]

**III. AODV PROTOCOL**

AODV denotes to Ad Hoc on Demand Distance Vector Routing Protocol. The AODV protocol is the most widely used and commonly discussed in research on MANET protocols. According to the authors in [19],[20],[21], they found that AODV protocol is best suited to work with WBANs compared to other MANET protocols when comparing the network performance basis on the end-to-end delay, packet loss rate, throughput, and energy consumption. Therefore, in this section, we provide a brief overview of the AODV routing protocol [22] and explain the algorithm of this protocol. In addition, we discuss the features and performance of the AODV protocol and whether it is suitable for working with WBANs with special requirements.

The basic principle of this protocol is to discover and establish routes between nodes on demand. The nodes maintain these paths and update them when required. Therefore, this point is important for WBANs because the number of nodes is small and limited; therefore, compared to WSN and MANET, it will require finding paths and identifying the nodes with less time and energy. AODV uses sequence numbers to refer to the guarantee and originality of the routes. The source node to explore a path to the destination advertises a broadcast route request (RREQ) packet depending on the constant time to live (TTL) value. RREQ packets are composed of the current sequence number, IP address of the node, broadcast ID, and latest destination node sequence number known to the source node. The destination node when receiving an RREQ sends a specific response message, which is a route reply (RREP) packet including the reverse route established at the mediator node in the route discovery phase [23][24]. This could potentially result in the connection breaking or invalid TTL values. Therefore, a route error packet (RERR) is sent to the destination and source nodes. The source nodes are still able to find new valid paths because of the use of sequence numbers. The authors of [25],[26],[27] provided a reason for the chosen AODV for the wireless network over many other protocols, such as DSDV, as it does not waste bandwidth, reliability, and less control overhead. It does not have to maintain the entire route, and only the next hop is maintained. A flowchart of the AODV protocol is shown in Fig. 2 [28].

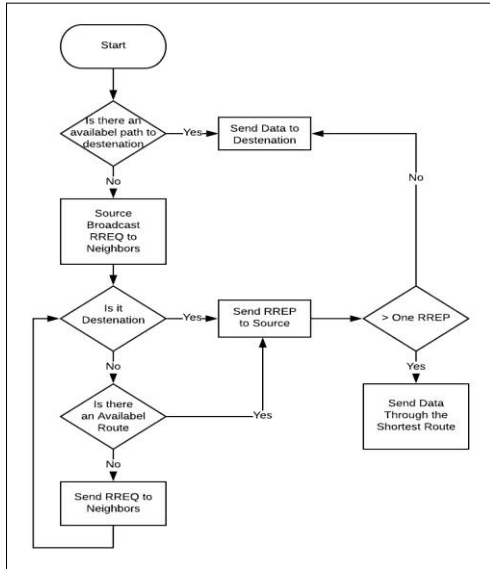


Figure 2. Flowchart of AODV [28].

#### IV. RELATED WORKS

Many researchers have contributed to the improvement and enhancement of the AODV protocol to satisfy the requirements of WBANs. Several authors proposal is to improve energy consumption, increasing throughput, reducing delay, PDR, and reliability. In this section, the enhancement of AODV in recent years for WBANs is presented and analyzed.

Raja et al. [29] identified that reliable and real-time transmission of patient data is essential for WBANs. Therefore, an updated version of the AODV protocol called Reliable AODV (RelAODV) to increase network reliability. To save power, RelAODV uses two modes for every node: direct mode (DM) and relay mode (RM). The transmission power is set to the highest level and a minimum hop count or just one hop is required in the direct mode. In the second mode, the power level is much lower, so the nodes will only be able to communicate with their neighboring nodes. The nodes can change between modes depending on the calculation of the signal-to-noise ratio (SNR) and the residual energy, as shown in equation (1) and equation (2), respectively, and the sensors can communicate only to nodes whose SNR is less than a threshold value. It also classifies the data into non-critical and critical data. It only transfers critical data to the sink node and non-critical data are stored in the database. Such protocols also minimize network traffic by minimizing pre-transmission data.

$$SNR(t) = SNR_{min} + ((\delta)(t, d) - p_s) \quad (1)$$

where,  $P_s$  represents the power sensitivity in dBm and  $\delta(t, d)$  represents the currently received power in dBm.

$$BP_{res}(t) = BP_i - BP_c(t) \quad (2)$$

$$BP_{res}(t) = BP_i - \sum_0^t (BP_{tx}(t) + BP_{rx} + BP_{idle}(t)) \quad (3)$$

Where  $BP_{res}(t)$  represent the residual battery power

$BP_i$  : Initial node energy

$BP_c$  : consumed node energy.

$BP_{tx}(t)$  : Data transmission consumes energy

$BP_{rx}$  : Data reception consumes energy

$BP_{idle}(t)$  : Nodes idle consume energy

Ambigavathi et al. [30] highlighted that the normal AODV protocol needs to prioritize data transmission to work efficiently with WBANs. This is because some patient monitoring data are critical and require end-to-end reliable transmission and a lower delivery delay. In this context, the authors suggested in [30] a new AODV routing priority queuing algorithm based on critical pertinent information. The classical AODV protocol uses the FIFO scheduling algorithm to send packets. Therefore, if any critical packet detects when mentoring a patient, it will wait in the queue for a long time. As expected, this delay is life-threatening or potentially fatal. Therefore, sensor nodes must deal with data based on their importance and priority. When a packet initially enters the queue, it scans the packets to determine whether it is life-threatening, urgent information, on-demand, and usual data. Thus, life-threatening or urgent information and all of that packet are placed in the L1 queue, as shown in Fig. 3. Likewise, usual information is placed in L2 and so on for all packets.

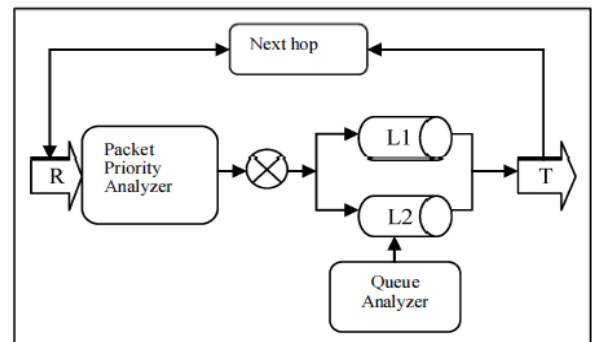


Figure 3. Priority queuing AODV sensor architecture [15]

Kumari et al. [31] focused on enhancing the reliability of the route discovery of the AODV protocol. A reliable energy-economical adaptation (REEA) protocol is introduced. The protocol methodology relies on three measurements: hop count, link quality, and residual energy. Link quality is measured by the received signal strength and the signal to noise quantitative relation. In addition, nodes with low residual energy were avoided. Routing is given priority according to the REEA method based on the highest residual energy with large link

quality and at least hop count or equivalent to the threshold.

Singla et al. [32] proposed a CSEER algorithm to modify the ReAODV protocol by using a cost function to enhance the security and increase the battery lifetime of the sensors. Suggest taking advantage of a cost function for next-hop selection, as shown in equation (4)

$$\text{cost function} = \frac{\text{Delay (i)}}{\text{Residual Energy (i)}} \quad (4)$$

where, Delay(i) and residual energy (i) are calculated using equations. (5) and (6), as follows:

$$\text{Delay (sn,dn)} = \frac{\text{Distance (sn,dn)}}{c} \quad (5)$$

where Distance (sn,dn) represents the distance between the source node (sn) and the destination node (dn) and C is the speed of light.

### Residual Energ = Initial Energ – Consume Energ

The node with the lowest cost was chosen as the next hop. In each round, the energy usage between the sensor nodes in the network is regulated. In addition, it improves the delay and throughput of the existing AODV protocols.

A new optimized routing protocol (AODV+GA) was proposed by Singh et al. [33] Exploiting and using a genetic algorithm to work with the AODV protocol. A genetic algorithm was used to optimize route errors in the WBAN. In addition, through the use of the fitness function, they were able to find the optimal and best path between a source node and the destination node. The fitness function is calculated by computing the distance between the sensor nodes, residual energy, and data rate of the sending data. In our view, these results represent an excellent initial step toward improving the sensor life time through the use of a genetic algorithm and fitness function with the AODV protocol.

Few researchers have addressed the energy problem of WBANs using optimization functions. K. Guru, et al. [34] proposed an Energy and Network Connectivity concerned Adhoc On-Demand Distance Vector Protocol (ENC-AODV) that solves the energy problem by using the objective function. This protocol focuses on the restricted resources of sensors and guarantees the efficient transmission of data. The sink node divides the network into clusters based on the traffic density, delay, energy, and distance. The cluster leader is chosen from a node with the maximum residual energy and minimum gateway distance. Equation (7) represents the objective function of the optimum cluster-leader choice.

$$J_m(U, V) = \sum_{j=1}^N \sum_{i=1}^C u_{ij}^m d^2(x_j, v_i) \quad (7)$$

Where, N indicates a number of nodes, C represent a number of clusters, coordinates of node j is represented as

$x_j$ , center coordinates of cluster i is given by  $v_i$  and Euclidean distance between  $x_j$  and  $v_i$  is represented as  $(x_j, v_i)$ .

None of the previous studies supported load balancing when selecting the route from the source to the destination. This is because a higher load results in increased power consumption rates. Q. Huang, et al. [35] has introduced a new AODV- LBEE (Load Balance and Energy Efficient) protocol for balance the traffic load. The amount of load assigned to each node must be proportional to its power. Therefore, the route is chosen according to cost. Any node that receives the RREQ packet calculates the cost value according to equation (8) and compares it with the last cost value if greater than holds the value unchanged.

$$\text{cost}_k = a \times \frac{T_k}{E_k} \quad (8)$$

where k indicates the ID of node, a is the constant coefficient,  $T_k$  is the traffic load of node k, and  $E_k$  is the residual energy of node.

Waheed et al. [36] proposed CARE-AODV to solve emergency data loss by improving the reliability of WBANs for remote patient monitoring. The theory is based on cross-layered, so routing selection is based on channel conditions and link quality. The cost function is added to the standard AODV protocol. It is assumed that there are two states in the network if the network is normal, the standard AODV protocol is used, and if the network transmits critical data, the CARE-AODV

protocol is used. The CARE-AODV protocol imposes on each node to calculate the accumulated cost when sending the RREQ and RREP packets using equation (9) and equation (10), respectively:

$$\text{cost} = \alpha(\text{Hop Count}) + \beta(\text{ETX}) + \gamma(\text{SNR}) \quad (9)$$

$$\text{Total cost path} = \prod_{i=1 \text{ to } n} (\text{cost}) \quad (10)$$

where hop count represents the number of hops in the path between the source and destination. The (expected transmission count (ETX) is described as the average number of MAC layer transmissions required to successfully deliver a packet successfully over wireless. The SNR represents the signal-to-noise ratio. Therefore, CARE-AODV modifies the RREQ and RREP of the standard AODV, as shown in Figs. 4 and 5, respectively.

| Type | Reserved                    | Hop Count |
|------|-----------------------------|-----------|
|      | RREQ ID                     |           |
|      | Destination IP              |           |
|      | Destination Sequence Number |           |
|      | Source IP                   |           |
|      | Source Sequence Number      |           |
|      | TTL                         |           |
|      | Cost Value                  |           |

| Type                        | Reserved | Prefix | Hop Count |
|-----------------------------|----------|--------|-----------|
| RREQ ID                     |          |        |           |
| Destination IP              |          |        |           |
| Destination Sequence Number |          |        |           |
| Source IP                   |          |        |           |
| Source Sequence Number      |          |        |           |
| TTL                         |          |        |           |
| Accumulated Cost Value      |          |        |           |

Figure 5. CARE-AODV RREP packet [10].

Saini et al. [37] suggested that clustering AODV takes advantage of the idea of clustering in WBANs. The author believes that this solution will aid in improving the energy consumption, throughput, and packet delivery ratio in WBANs. This protocol appears to indicate the selection of the node with the highest residual energy to act as the Cluster Head (CH). This node then broadcasts an announcement packet that works as a CH to organize the other nodes for joining it. Then, the group members send their data to the CH, and then it is sent through the CH to the sink node.

Table 1 lists details and the features of above literature review protocols. The summary highlights the objectives,

TABLE I. SUMMARY OF LITERATURE REVIEW

| Author/Date                   | Protocol  | Objectives  | Methodology  | Metric used   | Purpose            | Simulation         |
|-------------------------------|-----------|---|--|---|--------------------|--------------------|
| Raja et al. [13], 2015        | RelAODV   | Secure and Reliable Data Transmission                                   | To save power, RelAODV uses two modes for every node: direct mode (DM) and relay mode (RM). And use Nonce for Security and Authentication  | Signal-to-Noise Ratio (SNR) and residual energy                                       | Patient Monitoring | MATLAB simulator   |
| Ambigavathi et al. [15], 2015 | new AODV  | Reliable transmission and reduce delivery delay                         | Prioritize data transmission based on critical pertinent information   | Critical and Non-critical data  | Patient Monitoring | NS2 simulator      |
| Kumari et al. [17], 2017      | REEA      | Enhancing the reliability of the route discovery and energy consumption | Nodes with low residual energy were avoided. Routing is given priority based on the highest residual energy with large link quality and at least hop count or equivalent to the threshold. | Hop count, link quality, and residual energy  | Patient Monitoring | Castalia Simulator |
| Singla et al. [14], 2018      | CSEER     | Enhance the security and increase the battery lifetime of the sensors   | Use cost function for next-hop selection. The node with the lowest cost was chosen as the next hop   | Residual energy   | Patient Monitoring | MATLAB simulator   |
| Singh et al. [12], 2019       | AODV+GA   | Optimize route errors in the WBAN and increase the network life-time    | Use a genetic algorithm to work with the AODV protocol   | Distance between the sensor nodes, residual energy, and data rate of the sending data | Health-care        |                    |
| K. Guru, et al. [18], 2019    | ENC-AODV  | Reduce energy consumption   | Use clustering and objective function for optimum cluster-leader choice  | Traffic density, delay, energy, and distance  | Patient Monitoring | NS2 simulator      |
| Q. Huang, et al. [19], 2019   | AODV-LBEE | Load balancing  | The route is chosen according to cost function and the amount of load assigned to node proportional to its power   | Traffic load and residual energy  | Patient Monitoring | Castalia Simulator |

methodology, metric used, purpose and simulations tool of each protocols. However, most of these protocols work on a single metric to improve the AODV protocol. While the typical requirements of WBAN need to develop the protocol within more than one metrics to improve the performance. To further our research, we plan to take into account composite metrics to enhance the AODV protocol. Future work will concentrate on increase network lifetime by choosing the routing path to depend on many metrics.

## V. TRENDS IN AODV RESEARCH FOR WBANS

This section takes a look at the latest work being done by researchers on the AODV protocol for wireless body networks. Below is a list of what is currently focused on the AODV protocol in the field of wireless body networks. For more details on this topic can be found in [38][39][40].

- Performance analysis of WBAN based on AODV and DSDV routing protocols.
- AODV routing protocol for critical data.
- Energy efficient AODV protocol for healthcare applications.
- Clustering AODV Algorithm for WBANs.
- Secure AODV for WBANs.

|                          |                 |   |   |   |                    |                    |
|--------------------------|-----------------|---|---|---|--------------------|--------------------|
| Waheed et al. [10], 2020 | CARE-AODV       | Improving the reliability   | The protocol is based on cross-layered, so routing selection is based on channel conditions and link quality by added the cost function is to the standard AODV protocol. | Hop count, link condition, and RSSI   | Patient Monitoring | Castalia Simulator |
| Saini et al. [11], 2020  | clustering AODV | Improving the energy consumption, throughput, and packet delivery ratio | This protocol appears to indicate the selection of the node with the highest residual energy to act as the Cluster Head (CH).   | Energy consumption, throughput, end to end delay, and packet delivery ratio | Patient Monitoring | NS2 simulator      |

## VI. CONCLUSIONS

It is clear that the routing protocol significantly affects the performance of WBANs. Several researchers have proposed routing protocols for WBANs to improve QoS via routing algorithms. However, the AODV protocol has received more attention from researchers to develop it to work with WBANs. In this paper, we explain the mechanism of the AODV routing protocol and explain why this protocol is best suited to work with WBANs. In addition, we outline the applications and architecture of the WBANs. Finally, this paper highlights and reviews recent developments in the AODV protocol for WBANs. The conclusion is that Previous work has only focused on the work to improve the AODV protocol by developing a single metric. An additional weakness the path is chosen based on one criterion and neglecting other important criteria, and thus this affects the network performance in general. We hope are that our research will serve as a base for future studies on enhancing AODV protocol for WBANs. We suggest the future studies should target work on choosing the routing path based on more than one criteria.

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