Energy Aware Routing using AODV Protocol for Low Energy Consumption in WSN

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Abstract*: *Wireless Sensor Network (WSN) is a self-configured and infrastructure-less network that is used to monitor the environmental conditions and transfer sensor data to the desired destination in a particular region. Energy consumption is the most important concern in WSN, which is considered as an active research area. Routing selection is one method that is used to optimize energy in WSN. There are many protocols for discovering a route between two nodes. However the performance of the Ad hoc On-Demand Distance Vector Protocol (AODV) routing protocol is a more suitable one. It is a generic reactive protocol for routing mostly used in MANET (Mobile Ad Hoc Networks) and WSNs (Wireless Sensor Networks). This protocol supports unicasting and multicasting and will also identify the shortest path. The aim of this paper is discuses about energy-aware routing, is implemented in the AODV protocol which is derived from nodes remaining energy. The remaining energy of node is computed by Max-Min energy algorithm in order to extend the network's life span and facilitates to keep the network lively. The performance of AODV is compared with Modified AODV protocols. The comparison is done by various performance metrics such as PDR (Packet Delivery Ratio), throughput, delay time, loss rate, and energy consumption. Analysis on the experimental results showed that MAODV protocol gives better results than traditional AODV protocol and it is also inferred that MAODV avoids too much energy consumption of nodes in the network.

***Keywords*: AODV protocol, Modified AODV (MAODV), Energy Consumption, Max-min algorithm, Routing Mechanism, Wireless Sensor Network.**

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I. INTRODUCTION (*HEADING 1*)

WSN (Wireless Sensor Network) is an essential field for monitoring the remote environment and target tracking. It collects the information about a particular region and communicates wirelessly by using interconnected sensor nodes and the physical or environmental circumstances like sound, temperature, motion, vibration, pressure and so on. These sensed information will be transmitted to the destination through the wireless network. This network is widely used in distinct areas such as (Identical to) home surveillance, environmental surveillance, farming, health care, military, industrial, urban areas etc. These sensor nodes must work independently in the complicated hostile environments with no human involvement. The sensor nodes are the electronic devices that contain sensing unit, processing unit, communication unit and power unit which is shown in Fig. 1 [1]. In this, the sensing unit has two subunits. They are, sensors and ADC (Analogue to Digital Converter) used to convert analog signal to digital signal to provide the information only in analog format. The processing unit in the sensor controls the operations that allow the nodes interacted with others to perform the tasks and it is connected with storage unit. The communication unit is used to create the connection between sensors to network. In this network, energy efficiency is the main challenge of WSN, because, every sensor node contains batteries for energy which is maintained in the power unit.

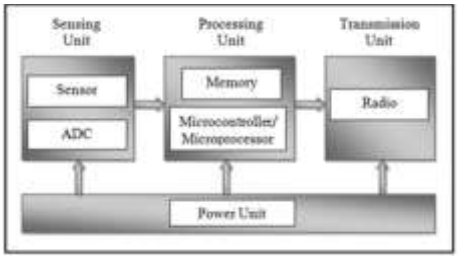

Fig. 1 Sensor node's fundamental components

Energy consumed in a network which is very essential factor as it enhances the network's lifespan and network failure also unbalanced energy when energy of the node becomes drain totally. This problem can be solved by changing the routing selection method based on the protocol. Many routing protocols are available in WSN like DSDV (Destination Sequenced Distance Vector), DSR (Dynamic Source Routing), AODV (Ad hoc On-Demand Distance Vector Protocol), OLSR (Optimized link State Routing), etc. In a WSN network, the route discovery method is utilized to find the path between source and destination. Though there are many other protocols used for route discovery between two nodes, the performance of the AODV Routing Protocol has proved to be the best. AODV is used for routing and also designed for wireless network which find the shortest path from starting to destination in WSN. It has two phases for routing. One is Route Discovery that is based on DSR protocol, and the other is Route Maintenance based on DSDV protocol.

The AODV protocol identifies the possible routes to the target node in the same way as the Dynamic Source Routing (DSR) protocol does. But the node's route determination is done by hop count of that route without considering node energy. This protocol also uses the same path frequently when the data is transmitted. Therefore, the node energy is totally drained and unbalanced when the same path is used frequently in the network. The MAODV protocol is used to overcome this problem by setting the energy threshold value for each node and route discovery method predicted on nodes residual energy. In MAODV protocol, the lively network is maintained, and energy is balanced in each node by using a threshold value. This protocol selects the best route based on remaining energy of the nodes. The nodes remaining energy is computed by using max-min energy algorithm. In MAODV protocol, routing is dependent on hop count and the remaining energy of nodes in WSN.

The summary of the paper is formulated as follows. Section I contains the introduction to this paper. Section II discusses briefly about literature review of this study. In Section III, describes the AODV routing protocol, and route discovery process and its issues. Section IV discusses briefly Modified AODV routing protocol, routing selection method and routing table format. Section V briefly describes experimental results and analysis which also explains the simulation parameters. In Section VI, this paper is concluded..

II. Related Works

The authors enhanced the AODV routing protocol dependent on the routing table which used for reinitiate the route discovery process when the routes are a failure. This method increased capability of the network and throughput, and also minimized the average delay of wireless sensor network [2]. The authors conducted a survey based on Wireless Sensor Network such as WSN applications, communication protocols, challenges and issues in WSN [3]. Here, WSN applications were classified in two different aspects: 1) Tracking and 2) Monitoring. In this, the author has discussed about the different network issues like underlying operating system, communication protocol stack, internal platform, provisioning, deployment, and network services.

A Grade-AODV protocol [4] is introduced which is applied reduce the energy utilization in each node. This method is used to avoid the ineffective broadcast of RREQ, and also selected the least hop count route, because, minimum resource is allocated to each packet. The performance results show that G-AODV has best results than AODV protocol. The new approach is introduced which is novel CBRP (Clustered Based Routing Protocol) scheme [5] predicted on AODV routing protocol that optimizes the energy efficiency on data transmission in wireless sensor network. The authors introduced MAODV protocol for MANET (Mobile Ad hoc Network) which is dependent on AODV routing protocol. The route selection considered on minimum remaining energy and the hop count of the route in this study. MAODV protocol was compared with basic AODV protocol and MAODV produces the best result.

A stable routing methodology is introduced in AODV routing protocol which is dependent on RSSI (Received Signal Strength Indicator) [7]. In this method, link breakage has been avoided in network which improved the duration of the network. This analysis is done by various node count used in different pause time. The authors introduced an new approach [8] in AODV routing protocol for energy efficiency in MANET (Mobile Ad-hoc Network) which is used to efficient energy utilization and adaptability. This method modifies the RREQ packet format based on remaining power of the nodes and drain count. This performance was evaluated by different performance metrics like, packet delivery ratio, network lifetime, throughput and end-to-end delay.

The authors [9] proposed an AODV-ECA (AODV-Cellular automata) routing protocol based on cellular automata mechanism which is used for reduce the energy utilization and energy balancing in each node. The network lifetime is extended by working and sleeping state of nodes in wireless sensor network. The SLE-AODV (Secure Low Energy - AODV) is developed [10] dependent on AODV protocol for data transmission in wireless sensor network. It is used for safe communication of wide area network which is based on AODV and LEACH (Low energy Adaptive Clustering Hierarchy) protocol.

III. AODV Protocol

AODV is a reactive routing protocol that allows both unicast and multicast communication which is used to establishes routes to the destination. The route exploration and route maintenance are most essential parts in this protocol for finding the shortest path between senders and receivers. In this protocol, route exploration mechanism is used to find the route to destination, and the route maintenance activity is used to maintain the route activities. Each one of the node maintains a routing table and it is used to store information about the neighbor, and also maintains the routes till it expires the network. Every routing table maintains the routing statistics such as destination, sequence number of destination, neighbor node, hop count and the node's lifespan. The contains sequence number that is used to identify the current route during the route exploration and also to reduce loop generation.

Source node check the current available routes to the destination in that routing table when a node must deliver

data to a certain location. When it identifies the path to the target node in the routing table, that node delivers the data packets. Otherwise, node initiates the route discovery method in the network. AODV protocol maintained four types of messages such as Route Request (RREQ), Route Reply (RREP), Route Error (RERR) and Hello messages to control the route discovery process. The sender node broadcast the RREQ message to the intermediate nodes. The neighbor node sends the RREP message when it receives RREQ message [11]. The intermediate nodes on both side of the link receive an RERR (Route Error) message when an active route is lost. The HELLO packet is utilized to know about neighbors and this is communicated directly with others.

A. Route Discovery Process

Route discovery process is followed in AODV protocol for finding all available routes to the target node and to choose the best route for data communication. Below are the steps of the route exploration process.

Step 1: The source node creates the RREQ packets when it starts a route discovery method and broadcasts to neighbors in WSN. The RREQ packet maintains some information about nodes such as Source Address, Request ID, Source Sequence number, Destination Address, Destination Sequence number and the Hop count. The RREQ packet format of AODV routing protocol is shown in Fig. 2.

Source Address	Request ID	Source Sequence number	Destination Address	Destination Sequence Number	Hop Count

Fig. 2 The format of RREQ packet in AODV

Step 2: Check intermediate nodes whether it is a destination and then send the RREP packet to starting point of RREQ on receiving RREQ packets. Fig. 3 illustrates the RREP packet format used by the AODV routing system.

Source Address	Destination Address	Destination Sequence Number	Hop Count	Lifetime

Fig. 3 The format of RREP packet in AODV

Step 3: The neighbor information is stored in routing table for identify the route and also increase the hop count at once.

Step 4: The route-finding procedure will be repeated in all the neighbor nodes till it finds the destination.

Step 5: Destination node has a lot of RREQ packets from various routes at the end of this route discovery. The destination node selects only the best path for data transmission in all available routes.

Step 6: The target node sends a RREP message to the source node only by minimum hop count route in all available routes. That route is considered as the best route in Wireless Sensor Network.

Step 7: The source node will transmit data packets to destination by receiving RREP packets from destination.

In AODV routing protocol, it selects the best path based on minimum hop count routes and not about nodes and that energy in the routing. In this method, energy utilization of the node is not balanced also, it creates more death nodes when the same path is used frequently. Moreover, network lifetime is mostly affected in this protocol. In MAODV protocol, an energy aware routing method is developed to overcome the unbalanced energy problem. Routing is done dependent on the nodes residual power and number of hops available to reach the destination. Nodes energy is balanced equally, and it will increase the lifetime of the network by using this protocol. It also helps to keep the network lively and find shortest path of destination in this network by balancing the node energy. Then next section briefly explains MAODV routing protocol.

IV. MAODV PROTOCOL

Modified Ad hoc On-Demand Distance Vector (MAODV) protocol is used to find the best path of destination based on residual energy of the nodes in WSN. In this, the route investigation process is based on AODV protocol, but route selection method is different. The MAODV protocol consists of two methods for route discovery process. One is local forwarding decision and the other is route maintenance. In MAODV routing protocol, the element of the residual energy is added in RREQ and RREP messages. In route discovery, nodes are involved to routing when the node energy is maximum level of threshold. The max-min algorithm is used for finding the minimum and maximum remaining power of the routes in WSN. This algorithm's pseudo code is described further down.

Algorithm1 Pseudo-Code for Max-min Algorithm

```
Initialize the parameters
    // S indicates the number of routes to destination
    // T indicates the number of nodes involved in each route
for i = S
  for j = T
    C = [];   // Created array for store the information
      // Create empty array
      // Store the remaining energy of the nodes in each routes in array C
  end for
end forS
for i = S
   D = min(C(i,:));  // D is the variable name
     find the minimum remaining energy is selected in each route
     minimum energy is stored in a variable
  end for
```

The following steps explain MAODV routing protocol and route selection methods in wireless sensor network.

Step 1: The source node creates the RREQ packets when it starts a route discovery process and broadcast to neighbors in WSN. The RREQ packet maintains some information such as Source Address, Request ID, Source Sequence number, Destination Address, Destination Sequence number, Hop count and Residual energy. The RREQ packet format of this protocol is shown in Fig. 4.

Source Address	Request ID	Source Sequence number	Destination Address	Destination Sequence Number	Hop Count	Residual Energy

Fig. 4 The format of RREQ packet in MAODV

Step 2: Check neighbor nodes in routing when the node energy is greater than threshold otherwise not considered for routing.

Step 3: The intermediate nodes send RREP packet to starting point of RREQ on receiving RREQ packets and then check if it is the destination. The RREP packet format of AODV protocol is shown in Fig. 5.

Source Address	Destination Address	Destination Sequence Number	Hop Count	Lifetime	Residual Energy

Fig. 5 The format of RREP packet in MAODV

Step 4: The neighbor information is stored in routing table to identify the path and also to increase the hop count at once.

Step 5: The same route discovery process will be repeated in all the neighbor nodes till it finds the destination.

Step 6: Destination node has a lot of RREQ packets from various routes at the end of this route discovery. The destination node only selects the best path for data transmission in all available routes.

Step 7: In each path, the node which has least amount of residual energy is chosen. The selected remaining energy is divided by hop count of that route, and that value is considered as α.

Step 8: The route has maximum alpha value in the available routes is related best α path. Then send the RREP packet to the source node in selected path.

Step 9: The source node transmits the data to destination by receiving RREP packets from destination.

This protocol selects the best path in all possible paths than AODV routing protocol in WSN. In this, nodes energy are balanced equally, and the node failure is controlled by using the energy threshold value in MAODV routing protocol. It is used to extend the lifespan of the node and also avoid too much energy utilization in WSN by keeping the network lively. In MAODV protocol, efficient route is selected by using remaining power of the nodes and the hops number is available to reach the target node of a specific path.

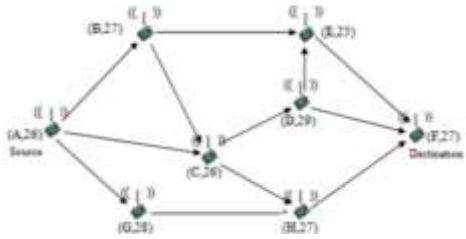

Fig. 6 Example Scenario of WSN

In Fig. 6, shown the example WSN scenario which contains source, destination and intermediate nodes. In this scenario, (A,26) represents the node name, and remaining energy is mentioned in digits. Node A is the source node F is the target node and other nodes are neighbor nodes of WSN. Arrows represents the neighbor nodes for communication. In this scenario, totally seven routes are available to reach the destination from source node. The details of this scenario are explained in Table I.

In this table, route number is the available routes of the network and nodes represent the involved nodes till end of the routes from starting node to target node in a route. Remaining energy of that node is mentioned in remaining energy column in the table. In the available routes, minimum unconsumed energy of the sensor node is represented in minimum power column and hop count of the routes.

TABLE I. ROUTE DISCOVERY PROCESS

Route No.	Nodes	Remaining Energy	Minimum power (a)	Hop Count (b)	a/b	α Value
R1	A-B-E-F	26-27-**25**-27	25	4	25/4	6.25
R2	A-C-D-F	26-**26**-29-27	26	4	26/4	6.50
R3	A-G-H-F	26-28-**27**-27	27	4	27/4	**6.75**
R4	A-B-C-D-F	26-27-**26**-29-27	26	5	26/5	5.20
R5	A-B-C-D-E-F	26-27-26-29-**25**-27	25	6	25/6	4.16
R6	A-C-D-E-F	26-26-29-**25**-27	25	5	25/5	5.00
R7	A-C-H-F	26-**26**-27-27	26	4	26/4	6.50

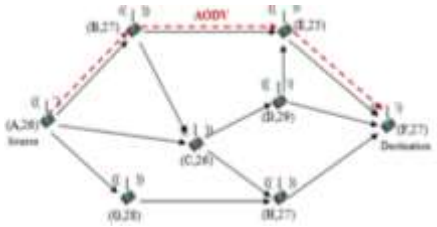

Fig. 7 Route selection of AODV protocol

In this scenario, totally seven routes which represents the route number in the table are available. The AODV routing protocol selects a minimum hop count path in available minimum hops routes of the destination. There are four routes that have minimum hop count. They are, R1, R2, R3 and R7. This routing protocol selects a route in the available minimum hop count routes because this protocol consider the appropriate route dependent on least hop count. This way, the AODV selects the first route (R1) for data transmission which is shown in Fig. 7. The red color arrow represents the best path (ABEF) of AODV which has four hop count.

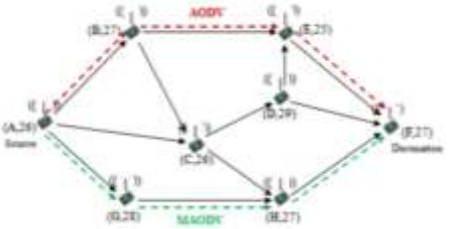

Fig. 8 Route selection of MAODV protocol

The MAODV routing protocol selects the path predicted on the nodes residual energy and the hop count in same network scenario. In this protocol, the remaining power of all involved nodes in each route which is represented by remaining energy column in the table is found. Then it selects the minimum remaining energy in each route and this is represented in minimum energy in the table. The minimum remaining energy is divided by hop count of that route which is indicated as a/b in the table. This value is considered to be α and it is represented by the α value in the table. The MAODV protocol selects the maximum alpha value which is considered to be the best route in available routes. In this scenario, route 3 (R3) has maximum alpha value and it is selected as the best path for data communication as shown in Figure 8. In this, the green color arrow is represented the best

route (A-G-H-F) from source to destination. The MAODV protocol also selects the four hop count path, but the different is AODV routing selection is based on hop cont and MAODV routing is based on remaining energy with hop count.

V. Experimental Results and Analysis

Five performance indicators are employed in this experiment: energy consumption, delay, packet delivery ratio, loss rate, and throughput. These metrics are used to identify the network performance. Some parameters are used for simulation and environmental setup which are described in the following section.

A. Simulation Parameters

A Wireless Sensor Network consists of some parameters that create the network environment and data transmission to know about the network. The network parameters are like nodes, protocols, number of nodes, node placement strategies, Transmission Range, Terrain Area, packet Size, energy, etc. The parameters are changed every time based on different applications of WSN. In this simulation, sensor nodes are placed randomly within a particular terrain area to collect the information. Nodes are deployed randomly in selected region and nodes located at individual place without any order. The parameters and their values for this investigation are shown in the table below (Table II).

TABLE II. Simulation Parameters

Parameter	Value
Nodes Number	50 nodes
Routing Protocols	AODV and MAODV
Node Type	Sensor Node
Transmission Range	250
Size of the Packet	512 (bytes)
Region Size	1000*1000 m
Traffic Type	CBR (Constant Bit Rate)
Node Placement	Random Node Placement
Initial Energy	100 J

The wireless sensor network scenario created using above simulation parameters for analysis is shown in Figure 9. The sensor nodes are placed randomly with 1000*1000 meter in the terrain area and selects the source and destination nodes, like first node is source and second node is the destination. In this network, each sensor node communicates with the neighbor nodes only with fewer than 250 meters range which is called the transmission range.

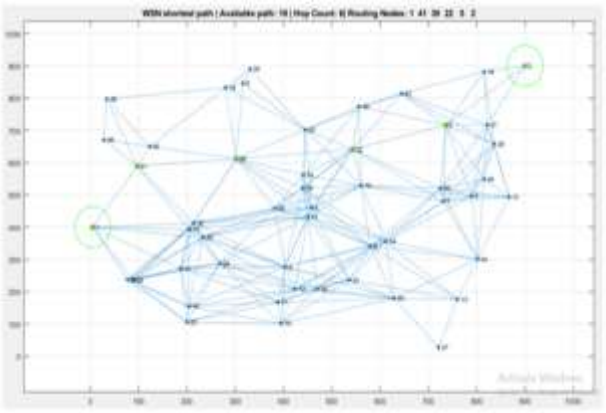

Fig. 9 Network scenario of simulation parameters

The network scenario of given parameters is shown in Fig. 9. In the figure, the blue lines indicate the neighbor nodes of communication based on transmission range. The green circle denotes the source and destination when node1 is source and node2 is the destination. Then the intermediate nodes are represented in blue color dots also, along with the node number in this scenario. The purpose of this scenario is to transfer the data bytes from source to target by optimum route. The AODV and MAODV routing protocols are used to find all available paths to the target node and to select the best path in all available routes.

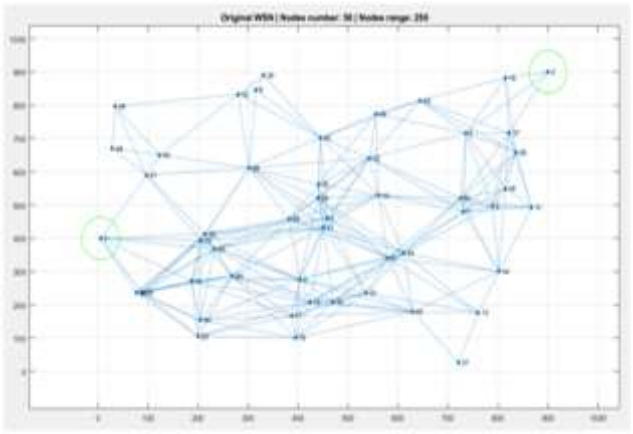

Fig. 10 Snapshot of route selection in AODV protocol

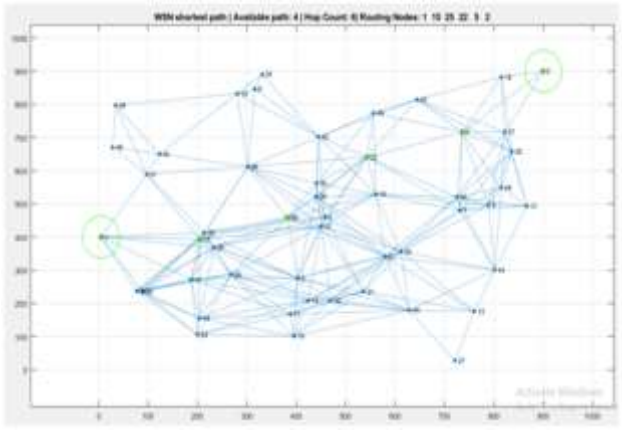

Fig. 11 Snapshot of route selection in MAODV protocol

The AODV routing protocol selects the route in the given scenario based on the minimum hop count as shown in Fig. 10. Totally, six hops are available to reach their destination like 1-41-39-22-5-2. The MAODV protocol selected the best path in the same network scenario based on the local forwarding decision and remaining energy of the node. The selected path is shown in Fig. 11 which also has six hop count to reach their destination like 1-15-25-22-5-2. In this route discovery process, the AODV and MAODV protocol selects the routes in different perspective but MAODV select the better path than AODV protocol.

B. Performance Metrics

1) Energy Consumption

Energy utilization is the most important parameter in this experimental analysis. Each node has a small battery for energy which is used to provide the energy to nodes. In

WSN, energy is consumed when there is data transmission from one node to another. The overall quantity of energy required till the data transmission is completed is referred to as energy consumption. This value is measured in nanojoules and the minimum value is considered to be the best. The following equations 1 and 2 are used to measure the energy consumption. The equation (1) calculates the transmission energy and equation (2) is used to calculate the receive energy (Liu et al. [11]; M. Elshrkawey et al. [12]).

$$E_{Tx} = \begin{cases} l * E_{elec} + l * \varepsilon_{fs} * d^2, d < d_0 \\ l * E_{elec} + l * \varepsilon_{amp} * d^4, d \geq d_0 \end{cases} \quad (1)$$

$$E_{Rx} = l * E_{elec} \quad (2)$$

where,

E_{Tx} = Energy utilization of data sending.

E_{Rx} = Energy utilization of data receiving.

l = Data bits.

E_{elec} = Circuit energy loss.

ε_{fs} = Free space model.

ε_{amp} = Multipath fading model.

d = Distance between nodes.

2) Loss Rate

Data loss is created when the network transmits the data packets from one starting node to ending node in Wireless Sensor Network. This parameter is the difference between number of data packet generated in sender and the number of packets that have been received in receiver. This parameter indicates the total amount of data packets lost until the network's data transfer is complete. The least value is considered as the best performance, and it is identified by percentage. The equation (3) is used to calculate the loss rate.

$$Loss\ Rate = Send\ packets - Received\ packets \quad (3)$$

3) Packet Delivery Ratio

The packet delivery ratio is the difference between the amount of data packets created in the source node and the amount of data packets successfully received in the destination node. In data transmission, source node generates the data packets based on collecting information. Destination node receives those packets via wireless network. The packet delivery ratio is calculated based on generated packets and received packets. This parameter is measured in percentage (%) and the value should be of high level. The following formula (equation (4)) is used to calculate the packet delivery ratio.

$$Packet\ Delivery\ Ratio(PDR) = \frac{\sum RP}{\sum SP} \quad (4)$$

where,

RP = the amount of data packets successfully reached their destination.

SP = the amount of data packet send in source node.

4) Throughput

Throughput is calculated by the amount of data bits successfully reached the destination in a particular time. High amount of value is measured as the number of data bit reached successfully per second (bits per second (bps) or (bits/sec)). The equation (5) is used to measure the throughput in Wireless Sensor Network.

$$Throughput = DB * 8/(LT - ST) \quad (5)$$

where,

DB =the total amount of data bytes effectively delivered in destination node.

LT = Received time of last packet.

ST = Received time of first packet.

5) Delay

Delay is considered by time which is created due to network problems. It is the time it takes for a data packet to be sent from a source node to a target node. The minimum time is considered as the best performance of the network and it is measured by milliseconds (msec).

C. Discussion

The following figures show the performance of AODV and MAODV routing protocols which is utilized to find the difference between two protocols.

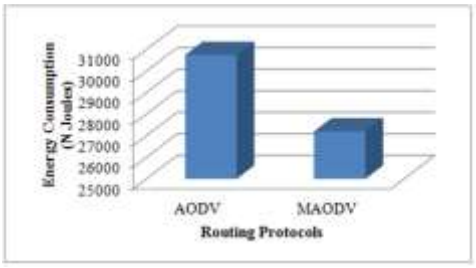

Fig. 12 Energy Consumption

The energy utilization of this experimental analysis is shown in Fig. 12 which is considered in nanojoules. The energy consumed in AODV protocol is 30745 and MAODV consumed is 27197 for the data transmission in WSN. AODV consumed more energy when compared with MAODV protocol, because, AODV routing selection is based on minimum hops number and distance of the route. In MAODV protocol, routing selection is predicted on minimum maximum power of the nodes and the hops number. Finally, the MAODV protocol has consumed minimum energy for data transmission which is considered the best result of this study.

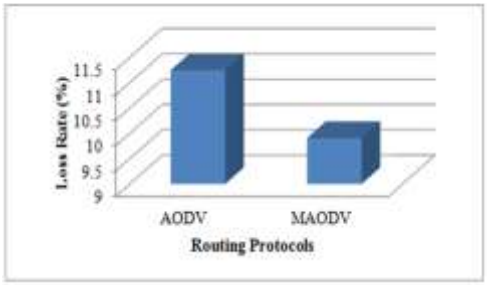

Fig. 13 Loss Rate

Fig. 13 shows the loss rate performance of this experiment which is analyzed in percentage. The total loss rate in AODV is 11.2485, the MAODV is 9.9089 as observed at the end of the data transmission. The AODV protocol gives poorer performance of loss rate than MAODV due to link failure. The link failure is because it used the same path frequently. The MAODV protocols manages this problem by using threshold value to keep lively network. In this, MAODV protocol shows better performance when compared with AODV protocol.

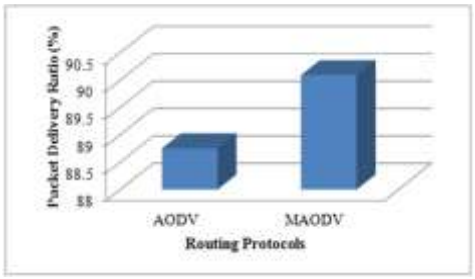

Fig. 14 Packet Delivery Ratio

The packet delivery ratio performance of the AODV and MAODV routing protocols are compared as shown in Fig. 14. In this comparison, packet delivery ratio in AODV is 88.7515 and MAODV is 90.0911. The result is high in MAODV, and the AODV have minimum percentage of this metric. MAODV protocol selects an efficient route based on minimum distance, and minimum and maximum residual power of the nodes in routes to avoid the packet loss. The MAODV gives better results when compared with AODV routing protocol.

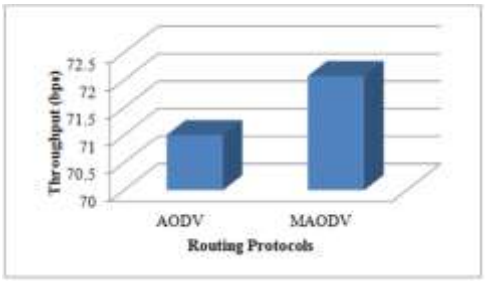

Fig. 15 Throughput

The throughput results shown in Fig. 15 is calculated in bits per second. This calculation is based on the amount of data packets successfully delivered and the entire time taken for packet transmission. In these results, throughput in AODV is 71.0012 and MAODV is 72.0728. Highest value is considered as the best value, but AODV protocol gives the minimum result because it consumes more time for each packet transmission. The MAODV protocol provides better performance than AODV protocol in these experiments.

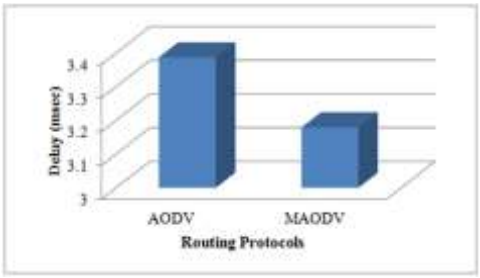

Fig. 16 Delay

Fig. 16 shows network delay of this experimental analysis which is considered in mill seconds. The delay in AODV protocol is 3.3873 and MAODV is 3.1792 for the data transmission in WSN. The AODV routing protocol gives more delay time when compared with MAODV protocol, because, AODV select the path based on minimum hop count and the distance is not considered. The AODV protocol selects the high distance but MAODV protocol select the best route for data transmission. Finally, the MAODV protocol provides better result when compared with AODV protocol. In all the performance metrics, the MAODV routing protocol gives better performance when compared with AODV protocol.

VI. Conclusion and Future Work

The MAODV routing protocol is introduced in this paper to extend the network's lifespan and discover the most effective route to the target node in Wireless Sensor Networks. This protocol reduces the energy consumption by using max-min energy concept for identifying the nodes residual energy and threshold. The comparison of this study is done by two routing protocols namely, AODV and MAODV. The energy consumption, loss rate, packet delivery ratio, throughput and delay metrics are used to identify the network performance. In this study, MAODV protocol provides the best results in each performance metrics when compared with AODV routing protocol. Further, lifetime of the network is increased and energy is balanced of each node in the network. In future, emphasis on different environments and real time applications can be carried out.

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