DEVELOPMENT OF ENERGY EFFICIENT PROTOCOL FOR AD HOC NETWORK

Thesis submitted to Srinivas University in Partial Fulfillment of the requirements for the award of the Degree of

DOCTOR OF PHILOSOPHY IN COMPUTER SCIENCE

By

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Certificate

RESEARCH SUPERVISOR'S REPORT

This is to certify that thesis entitled **"Development of Energy Efficient Protocol for Ad Hoc Network"** Submitted to **Srinivas University, Mukka, Mangaluru, Karnataka State, India**, by **Soumya S** for the award of degree of **Doctor of Philosophy** in **Computer Science** is a record of bona fide research work carried out by her under my supervision. The thesis has reached the standard of the regulations for the degree and it has not been previously formed the basis for the award of any degree, diploma, associateship, fellowship or any other similar title to the candidate or any other person (s).

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Date: 19-09-2022

Declaration

Declaration

I, Soumya S., hereby declare that the thesis entitled "**Development of Energy Efficient Protocol for Ad Hoc Network"** , submitted to Srinivas University, Mukka, Mangaluru, Karnataka State, India, in partial fulfilment of the requirements for the award of the degree of Doctor of Philosophy in Computer Science is the record of original research work carried out by me during the period from 14-06-2012 to 01-09-2022 under the supervision and guidance of Dr. Krishna Prasad K, and has not formed the basis for the award of any degree, diploma, associate-ship, fellowship, or other similar title of any candidate in this or any other university or other similar institutions of higher learning. This thesis is free from any kind of plagiarism.

Place: Mangaluru

Date: 19-09-2022

Signature of the candidate

Mrs. Soumya.S.,

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Acknowledgement

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Soumya S

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Synopsis

SYNOPSIS/ PREPHASE

Development of Energy Efficient Protocol for Ad Hoc Network

Ad-Hoc Network is a broad research field where we can find a network node communicating wirelessly with dynamic network architecture. And this network is known as ad hoc because its network infrastructure is dynamic without a base station. The Ad-Hoc Network communicates wirelessly by forwarding data to each other. A set of wireless mobile devices can dynamically reconfigure the network.

The application area of Ad Hoc Network is initially focused on in this work is MANETs, and MANETs are mainly battery-powered. Eventually, energy in the node depletes, then the node drops out of the network. Unless the nodes are replaced and recharged network gets disconnected from the communication line. Another feature of Mobile Ad Hoc Networks is nodes discover the routes. Thus, the protocol must incorporate routing functionality into the nodes. Every node in the network act as routers, and manages themselves; therefore, arbitrary and changing topology is created. Mobile Nodes interact with other nodes within radio range, also helps to route packets. AODV is a popular routing protocol with high performance. Thus, its performance needs to be evaluated using different metrics. Therefore, it is necessary to obtain results from the NS3 Simulation, comparing the performances of AODV and the newly proposed protocol called Optimal Residual Energy Selection ORES-AODV protocols.

The results obtained from the comparative analysis of protocols AODV and ORES-AODV using NS3 simulation help to understand the energy consumption in each node during communication. The proposed work can be further integrated with Wireless Sensor Networks since Ad Hoc Network has several applications area, and Wireless Sensor Networks is popular among them. The Wireless Sensor Network protocol introduced in this work effectively integrates the energy model evaluated in MANET by NS3 simulation.

In this work, the Optimal Residual Energy Selection ORES-AODV protocol is introduced. This algorithm overcomes the problem of identifying the low-energy nodes and finding the optimal way by selecting the nodes with maximum energy levels. The solution to the path's energy loss problem is finding the node with minimum residual energy and using efficient hop count metrics. When choosing the best path selection, the protocol always chooses the path with minimum hop count by counting the number of hops from the source to the destination. The protocol always looks for minimal hop count, and then the path is selected depending on the hop count minimum. But this technique always leads to the selection of routes with inefficient energy levels in the nodes and results in path failure during the transmission of packets. So, the proposed protocol is mainly based on the AODV protocol. To overcome the failure hop count in the route, minimal residual Energy and residual Energy are the optimal path selection cost metric. The protocol can sustain the network lifetime for a longer time with the help of cost metrics, a method for determining the best path through a protocol. The AODV protocol transmission takes place with the help of RREQ and RREP. When the source node initiates the communication, the RREQ packets are sent and received by each and every node in the network, and the source node is the one who started it. All nodes in the network send and receive RREQ packets, so the RREQ packet is propagated through the path until the destination gets the first RREQ. Once the destination node receives the RREQ, it will generate a route reply RREP to the source and forwards it via the same path.

The proposed research has also focused on the Wireless Sensor Network and developed a modified routing protocol. The suggested research will be based on the LEACH protocol, which has multiple problems due to the fact that it is a hierarchical cross-layer protocol.

To address the issue of energy dissipation,the LEACH protocol uses a hierarchical approach, which requires numerous iterations. The bulk of iterations consists of preparation and sustained data transmission phases. The protocol will dynamically establish the cluster, and randomly chosen cluster heads will be selected during the preliminary stage.

LITERATURE SURVEY

Ashish Kumar et al. (2012) This study performed a quantitative analysis of the DSDV, AODV, and DSR routing protocols. The simulation analysis suggests that these three protocols will help to reduce the communication delay but not energy consumption. DSDV is an efficient protocol for energy consumption but creates routing overhead. DSDV is a variant that can prolong network lifetime but consumes comparatively more energy. DSR and AODV performance is similar in the case throughout, but the energy consumption is lesser than AODV.

S. Mohapatra al. (2012) has analysed nearly four quantitative metrics using NS3, initially Packet delivery ratio, and found that the average packet delivery ratio of DSR is highly efficient than other protocols. In the case of network size, it is observed that DSR outperforms and is highly applicable to large networks. It is also found that OSLR is another protocol highly suitable for the mobility of nodes. The study also focuses on energy metrics for the QoS of the protocols.

S.Sridhar et al. (2013) have proposed a protocol named ENL-AODV, which can identify the node with a low energy level during the data transmission. And another parameter added to this work is that the protocol can select the node based on the energy level. The protocol improves the QoS by selecting a node with maximum energy levels.

Hannan Xiao et al. (2014) The proposed work has evaluated energy consumption in the network during data transmission. The author has chosen the popular ad-hoc protocols DSR, AODV, and DSDV with representative parameters. This research also identified that a considerable amount of energy is used at the idle state of the node, and the rest of the power is consumed at the MAC layer.

Hitesh Kumar Rinhayat et al. (2014) evaluated that the critical success of the network lifetime is the consumption of minimal energy by the nodes. This study also minimizes the overall energy consumption and increases the network lifetime.

Rieha Sharma et al. (2015) have performed an analysis to verify the performance of the different routing protocols ADV, DSR, and GOD in different scenarios, either in city scenarios or in highway scenarios. Finally, it is evaluated that GOD is a protocol designed to suit the requirements of the city scenario due to the low network density. ADV is best suitablefor highway scenarios due to the high network traffic and traffic congestion in highway scenarios.

Kamalesh Chandra Purohit et al.(2016) have compared existing routing protocols suchas AODV, AOMDV, DSR, DSDV, TORA, and ZRP. This protocol evaluates these protocols against VANEt as well as in MANET. Different evaluation metrics, such as delay and PDR, are assessed to get comparative study results with the help of simulations.

RagulRavi.R al., (2015) The authors of this work have introduced neighbor coverage protocol (NCP). This protocol is capable of identifying neighbor connectivity possibility and ratio (NCPR). This algorithm prevents rebroadcasting due to neighbor coverage, and energy optimization is also introduced. And it is concluded that the proposed algorithm is better than AODV and NCPR.

Rohini Sharma al. (2015) has performed simulation on wireless sensor networks, and simulation is performed using an NS3 network simulator. The network simulation is achieved by taking the nodes with different densities and workloads. When the NS3 simulator simulated for the protocols AODV and DSR, the number of packet drops was high. And the algorithm TORA was highly incapable during high density and created packet routing. And during the energy consumption analysis of the protocols, DSR worked efficiently. And AODV has outperformed in the energy evaluation.

K.Sumathia al., (2015) the proposed study can evaluate and understand the functionalities of MANET routing protocols. And the author suggests that one protocol is insufficient to provide energy efficiency during the routing of MANET. Also, a new protocol called EEARP was introduced. It has features such as min-max formulation, which selects a path for transmission of packets by identifying the path capable of transmitting the largest packet and smallest residual packet.

Marco Fotino et al. (2016) have demonstrated the working behaviors of DSR and OLSR protocols based on energy consumption during the routing. In this work, the reactive protocols perform efficiently in low traffic load. But during high traffic rates, the proactive routing protocol can outperform by enabling appropriate refresh rates.

Zhihao Guo al. (2016) has demonstrated a new mechanism called the ARIMA model, which can measure the per-interval consumption of energy as a time series. This scheme can prolong network lifetime and saves energy in homogeneous scenarios, and it uses the OLSR_EA protocol for an even larger network lifetime in heterogeneous scenarios.

Juan-Carlos Can al. (2016) has compared four significant protocol behavior AODV, DSR, TORA, and DSDV. And all these protocols are effectively evaluated based on energy consumption. And evaluation produced the following results each protocol has its capabilities and weaknesses. Also, the study concluded that the cost of data transmission using packets is higher than the node is idle. But in specific applications, the inactive state also can be considered cost dominant.

S. Russia et al. (2016) have proposed Node Disjoint Energy Efficient Multi-path routing, designed for MANET to overcome energy depletion issues in MANETs. This method of improving energy efficiency has used seven scenarios to prove the efficiency of the NDE-MR protocol. The protocol successfully adapted to different topologies by initializing the multi-path.

K.AnishPon Yamini et al. (2018) proposed study suggest several techniques introduced to reduce energy consumption. But a single protocol is not capable of reducing power consumption. So, the proposed protocol can incorporate a new approach to making it possible with the help of cross-layering techniques to increase high energy preservation and network lifetime.

Kumar Nithesh et al. (2017) have developed a new technique for WSN, where the mobile sink trajectory is designed, which is delay efficient. The protocol also decides the rendezvous points for the mobile Sink based on the Voronoi diagram. The recovery technique for cluster member nodes is also involved in this technique to recover the nodes which have become orphans due to the energy depletion of the cluster heads.

Sudhakar Pandey et al. (2018) have proposed a new method for picking a cluster head, the selection relies on residual energy in the node, and for the distance pre – clustering is applied in the clustering phase. The load balancing feature is also included in this algorithm to change the location of the sink node when energy depletion issues occur in the nodes surrounding the sink node.

Djamila Mechutu et al. (2018) have developed a new protocol called TMSRP2, which gives improved and efficient outcomes in the case of the packet received. The protocol has also successfully kept the network nodes alive for extended periods. And the time required for delivering the packets is considerably reduced by the protocol. The location of the mobile Sink is identified with the help of a routing tree to decrease the amount of time needed for data delivery.

V. Saranya et al. (2018) have developed a new protocol called Energy Efficient Clustering Scheme (EECS). The work helps to improve the number of packets delivered to the sinknode. Estimates are made of the protocol's effectiveness using different metrics, and its efficiency is compared with Modified - LEACH (MOD-LEACH).

Amer O Abu Salem et al. (2019) proposed a work that improves the lifetime and energy, which can resolve the drawbacks of the LEACH protocol. A simulation is performed for the analysis. It has been proved that the proposed method is more potent than LEACH.

Abdellah Nabou et al. (2019) have evaluated several protocols, such as AODV and DSDV because both protocols are reactive routing protocols, and separately OLSR and DSDV are analyzed since they are proactive routing protocols. All the chosen protocols are evaluated for the energy needed for transmitting the packets. When the energy necessary for sending data is low, all the protocol performance becomes poor except the AODV protocol. And high transmit power increases the efficiency of almost all the protocols.

Hemin Akram Muhammad et al. (2019) have evaluated energy consumption inproactive and reactive routing protocols. In their comparative analysis ,it is understood that the proactive protocol's energy consumption is higher, and the protocol exhibit a steady state behavior in all scenarios. The proposed work evaluates that the efficiency of the proactive protocol is high in the static network or a network with a minimum movement of nodes. Proactive protocol spends more energy at the application layer due to the energy required to send routing messages. This work analyses that the receiver nodes spend more power at the receiving end because the receiving node obtains data from the neighbors' node, but the sender node transmits data.

MuchtarFarkhana et al. (2019) stated that NDN-based MANET could improve the energy efficiency of nodes. And NDN-based MANET is not possible with wireless broadcast communication. When analyzing previous NDN, it is found that NDN can use them to improve efficiency.

H K Sampada et al. (2019) have developed M-AODV, which is set by modifying the popular AODV protocol. M-AODV protocol is proven more efficient than AODV and increases efficiency by improving the network's longevity. M-AODV uses a specific control packet called HELLO packet by including two parameters: trust and residual energy. The parameters evaluated by the NS3 simulator and the Willingness range from 0 to 7, and trust ranges from 0 to 1.

Mohammed Alaei et al. (2020) have developed a new clustering technique called Energy Efficient Load–Based Clustering Method for wireless Mobile Sensor networks. The protocol considers the network and sensing areas as a circular field. And the base station is situatedin the middle of the network region.

RESEARCH GAP

Evaluating energy consumption in Mobile Ad Hoc networking using routing protocols helps to analyse the different quantitative metrics using NS-3 Simulation.

Several studies evaluating Mobile Ad Hoc networks considered theoretical aspects. Still, the proposed research is unique as it will perform the quantitative analysis of the routing protocols with performance metrics based on energy consumption.

In the proposed study, the energy consumption analysis is also analysed in Wireless Sensor Network devices, and a novel, innovative analysis is performed.

- Researchers analyse the Energy issues in Mobile AD-HOC Networks, but the path selection methodologies are not convincing and are not concluded effectively in the earlier studies.

- Architecture selected by the researchers in previous work on WSN is found inefficient with problem of energy holes and load imbalance in the network.
- The nodes are not evenly distributed in the network, which may cause inefficient energy use.

OBJECTIVES OF THE PROPOSED WORK WITH JUSTIFICATION

The primary objective of this research is to optimize the energy of nodes of a mobile ad-hoc network to enhance the lifetime of nodes.

The WSN implementation study accurately analyses the Muti-MECA protocol and its predecessors. The various objects of the research work are:

- To study the working of Existing Energy Efficient Protocols, such as Ad Hoc On-Demand Distance Vector (AODV) protocol, and analyze using simulation tools.
- The existing Energy Efficient Protocol AODV is then compared and analyzed with the proposed Modified protocol, Optimized Residual Energy Selection AODV (ORES-AODV) protocol.
- The energy variation in Mobile Ad Hoc networks to analyze, the network is examined under different mobility models using the proposed ORES-AODV protocol.
- To study the working of Existing Energy efficient routing protocols for Wireless Sensor networks such as the Low-energy adaptive clustering hierarchy (LEACH) protocol and its variant, Mobile-sink based energy-efficient clustering algorithm (MECA).
- To analyze the proposed Multi-MECA protocol and similar protocols such as MECA and LEACH protocols for their energy efficiency.

METHODOLOGY FOLLOWED

The methodology for the proposed study will explore the broad field, Ad Hoc Network, using quantitative analysis of energy-efficient routing protocols.

Initially, the overview of the selected protocols for the study is described. The newly modified protocol and compared with AODV, Optimal Residual Energy Selection ORES-AODV, in which the route request packet is modified with additional fields such as residual Energy, minimal residual Energy, and the hop count.

Two additional fields are added to calculate the average of residual energy. The first field is to calculate the average least residual energy, and the threshold field and average total residual energy have also been included in the routing table. The RREQ packet format.

ORES-AODV is described in Table 1. Two fields of the RREQ are additional in the packet format.

For the path selection, some of the metrics, such as the difference between the path with the most significant average residual energy and the path with the highest threshold are used. Another method is used by finding the difference between the highest average of minimum residual energy and the threshold to select the path.

Table 1. Packet format.

Broad Cast ID
Destination IP
Source IP
Destination Sequence Number
Source Sequence Number
Least Residual Energy
Total Node Residual Energy

Finally, the path selection with equal cost factors will again rely on minimum hop count.

The algorithm proposed has the following objectives.

1. The proposed algorithm aims to overcome the problem of link breakages in the selected path.
2. Path selection is typically performed based on the number of hop counts, and a path with a minimum hop count is selected. This trend of AODV has to be changed by choosing the nodes with maximum residual energy.

Algorithm for RREQ handling in ORES-AODV

Step 1: Receival of new RREQ packet, the Routing Table is searched for the Broad Cast ID of the RREQ packet.

Step 2: Checking whether the route is present or not. If Present, then update the routing path.

Step 3: if the RREQ packet is new, calculate the nodes' energy difference.

Step 4: If the energy level is less, then discard the Route Request Packet.

Step 5: If the node has sufficient levels of energy, then add the updated energy difference in the route table.

Step 6: Wait for an additional route request. If a link break is observed, check the routing table for the path; otherwise, continue forwarding the path.

In the proposed study, performance analysis is performed using NS3 simulation. A comparative analysis of the values of various metrics used to calculate the efficiency of routing protocols can be used to achieve the performance of AODV protocols in MANET.

The proposed work focuses on reducing energy-related issues by developing an improved protocol. The proposed work deeply analyses the working of the AODV protocol because AODV is considered a popular energy-efficient protocol by several researchers after the deep analysis of the protocol.

The AODV protocol has certain drawbacks, and the proposed work has identified the defects and has included remedial aspects to overcome the issues.

Ad Hoc network, WSN-based protocol proposed in this work called Multi-MECA protocol, is also analyzed for its efficiency.

Its efficiency is compared with other well-known protocols such as LEACH and its base protocol MECA. The methodology used is described for the protocol, as given below.

System Model for WSN

Basic assumptions

- The selected network zone has a sink node that moves within the network area and several static sensing nodes that do not have mobility. Still, all the sensing nodes share similar characteristics.
- The network's sensor nodes are spread out and equipped with enough storage.
- Depending on how far they are from the receiver, the sensor nodes' broadcasting strength can be changed by themselves.
- Although they can move in opposition to one another, sink movements are synchronized.
- The sinks go along a pre-determined path, arrive at a meeting place, and can communicate their locations to their close neighbors.

Hierarchical routing algorithm with low energy consumption

The following guidelines must be followed by a sensor node when it employs the suggested hierarchical routing mechanism to send data packets to a nearby sink. M-MECA is explained below.

1. The nearest Sink or cluster head is the direction in which the node's data are routed as affordably as possible.
2. The node may be close to the Sink as the mobile sinks migrate over long triangular diagonals.
3. In this case, the node may determine which Sink is closest by measuring the distance to the nearest Sink.
4. One of the routes a node can take to determine how much it will cost to run it: is the quickest way to the nearest CH, the route to the CH via several hops, the CH's path, and routing to its CH across several hops.
5. As a result, the node must send its data along the least energy-consuming path possible. Tomanage the energy used for data transmission, the sensor node in the network must assessthe best relay node (Kj) in the multi-hop routing process.
6. Each sensor node that participates in the multi-hop routing operation can preserve data about the location of the sinks nearby and the ID of Kj as the best node for subsequent data transmission at each rendezvous point based on Kj's remaining energy to save energy consumption.
7. The node must choose a new relay node if Kj's remaining energy is below the threshold.

Algorithm:

Step 1: Initialize all the parameters. Sink Node 1 and Sink Node 2 are moving at predefined path.

Step 2: Invoke Cluster creation and cluster Head election procedure.

Step 3: Appoint the central node as Cluster Head.

Step 4: Broadcast the advertisement to member nodes.

Step 4: Wait for Acknowledgment.

Step 5: Prepare a TDMA schedule and encourage other nodes to become new cluster heads.

Step 6: Select the new cluster Head based on Residual Energy and a Threshold value.

Step 7: Send a message with the time slot and further CH details to member nodes.

Step 8: CH begins data aggregation from member nodes.

Step 9: CH calculates the distance between sink node 1 and sinks node 2.

Step 10: When sink node 1 and sink node 2 reach the rendezvous point, and if the distance of CH is near to the Sink, send CH_DATA to the Sink. Else, wait.

Step 11: If the remaining Energy of CH is below the threshold. Repeat the steps, and invoke the cluster head creation procedure.

Step 12: Restart the broadcasting procedure.

RESULTS/FINDINGS

Total simulation time is 120 seconds, and Node pause time is 0. The protocol used in this proposed work is AODV and ORES-AODV, and both protocols are evaluated with other leading AODV-based protocols.

The proposed ORES-AODV protocol is evaluated and compared for received packets with AODV-based protocols such as ENL-AODV, IR-AODV, M-AODV, and AODV using the NS3 network simulator. the result is generated as shown in Fig.1.

The proposed ORES-AODV protocol is evaluated and compared for received packets with AODV-based protocols such as ENL-AODV, IR-AODV, M-AODV, and AODV using the NS3 network simulator. the result is generated as shown in Fig.2.

The proposed ORES-AODV protocol is evaluated and compared for throughput with AODV-based protocols such as ENL-AODV, IR-AODV, M-AODV, and AODV using the NS3 network simulator. the result is generated as shown in Fig.3.

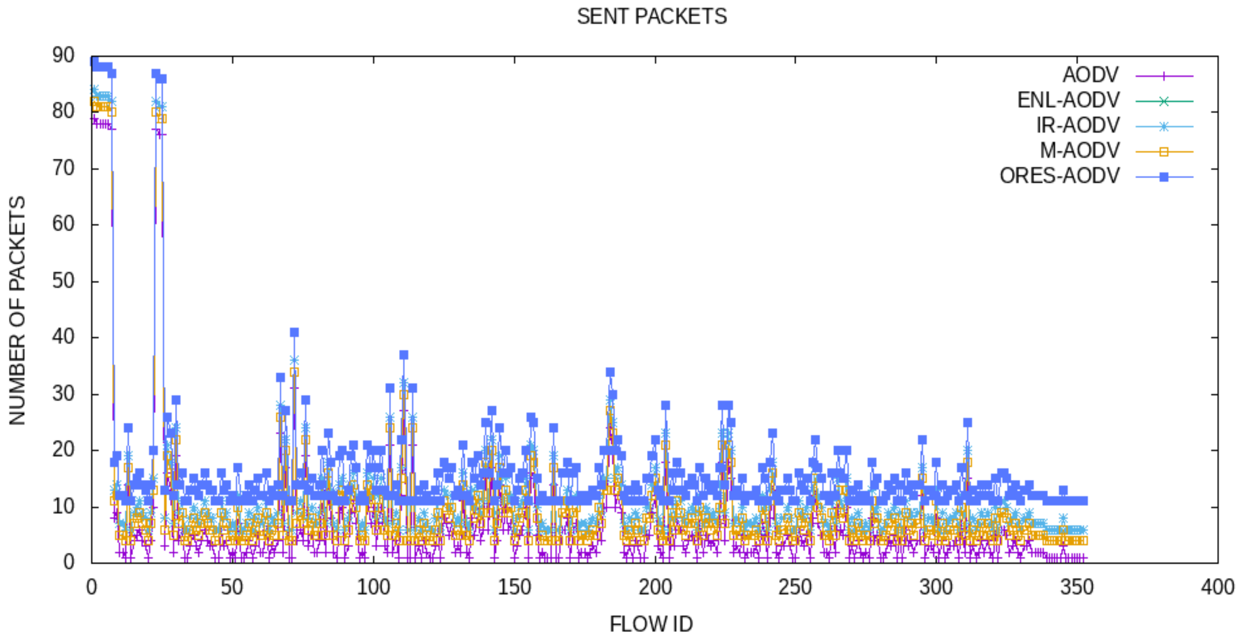

Fig. 1: Comparison of AODV and ORES-AODV protocol based on Sent Packets.

The proposed ORES-AODV protocol is evaluated and compared for current Energy with AODV-based protocols such as ENL-AODV, IR-AODV, M-AODV, and AODV using the NS3 network simulator. the result is generated as shown in Fig.4.

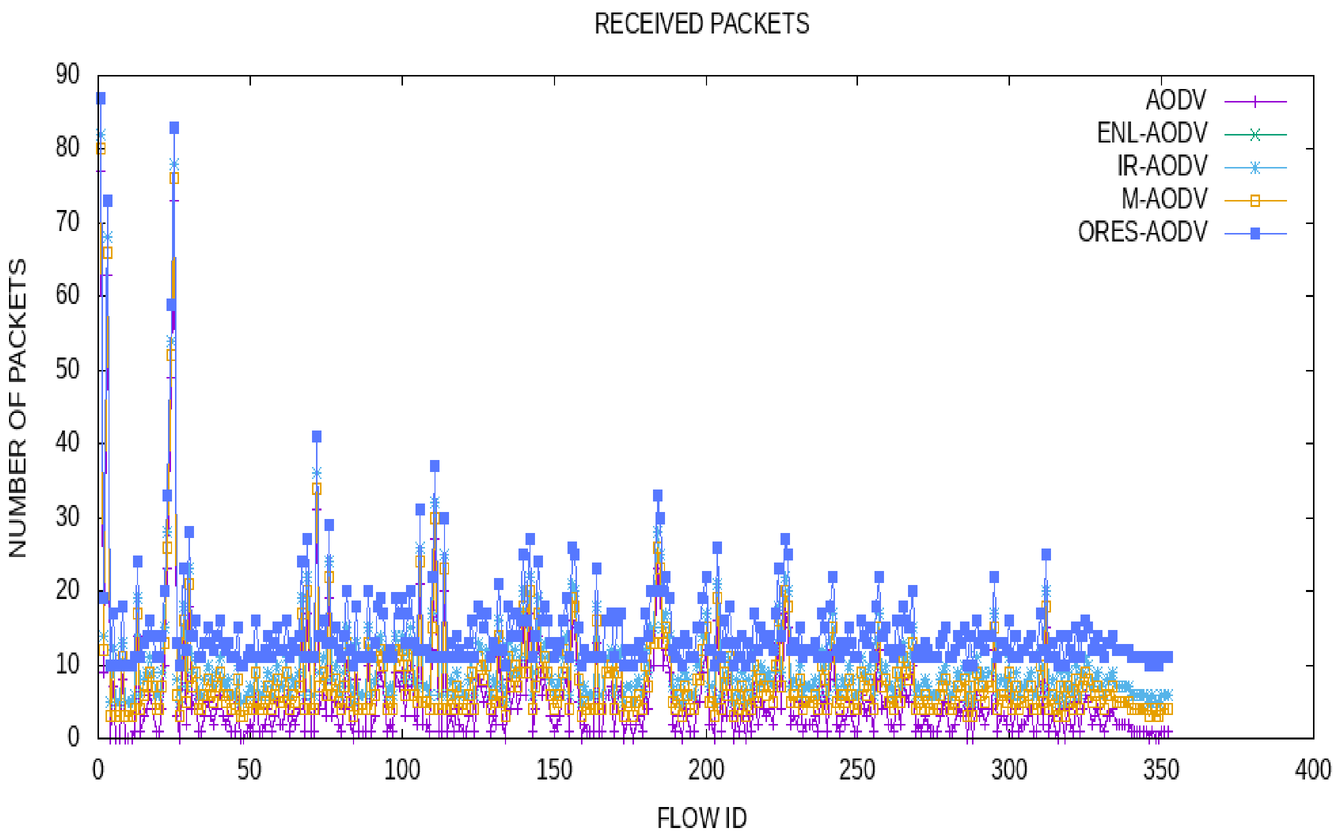

Fig. 2: Comparison of AODV-based and ORES protocols based on Received Packets.

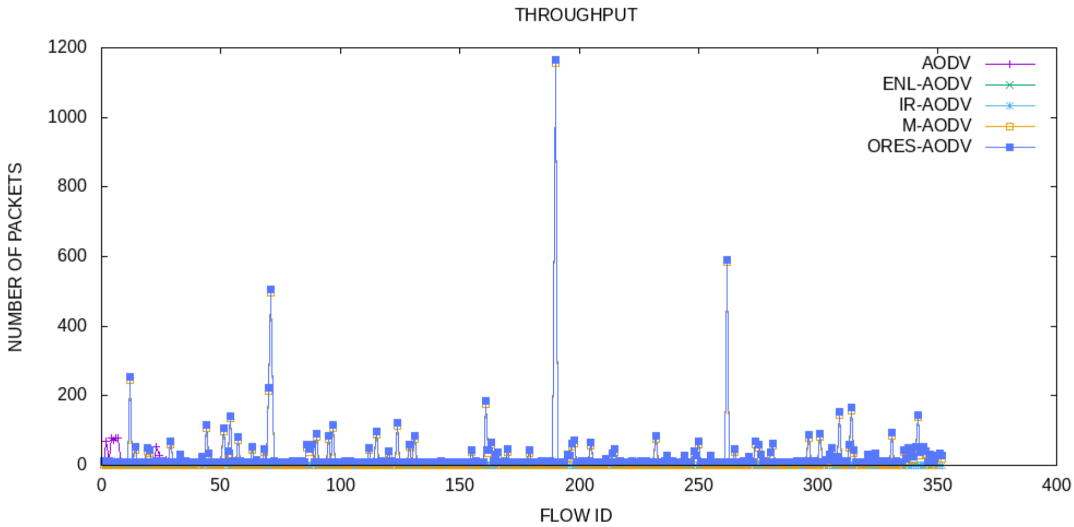

Fig. 3: Comparison of AODV-based and ORES protocols based on Throughput.

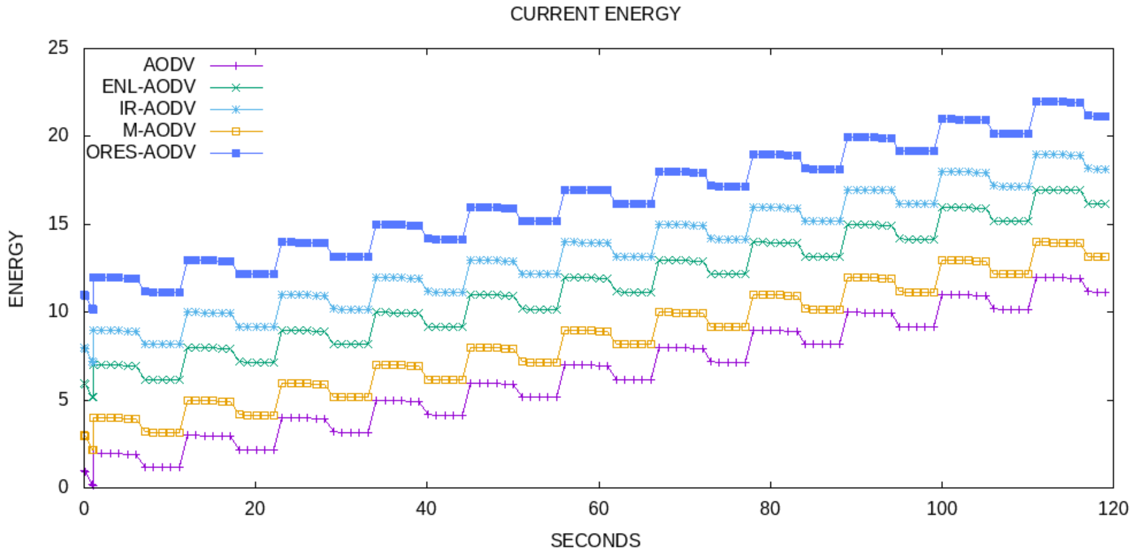

Fig. 4: Comparison of AODV-based and ORES protocols based on Current Energy.

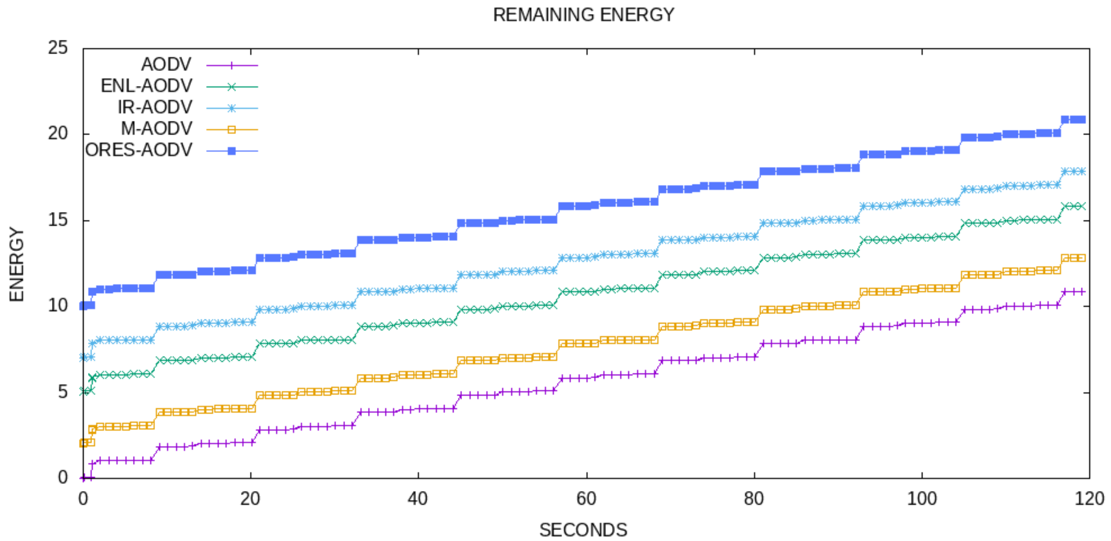

Fig. 5: Comparison of AODV and OLSR protocol based on Remaining Energy.

The proposed ORES-AODV protocol is evaluated and compared for remaining Energy with AODV-based protocols such as ENL-AODV, IR-AODV, M-AODV, and AODV using the NS3 network simulator. the result is generated as shown in Fig.5.

Using NS3, we simulate several Low Energy Adaptive Clustering Hierarchy (LEACH) and its modification protocols MECA, as well as the proposed protocol of our research study Multi-MECA in WSNs. The variables in Table.2 are used for simulation. Energy and residual energy network evaluation WSNs that have been examined.

Table 2: Simulation Parameters.

Parameter	**Value**
Area (m*m)	300 x 1500 m
Simulation Time(s)	500 Seconds
Speed (m/s)	20 m/s
MAC type	802.11 p MAC
Traffic type	Two-Ray Ground
Packet size	64-byte packets
Protocols	MULTI-MECA, MECA, LEACH
Mobility Model	Random Waypoint Mobility Model

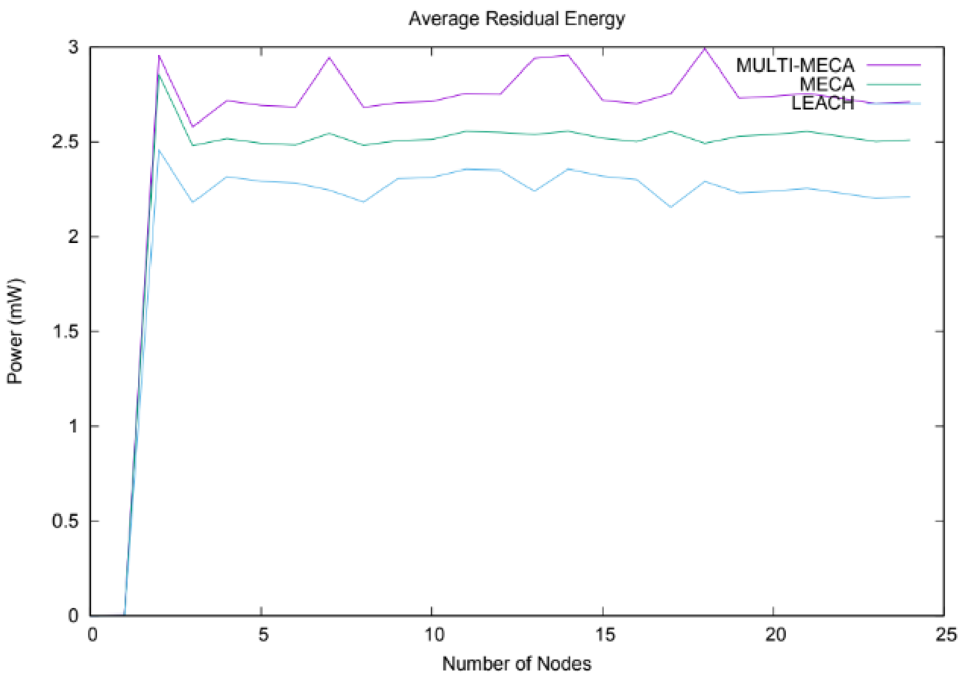

Fig.6: Average Residual Energy of LEACH, MECA and Multi-MECA for 25 nodes.

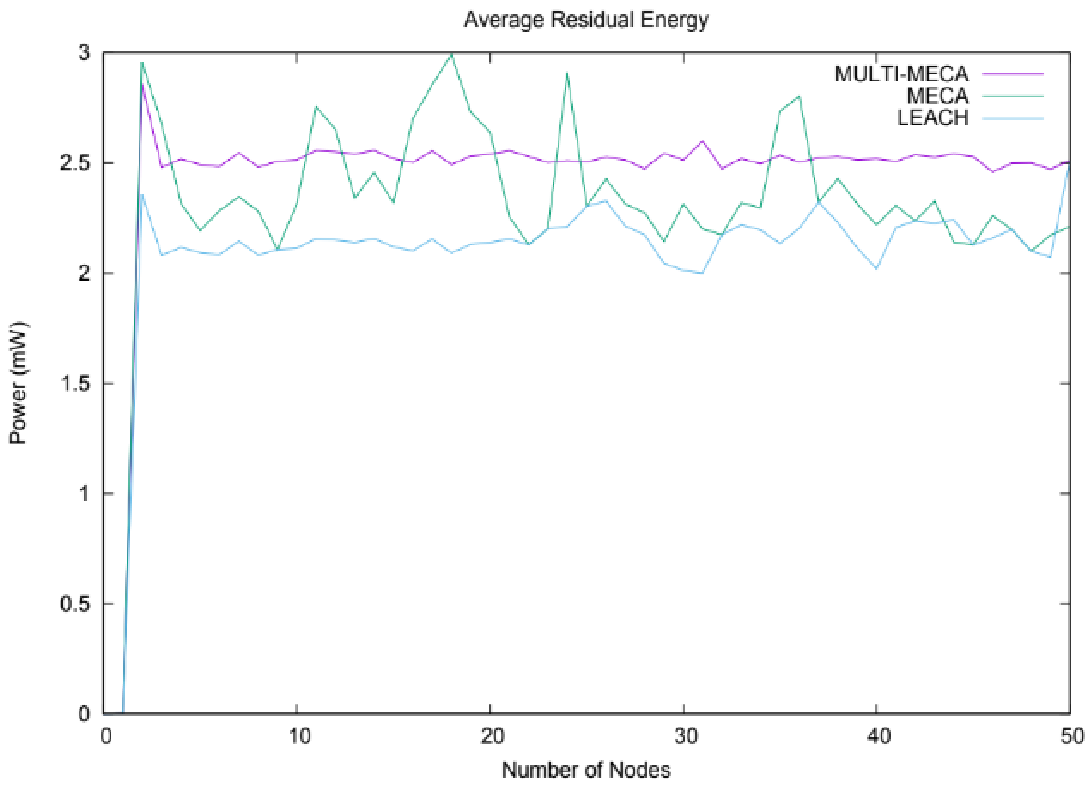

Fig.7: Average Residual Energy of LEACH, MECA and Multi-MECA for 50 nodes.

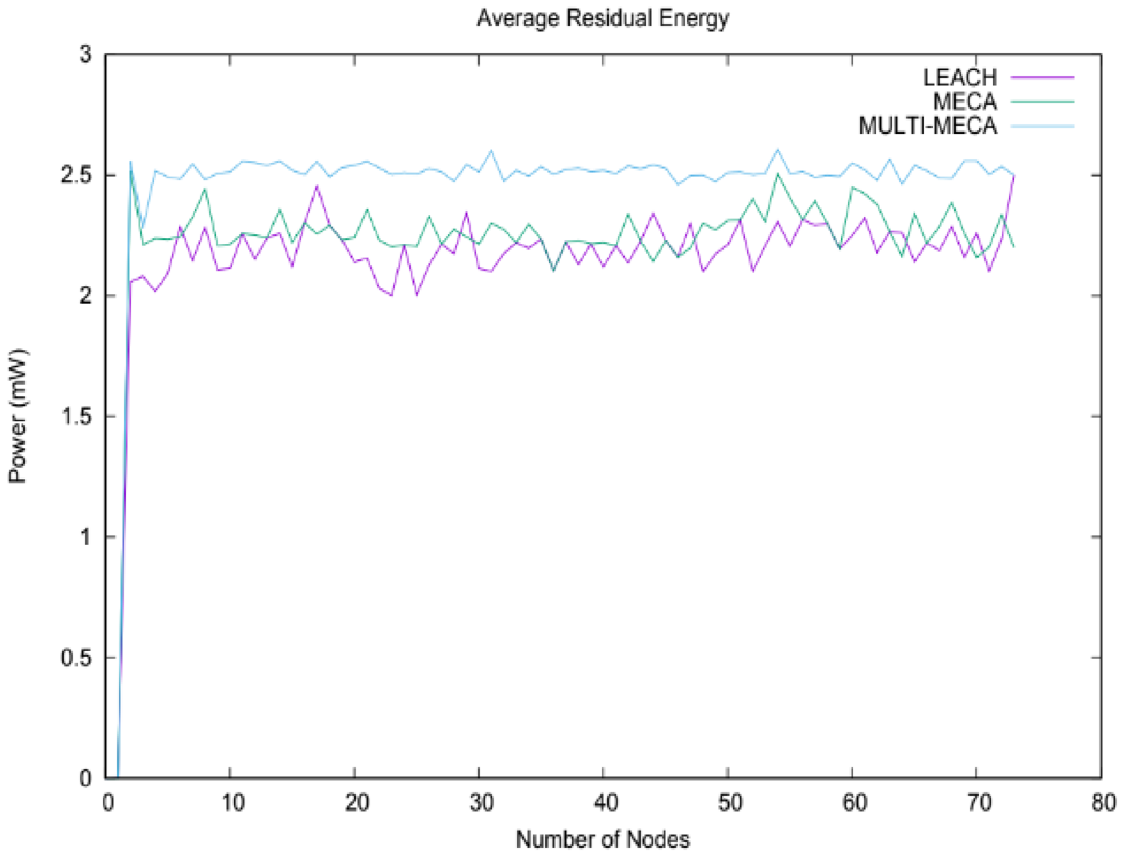

Fig.8: Average Residual Energy of LEACH, MECA and Multi-MECA for 75 nodes.

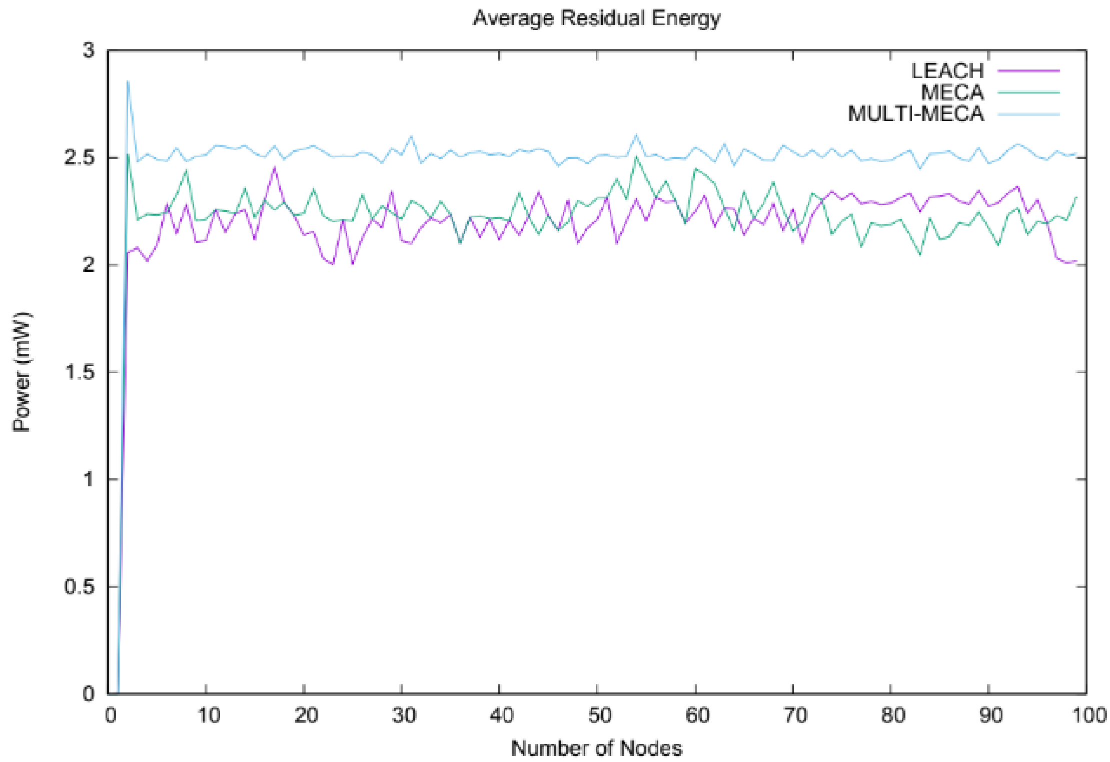

Fig.9: Average Residual Energy of LEACH, MECA and Multi-MECA for 100 nodes.

Fig.6 demonstrates the energy efficiency performance of Multi-MECA protocol with 25 nodes reaches the maximum compared to LEACH and MECA protocols. However, Multi-MECA performance is outstanding compared to other protocols.

Fig.7 demonstrates the energy efficiency performance of Multi-MECA protocol with 50 nodes reaches the maximum compared to LEACH and MECA protocols. However, Multi-MECA performance is outstanding compared to other protocols.

Fig.8 demonstrates the energy efficiency performance of Multi-MECA protocol with 75 nodes reaches the maximum compared to LEACH and MECA protocols. However, Multi-MECA performance is outstanding compared to other protocols.

Fig.9 demonstrates the energy efficiency performance of Multi-MECA protocol with 100 nodes reaches the maximum compared to LEACH and MECA protocols. However, Multi-MECA performance is outstanding compared to other protocols.

Using MATLAB R2021a, we simulate several Low Energy Adaptive Clustering Hierarchy (LEACH) and its modification protocols MECA, as well as the proposed protocol of our research study Multi-MECA in WSNs [35]. The variables in Table 3 are used for simulation. Energy and residual energy network, the number of nodes alive between rounds, and the number of data packets transferred to BS are the consequences of changing parameters used for evaluating clustering methods for heterogeneous WSNs that have been examined.

Simulation metrics

1- Dead nodes: Because they produce the fewest dead nodes, good performance is determinedby how many nodes have died since the previous round.

2- Alive nodes: The nodes that remained through the last round are the ones—with improvedperformance due to more active nodes.

3- Packets sent to the BS: specify how many packets the BS received for each round.

Table 3: a Table of simulation inputs in MATLAB

S. No.	Parameters	Values
1	Network Area	500*500
2	Number of nodes	500
3	Cluster head probability	0.1
4	Transmitter energy	50*0.000000001
5	Receiver energy	50*0.000000001
6	Number ofrounds	2500
7	Hard threshold	100
8	Soft threshold	2
9	Initial Energy	0.5
10	Aggregationenergy	5*0.000000001

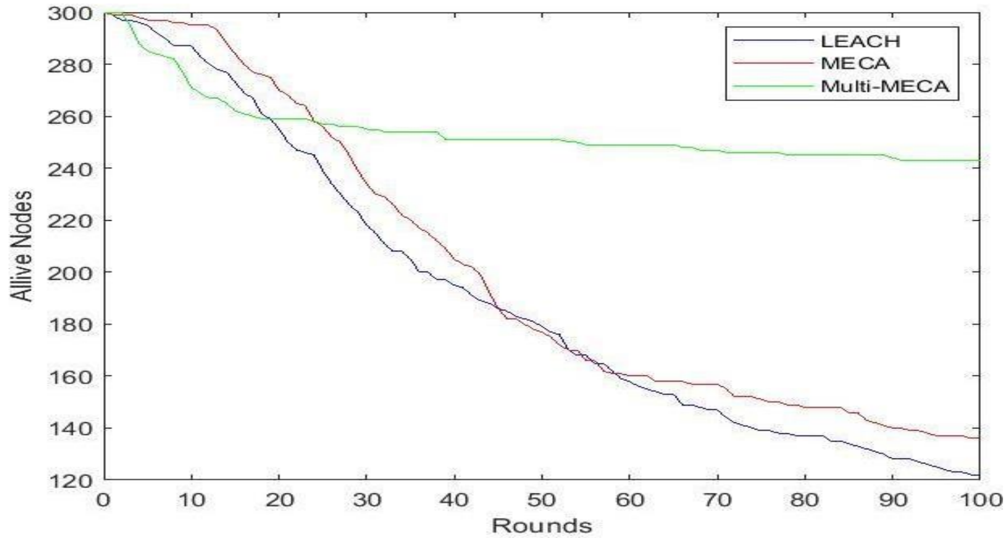

Fig.10: Alive Nodes

Fig. 10 illustrates how fewer live nodes are present for all protocols as the number of rounds rises. Multi-MECA operates well but requires multiple hops for all rounds, which has increased the lifespan of the protocol network for our comparisons. Multi-MECA has proven to be the best lifetime protocol.

Fig.11 demonstrates that as the number of rounds rises, all dead nodes exceed. Compared toother protocols, Multi-MECA has fewer dead nodes.

The Multi-MECA protocol counts dead nodes up to the limit in 2500 rounds, which is the finalround, while other protocols count dead nodes up to the limit in 2500 rounds more quickly andbefore Multi-MECA.

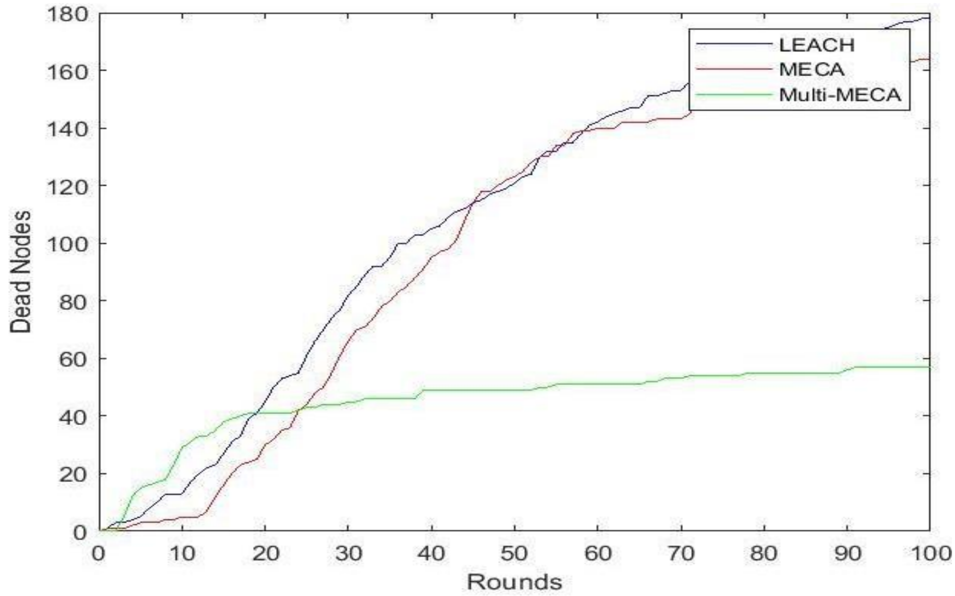

Fig.11 Dead Nodes

Fig.12 demonstrates that the package arrives at the base station with outstanding performance protocol and reaches the maximum with more rounds than it does with LEACH, MECA, and Multi- MECA protocols. However, Multi-MECA performance is outstanding compared to other protocols.

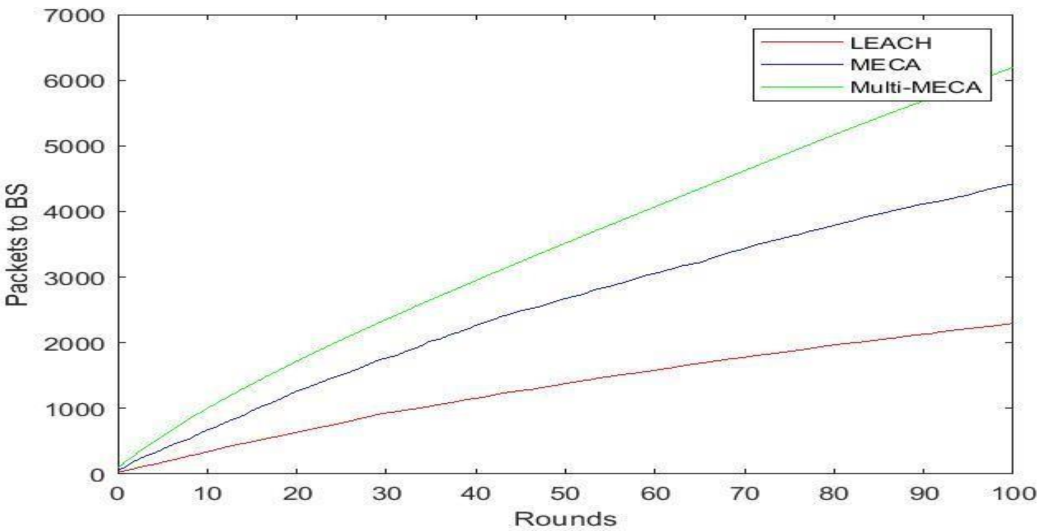

Fig.12: Packet sent to BS

OUTCOME OF THE PROPOSED STUDY

The proposed work attempts to give answers to these research questions:

- The proposed study can find the best energy-efficient routing protocol to enhance the node's lifetime in the Mobile Ad Hoc Network.
- Existing Energy efficient routing protocols for Wireless Sensor
- networks, such as the Low-energy adaptive clustering hierarchy (LEACH) protocol and its variants, are analyzed. Also, the Mobile-sink based energy-efficient clustering algorithm (MECA) is analyzed, and their working is understood.
- The Multi MECA protocol is more energy efficient than MECA and LEACH protocols.

The **Chapter 1** is **Introduction to Mobile Ad – Hoc and Wireless Sensor Networks**, whichconsists of elaborative introduction to Ad-Hoc Network, Ad Hoc Network Technology, Typesof Ad Hoc Network, Challenges of Ad Hoc Network, Ad-Hoc Networks Vulnerabilities , Ad-Hoc Networking Protocols, Ad-Hoc Networking , Ad-Hoc Networking Architecture, Ad-HocNetworking basic principles, Applications Areas of Ad-Hoc Networks, Mobile Ad-Hoc Networking Features, Challenges of Mobile Ad-Hoc Network, Vulnerabilities of Mobile Ad- Hoc Network, Mobile Ad-Hoc Networking Protocols, Wireless Sensor Networking Features, Challenges of Wireless Sensor Networks, Vulnerabilities in a Wireless Sensor Networks, Wireless Sensor Networking Protocols, Energy Management in Mobile Ad-Hoc Networks, Energy Management in Wireless Sensor Networks, Mobile Ad-Hoc Network Performance Metrics, Performance Metrics of Wireless Sensor Networks. An extensive literature survey on Energy Consumption Analysis of Mobile Ad-Hoc Network and Wireless Sensor Networks is depicted in **Chapter 2** and is **Review of Literature**. This chapter includes a review on Energy Efficient Routing Protocols in MANET, Energy EfficientRouting Protocol Based on AODV Protocol, Energy Efficient Protocols for Wireless Sensor Network, Energy Efficient Cluster Based Protocols for Wireless Sensor Network, Energy efficient mobile sink-based protocols for sensor network.

Chapter 3 is **Research Design and Methodology**, which explains the Objectives of the Research, Scope of the research, Proposed Methodologies, Mobile Ad Hoc Network, Method-1, Method-2, Method-3, Method-4, Method-5, Wireless Sensor Network, Method-1, Method- 2, Method-3.

Chapter 4 is **Energy Efficient Routing Protocols for Ad Hoc Network,** which explains Mobile Ad Hoc Network Routing Protocol, Ad Hoc On Demand Distance Vector Protocol, Limitation of AODV, Modified - AODV Protocol, Intelligent Routing AODV (IR-AODV) , Energy and Load Based Routing Protocol (ENL-AODV), Mobility Model and its Impact on Efficiency, Wireless Sensor Network Routing Protocols, LEACH Protocol, MECA Protocol, Network Model, Energy Model, Relocation of the Sink, Cluster Formation and Cluster Head Selection, Routing Procedure and M-MECA Protocol

Chapter 5 is **Simulation Design and Results,** which explains Protocols selected for simulation in MANET, Protocols selected for simulation in WSN, Performance Evaluation, AODV protocol, Comparison of AODV with other MANET protocols, Performance Evaluation of AODV with simulation Metrics, Performance Evaluation of ORES-AODV withsimulation Metrics, Comparative Evaluation of AODV and ORES-AODV with simulation Metrics, Performance Evaluation of AODV with simulation Metrics, Energy evaluation of AODV using Energy evaluation Metrics, Energy analysis and comparison of AODV and ORES-AODV, Comparative analysis of ORES-AODV and other leading AODV based protocols. Energy analysis of ORES-AODV and other leading AODV based protocols. Simulation for ORES-AODV, Simulation for WSN, Simulation metrics.

Chapter 6 is, **Analysis and Interpretation,** which explains, Effect of movement of node on Protocols, Mobility's Effect on Energy Use in MANET Routing Protocols, Varied node density andvarying mobility speed, the effect of mobility models on network routing performance, The effectiveness of MANET routing protocols under different node densities, Simulation of that

AODV, IR-AODV, M-AODV, ENL-AODV and ORES-AODV Routing Protocols for Differentiated Node Densities under Random Waypoint Mobility Model, Simulation of AODV, IR-AODV, M-AODV, ENL-AODV and ORES-AODV Routing Protocols for Various Node DensitiesDensity under Gauss Markov Mobility Model, Using the Basic Energy Model, the effect of mobilitymodels on Manet routing protocol energy consumption, Analysis in WSN.

Chapter 7 is **Summary, Conclusion and Future Scope**.

The overview, conclusion, limits, and findings of this study project are all stated in this chapter. Also recognized and mentioned are the potential directions for future research.

CHAPTER ONE

Introduction to Ad Hoc Network

Contents	Page No

1.1 INTRODUCTION

Ad Hoc Network is an infrastructure-less, peer-to-peer, Multi-Hop Network that does not require any fixed infrastructure. Ad hoc refers to the network without a base station and fixed topology. The fundamental aspect of Ad Hoc Networks is their simplicity of implementation, speed, and less reliance on infrastructure. The ad hoc network comprises more than two wirelessly connected devices [1]. As a result, each mobile host works as a router in an ad hoc network.

The ad hoc network faces several challenges because of its mobility and topology. The main challenges faced in Distinct ad hoc networks may have different traffic characteristics [2]. Besides traffic characteristics, the ad hoc network faces several other challenges dueto factors such as each host playing multiple roles. And topology changes after some time, nodes in the network might be mobile or stationary. There are frequent network splits, limited power capacity, wireless bandwidth, and varying channel quality. So, some ofthe questionable issues in ad hoc network is managing distributed entity without a centralized entity, routing support, channel access support, mobility issues, power conservation, and use of bandwidth efficiently.

The Ad Hoc network communicates by the infrared interface, where the transmission and reception occur with the same frequency band [3]. Ad Hoc network operates on Time Division Duplex mode, in which downlink and uplink are based on time slotswithin the frequency band.

In an Ad Hoc network, each layer of network protocol has to manage several issues, known asa multi-layer problem, which are typically not seen in fixed infrastructure [4]. The issue faced at the physical layer is rapid changes in the characteristics of the link. The problems arrive at the MAC layer, such as collisions, access, and data transmission over shared links [5]. The network layer is responsible for determining the paths and must maintain integration with traditional nonad hoc and ad hoc networks [6]. The transport layer of the Ad Hoc network also has to keep statistics of packet loss and delay in data transmission.

Ad Hoc networks are used mainly in hostile environments, where any fixed infrastructure is unavailable or cannot rely upon any fixed infrastructure in times of emergency. Suitable examples of Ad Hoc networks are military soldiers trying to communicate on the battlefield, Animal Behavioral Tracking in the forest, short-distance communication between laptopsin a conference room or communication within the campus, and biological detection sensors are dispersed across a metropolis., temporary network formation in office campaign headquarters,and undersea operations. The energy issues of the Ad Hoc network can be managed using sustainable renewable energies such as solar energy to recharge the batteries available in ad hoc network nodes.

The energyusage can be reduced using several routing protocols. The Ad Hoc Network evolved in the first generation, second and third generations can also characterize its life cycle.

1.2 AD HOC NETWORK TECHNOLOGY

The concept of packet radio was invented in the early-mid 1990s and was popularly used for defense purposes. Packet radios had several issues, such as massive data, considerably slow data rate, and link breakage due to high mobility [7]. The popularity of packet radio networks began to subside due to these issues. PRNET was a popular networking technology that provided communication among a collection of radios by sharing the broadcast radio channel. The characteristics of Packet Radio were quite similar to ad hoc networks. Because mobile repeaters were used, mobile terminals were used, but for routing, static stationswere used, due to which the PRNet was not ultimately infrastructure less.

In the mid-1990s, personal computers were gradually replaced by laptops, and the number of buyersfor laptops increased progressively. Due to this, the concept of an Ad Hoc network came into existence and became a research trend [8]. During this period of evolution, a new protocolcalled 804.11 was a popular technology.

1.2.1 TYPES OF AD HOC NETWORK WIRELESS MESH NETWORK

Mesh is a term used to recognize the highly interconnected nodes in the network. The mesh network is supported by a wireless backbone [9]. Wireless Mesh Network is formed usinglaptops, mobile phones, and other wireless gadgets. Mesh Network uses mesh routers, which send and receive traffic between gateways. The gateways are connected either connected to theinternet or not connected to the internet. Hence internet connection is not mandatory for forming a Wireless Mesh Network [10]. Another additional benefit of Wireless Mesh Network is network architecture does not require cabling. Mesh networks can include any device, either mobile devices with mobility or fixed devices deployed in a particular place and cannot move from one place to another. Mesh network is applicable in manyapplications, mainly VOIP services, because mesh network can route local telephone calls much efficiently through the mesh.

One example of Wireless Sensor Network usage in the real world is a Wireless Mesh Network. It is successfully implemented and deployed by the US military, and military laptopsknown as ruggedized laptops are interconnected using Mesh Networking Technology for fieldoperations [11].

Wireless Mesh Network is also used in electric smart meters in shops and homes. The electricity usage reading can be transferred to one another and finally reach the central electricity office for billing.

Through this feature, the mesh network collects meterreadings without the help of a human meter reader and avoids cable connections to the meters.

Wireless Sensor Network

Wireless Sensor Network is deployed in specific locations where environmental scenarios such as temperature, humidity, pressure, and other physical conditions are captured. The deployment of a Wireless Sensor Network is spontaneously installed in any hostile location, such as battlefield surveillance [12].

There are several application areas of Wireless Sensor Networks, for example, area monitoring, health care monitoring, Habitat monitoring, Earth sensing or environmental sensing, Air Quality Monitoring, Forest Fire Detection, Water Quality Management, etc.

Mobile Ad Hoc Network

A mobile ad hoc network differs from a wired ad hoc network because it does not rely on any pre-existing infrastructure [13]. The wired infrastructure requires routers and access points, butAd Hoc Network does not require such devices.

The instant formation of the network topology is possible in mobile Ad-Hoc networks, and onenode can communicate to another node only by sending data packets to neighboring nodes with the help of routing algorithms.

The routing algorithm selects the routes dynamically based on network connectivity. The mobile nodes of a network may move in any direction, and the mostchallenging factors are involved while routing the packets, such as sharing limited communication bandwidth like a slice of the radio spectrum.

1.2.2 CHALLENGES OF AD – HOC NETWORK

The Ad hoc network has several issues due to its infrastructure, limited resources, and the scenarios in which it is deployed. The most challenging issues of Ad-Hoc networks are described below.

Synchronization

The bandwidth reservation is the main challenge faced by Ad-Hoc networks because network nodes must reserve bandwidth using synchronization [14]. TDMA in an Ad-Hoc network requires synchronization of nodes because of the scarcity of bandwidth and energy.

Synchronization isessential to avoid the collision that can occur in the network. Synchronization control packetsalso can cause overhead in the network.

Hidden Terminals

Hidden terminals are network nodes that are inaccessible to the sender but accessible to the session's receiver. The hidden terminal problem of Ad Hoc network, as shown in Fig.1.1 (a) can cause a collision which results in a reduction in throughput.

Exposed Terminals

Exposed Terminals are within the sender's ongoing session's transmission range but cannot transfer data. As shown in Fig.1.1 (b), the protocols must control exposed terminals' transmission.

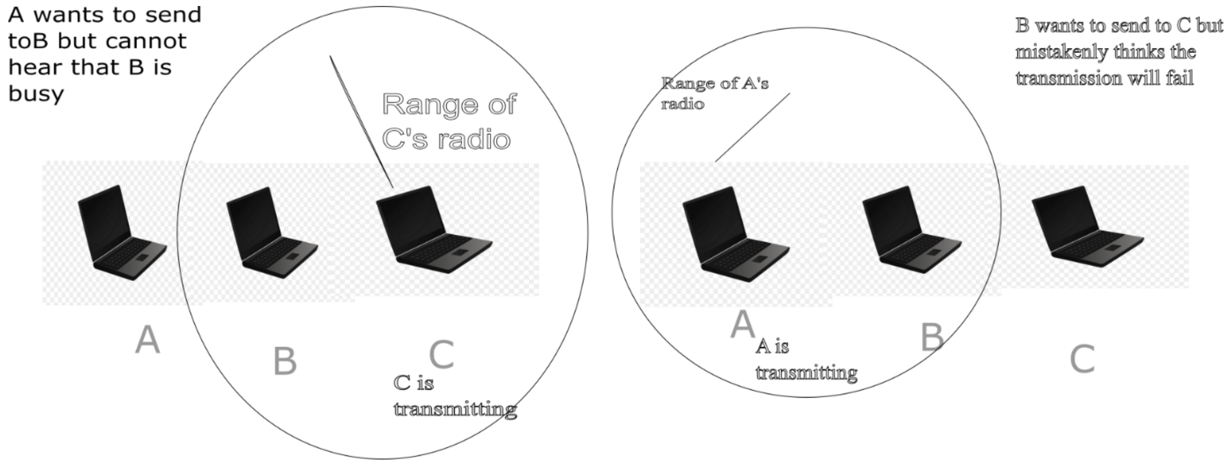

Fig 1.1 a) Hidden Station Problem b) Exposed Station Problem.

Throughput

Throughput will increase when the number of collisions minimizes, and channel utilization and control overhead minimize, as shown in Fig.1.2.

Access Delay

The MAC layer keeps track of delays that can occur due to obstacles in the transmission.

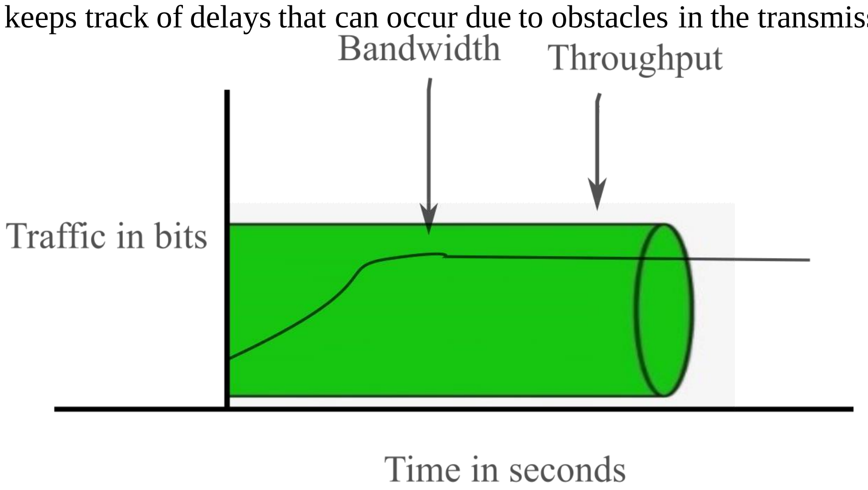

Fig.1.2 Throughput of the Network.

Fairness

Fairness is classified into two types, one is node-based, which gives the same share to every nodein the network, and another one is flow-based, which provides an equal claim to the competing data sessions.

1.2.3 AN AD-HOC NETWORK'S VULNERABILITIES

The principal vulnerabilities of an Ad-Hoc network are as follows.

Confidentiality

Maintaining information about network topology and its geographical location is a challenging task. If any flaws occur in handling the information related to these issues, then the network will lead to vulnerability in confidentiality.

Traffic assistance in real-time

In a contention-based channel access environment with limited bandwidth and no central coordination, the network must handle video, audio, and real-time data, which necessitates explicit support.

Resource Reservation

Resource Reservation is necessary due to the shortage of resources available in nodes and the network, such as bandwidth and energy.

Power Control Capability

Transmission power management decreases power control, lowering energy consumption atnodes, lowering interference at nearby nodes, and increasing frequency reuse.

Adaptive rate management

The data bit rate fluctuation obtained through a channel is referred to as this.

Directional Antennas are used to direct signals.

The directional antennas will allow for more spectrum reuse, less interference, and lower powerusage.

Integrity

Integrity within the Ad-Hoc network will prevent network form vulnerabilities. The loss of integrity will lead to incorrect routing, which may cause nodes to select the faulty router.

Availability

If a node has access to a route, it must be able to interact with other nodes with access tothe same route at any time.

Authorization

Unauthorized access to the network has to be verified and blocked, and only authorized nodes have access to the network. If unauthorized nodes are permitted to access the network, then those nodes will cause several issues.

1.2.4 AD-HOC NETWORKING PROTOCOL

Ad Hoc networking protocols are grouped into two categories based on its features.

Proactive routing (table-driven).

Proactive routing systems preserve information on all routes throughout the network, even if they are not necessary [15]. These protocols regularly send control information between nodes, ensuring each node has up-to-date routes. The main drawbacks of the proactive protocol are its sluggish response to restructuring and its failure.

On-demand (reactive) routing

Route discovery on demand is achieved by saturating the network with data packets. The main disadvantages of the reactive protocol are highly time consuming. In this protocol, the originator node starts the route search process while sending data packets to a destination node.

1.3 AD HOC NETWORKING

There is no central access point on an ad hoc network. This network doesn't have any access points [16]. The nodes in this network interact directly with its neighboring nodes. This type of network provides flexibility. Also, this type of network is fit for smallercoverage areas. Communication between the nodes is easily hampered by interference and noise.

However, detecting an error is accessible in an Ad-Hoc network compared to a structured grid.Also, configuring and reinstallation is pretty economical as well. These networks are costly for asmall coverage area. Also, the information transmission is unreliable compared to the infrastructure network.

But they are beneficial for emerging purposes like floods, earthquakes, etc. The transmission is not very secure, but it is fast and meets the demand for emergency communication.

1.3.1 AD HOC NETWORKING ARCHITECTURE

The Mobile Ad Hoc network architecture contains three parts, as shown in Fig.1.3. They are classified as Enabling Technologies, Networking, and Middleware & Applications.

1. Enabling Technologies can be further classified based on the coverage area as Body Area Network, BAN can only cover up to 1 to 2 kilometers. And this network is used for the connectivity of wearable devices [17]. The second classification is Personal Area Network (PAN) can range up to 10 meters. The PAN can give connectivity among mobile as well asstationary devices. The third classification is WLAN (Wireless Local Area Network). The range of communication is up to 500 meters. WLAN can establish communication betweenbuildings or groups of buildings. The fourth classification is
2. Networking: networking always aims to provide one-hop transmission from the source node to the destination node. Finding the best path from the source to the destination is a tedioustask for networking protocols due to the criteria and parameters for selecting an optimal path for transmission with minimal packet loss and delay.

3. **Middleware and application:** the technologies used in Mobile Ad Hoc Networks are WiFi, Bluetooth, IEEE 802.11, WiMAX, and Hyper LAN have drastically brought a revolution in networking communication and extensively improved the ad hoc networks and their applications in the fields such as natural disasters and other similar emergencies [18]. The recent development in the Ad Hoc network has not included middleware, and they have started completely to use applications. Applications are developed to provide all the necessary services required.

1.3.2 AD HOC NETWORKING BASIC PRINCIPLES

An ad-hoc network, as shown in Fig.1.4, is a tiny network connected via wireless networkconnections. The ad hoc network devices are only connected to the network during a communications session [19]. Ad hoc networks provide several useful applications.

Ad Hoc Networking Principles:

- Physical layer, medium access control, Bluetooth discovery and network construction, wireless network programming and protocols, and other major ad hoc network characteristics are all addressed.
- Detailed explanations of the critical components of ad-hoc networks are provided, along with several activities to enhance comprehension.
- Presents essential findings and incorporates both practical and mathematical aspects.

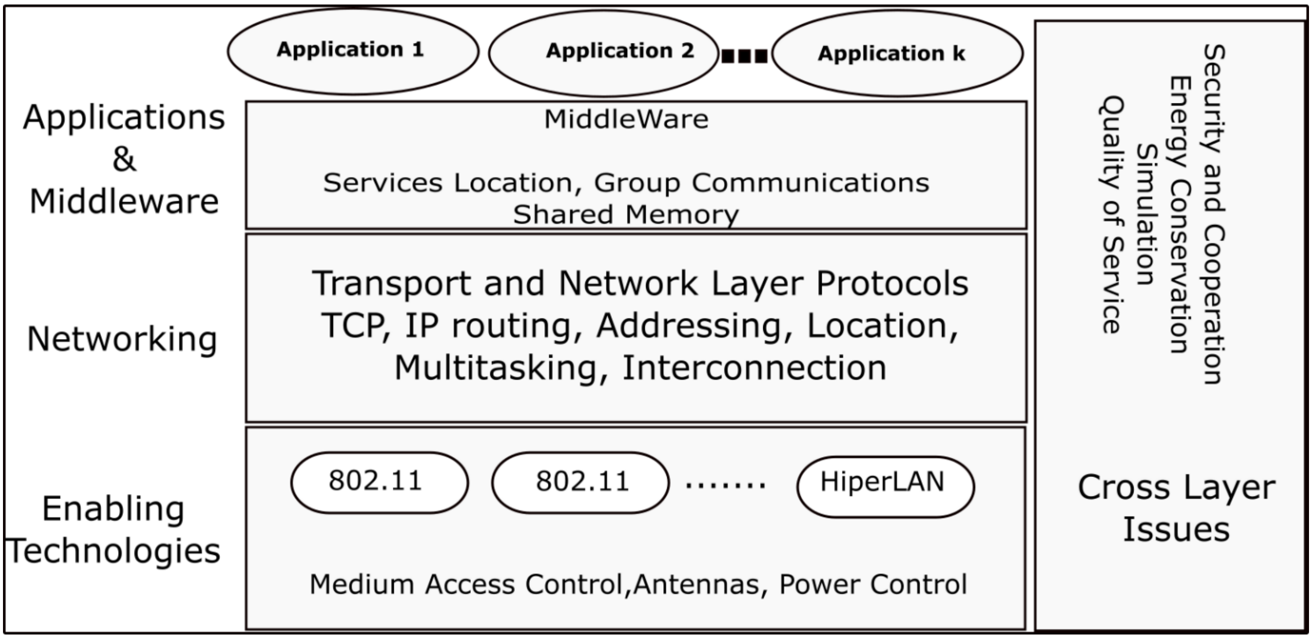

Fig 1.3: Architecture of Ad Hoc Network

1.3.3 APPLICATION AREAS OF AD HOC NETWORK

With a minimal or no communication base, one can employ ad hoc networking at any time and in any form by many organizations worldwide. The first framework is either costlyor inconvenient to use [20]. The ad hoc network architecture as shown in Fig.1.4 helps boost the efficiencyand benefit of continuous business applications and corporate organizations.

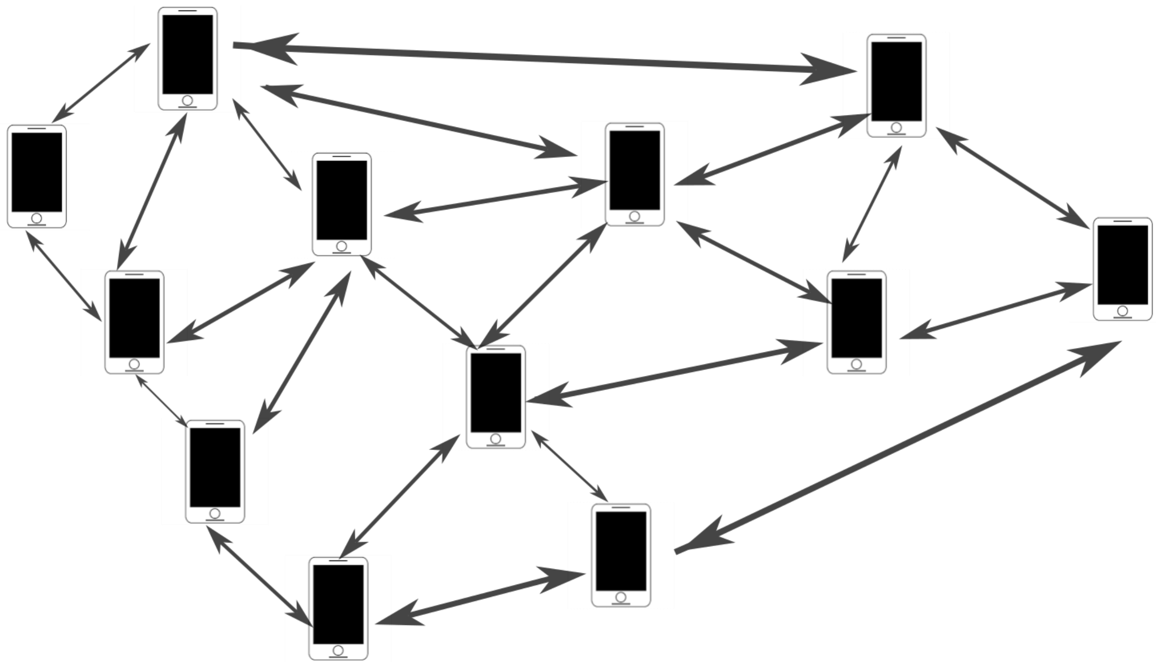

Fig 1.4: Ad Hoc Network

The following are the different types of ad hoc networks and how they are used:

MANET stands for Mobile Ad hoc Network, a self-organizing, infrastructure-free cell phone network interacting via a distant link.

VANET is a mobile network that employs autos as nodes [21]. A Wireless Sensor Network (WSN) is a collection of separate sensors that regulate ecological processes.

- Military – the Ad Hoc network is very efficient in providing a network to all the soldiers andtheir vehicles and communication to the headquarters.
- PAN A PAN (Personal Area Network) is a short-range, local network in which eachnode is generally connected to a specific range. Because it is effortless to develop, an individual may use it to convey emergency messages during a disaster.
- A doctor might use it to keep track of patients in a medical setting.
- Scientists may use it to check weather conditions, forest fires, and tsunamis, among other things.

1.4 MOBILE AD-HOC NETWORKING FEATURES

Some of the features are listed below.

- The mobile devices converse and transfer data directly to each other without using hardware or established infrastructure.
- Self-repairing.
- Configuration is done automatically.
- On-the-go, spontaneous networks are also called Mobile Ad-hoc Networks(MANET).
- Each node of the network does the functionalities of a router, sending data packets from one device to the next.

1.4.1 CHALLENGES OF MOBILE AD HOC NETWORKLimitations on Bandwidth

Wireless lines have a lower capacity as compared to infrastructure networks. The impact of fading, multiple accesses, and interference is minor compared to the maximum radio transmission rate. In Ad hoc networks, the effect on signal quality is much less severe than inan infrastructure network.

Dynamic topology

Because of the changed topology, the nodes have less trust between them. The trust level is also questioned if a resolution is established between the nodes.

High Routing

The table is based on the dynamic topology of ad-hoc networks, which means nodes can change from one network node to another over time.

The problem of Hidden terminal

Packet collision, also known as packet loss, happens when packets are transmitted and receivedoutside the sender's and receiver's direct transmission range.

Transmission problems and packet loss

Collisions, hidden terminals, interference, unidirectional connections, and frequent route breakdowns induced by node mobility have contributed to increased packet loss in ad hoc networks.

Mobility

Path breakdowns are common in Ad Hoc networks due to dynamic nature andchanges in the network architecture caused by node migration.

Threats to national security

Ad hoc networks introduce unique security concerns due to their wireless nature. Trust management between nodes in ad hoc orwireless networks leads to several security flaws.

1.4.2 VULNERABILITIES OF MOBILE AD-HOC NETWORK

The insufficient secure boundaries in Mobile Ad-hoc Networks are a crucial issue and the most notable difference from wired traditional networks. Nodes, in particular, can roam across the network at will and are the root of this vulnerability.

An attacker on a mobile Ad-hoc network does not need physical access to the network. On the other hand, accessing a wired network requires going through security obstacles such asfirewalls and gateways. As a result, the network can be harmed.

It may, for example, have a destructive impact on sent data by replacing confidential information or even disseminating vital information. Second, dangers emerge from inside the network, from hacked nodes. An attacker on a mobile Ad-hoc network does not need physical access to the network. On the other hand, accessing a wired network requiresgoing through security obstacles such as firewalls and gateways. As a result, the network can be harmed.

It is impossible to indicate which node has been attacked or to configure the malicious behavior.This drawback will lead complex for the user to regain trust in the network member nodes.

It's challenging for the network to detect assaults, let alone control or monitor traffic inhigh-speed environments, due to the lack of centralized management equipment.

Mobile Ad-hoc networks cannot regulate which nodes can be trusted and which cannot. The data transmission breaks down and fails as a result [22]. These nodes are not participating in any security activities, highlighting the large gap between them and the connected network.

1.4.3 MOBILE AD-HOC NETWORKING PROTOCOLS

An ad-hoc network's nodes are unaware of their network's topology and must figure it out on their own and interact with one another. The Ad-Hoc Networks are classified, as shownin Fig.1.5, into several categories based on their features and functionalities.

Pro-active routing protocols:

The topology of a mobile ad hoc network (MANET) is dynamic, and Nodes have no idea what their network's topology is and must figure it out for themselves. When a new node joins an ad-hoc network, the node advertises itself for its presence and pays attention to other mobile nodes' announcement broadcasts.

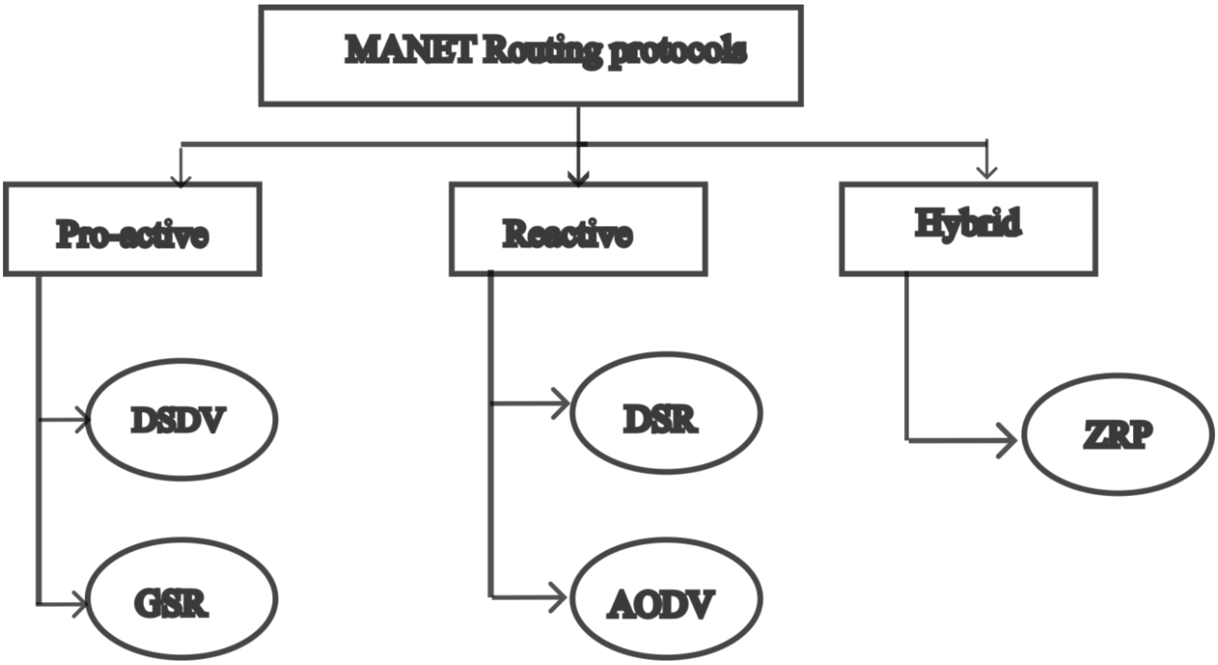

Fig 1.5: Classification of Mobile Ad Hoc Network Protocols

Destination Sequenced Distance Vector Routing Protocol (DSDV):

Bellman-ford routing extends the wired network's distance vector routing protocol. The count-to-infinity problem makes it inconvenient to use for mobile ad hoc networks. Another solution emerged called the Destination Sequenced Distance Vector Routing Protocol was created.

Every routing item in routing database stores a sequence number given to it known as destination sequence number. The database is updated when the entry to database has a new updated path with greater sequence number.

Global State Routing (GSR) is a proactive table-driven routing strategy. It enables wired Networks to extend their link state routing capabilities. Dijkstra's routing algorithm is used. GSR was not initially designed for mobile ad-hoc networks.

Global State Routing Protocol (GSR) was designed to prevent packets from flooding mobile networks. GSR maintains track of one list and three tables for each mobile node: adjacency, topology, next hop, and distance [23]. The protocol does not saturate the network with link-state routing packets.

Reactive routing protocols:

Route discovery is achieved by broadcasting request packets routed over the mobile network. There are two parts to route discovery: route discovery and route maintenance, as well as route identification and route mapping.

Dynamic Source Routing protocol (DSR):

It's an on-demand/reactive routing system, where the path is only identified when it is requiredby the phone operator or other network operator.

It is split into two sections:

Route Discovery: The optimized path for data packet transmission between the movable nodes of origin and destination is identified during this phase.

Route Maintenance: Because of this, numerous instances of connection breakage between mobile nodes cause failure. Hence, this phase carries out route maintenance.

Ad-Hoc On-Demand Vector Routing protocol (AODV):

It's a reactive or on-demand routing protocol. It's a DSR enhancement that helps to mitigatethe protocol's drawbacks. The whole path is included in the header when the movable node oforigin transmits the packets to the node's final destination.

AODV and DSR are both based on the Ad-Hoc On-Demand Vector Routing protocol. The real distinction is in the method of saving the path. The path is saved in the routing database by AODV,but DSR saves in data packet header. Functionalities are similar, with two levels: route discovery and route maintenance.

Hybrid Routing protocol:

The most popular and extensively used hybrid routing technology, as shown in Fig.1.6, is Zone Routing Protocol (ZRP). It effectively integrates reactive and proactive advantagesand proactive routing strategies into a single solution. These protocols are adaptable to the zoneand position of the movable nodes of origin and destination.

The system is divided into zones, and the mobile node's origin and destination whereaboutsare then monitored. Data is routed using proactive routing packet transfer between sources and

Destinations when they are in the same zone. The reactive routing method sendsdata packets between different mobile nodes.

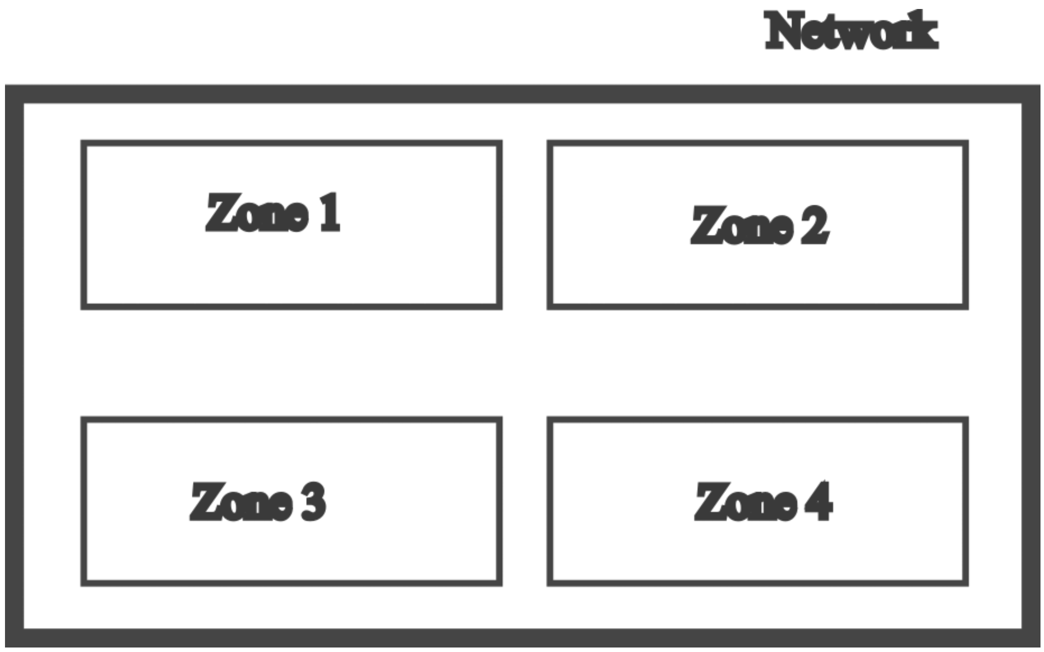

Fig 1.6: Hybrid Routing Protocols

1.5 WIRELESS SENSOR NETWORKING FEATURES

A sensor node is a tiny but significant portion of a wireless sensor network comprising many distinct components. Power efficiency, scalability, responsiveness, dependability, andmobility are all features of a successful wireless sensor network, as shown in Fig.1.7. A wirelesssensor network with these properties can be beneficial. Still, if they are not followed or assured, the network will suffer from overhead, reducing its usefulness.

Power efficiency in wireless sensor networks:

As the name suggests, power efficiency refers to a network's capacity to tolerate mobile nodesand changing data pathways.

Because of how the architecture is set up, a highly responsive wireless sensor network is required to deal with the situation. The ability of a network to manage mobile nodes and change data pathways is referred to as mobility.

According to the design, the wireless sensor network must be responsive to mobility [24]. As a result, designing a large-scale and mobile wireless sensor network becomes more difficult. As a result, developing a large-scale and transportable wireless sensor network becomes more difficult.

The efficiency levels of the equipment in issue are referred to as guests, the device can use less power to accomplish more by working atdeficient power levels.

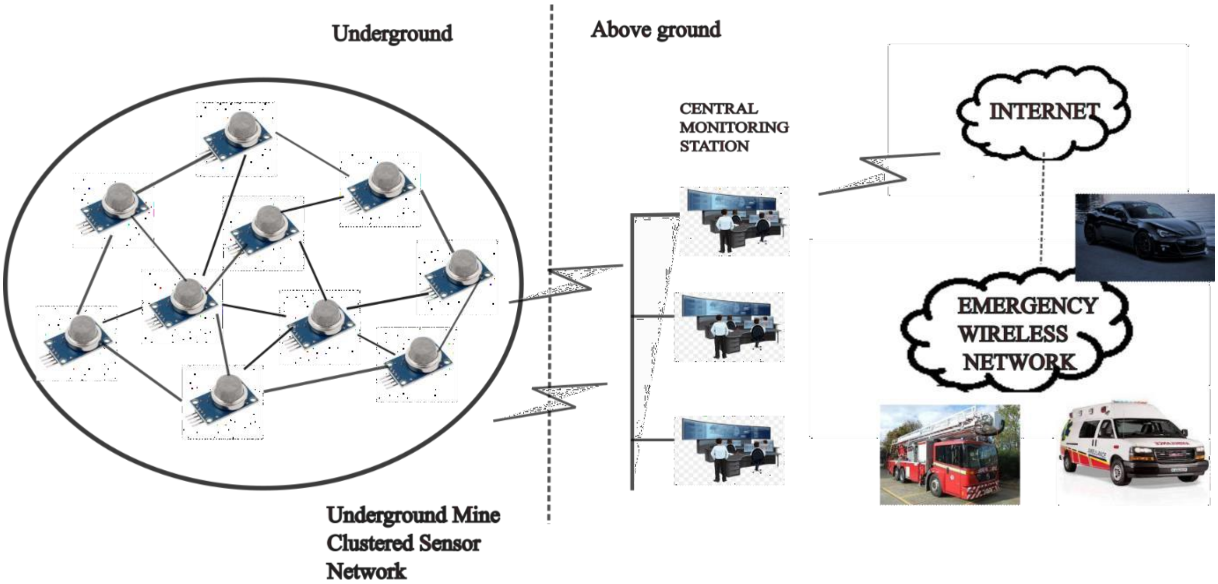

Fig 1.7: Overview of Wireless Sensor Networks

This is a critical feature, especially since sensor nodes in wireless sensor networks arefrequently placed in remote locations without appropriate access to a power source.

As a result, these gadgets are frequently designed to function with a power source other thandirect electricity. The most efficient design strategy would be to reduce each node's duty cycle.

Wireless sensors are also put into sleep mode to preserve energy, making them unresponsiveto neighbor communication.

Scalability in wireless sensor networks:

A network's ability to scale in terms of the number of nodes linked to it without incurring excessive overhead is called scalability. Although the fundamentals of such a network frequently only have a few nodes, they must accept more.

There are many different types of networks; for example, in an ad hoc network, the network isbuilt without any specified architecture. Therefore, nodes that want to connect must generate more packets than their data packets. As the network expands in size, more packets will be necessary.

As the network grows, the chances of communication links breaking rise. As the network increases, only a tiny amount of bandwidth will be available for application data transfer.

The responsiveness of a network is defined as its capacity to adjust swiftly to changes in topology. However, having a highly responsive network has drawbacks; the nodes must make sacrifices. In a highly responsive network, as shown in Fig.1.8, packet delivery latency and scalability will both reduce in a dynamic environment.

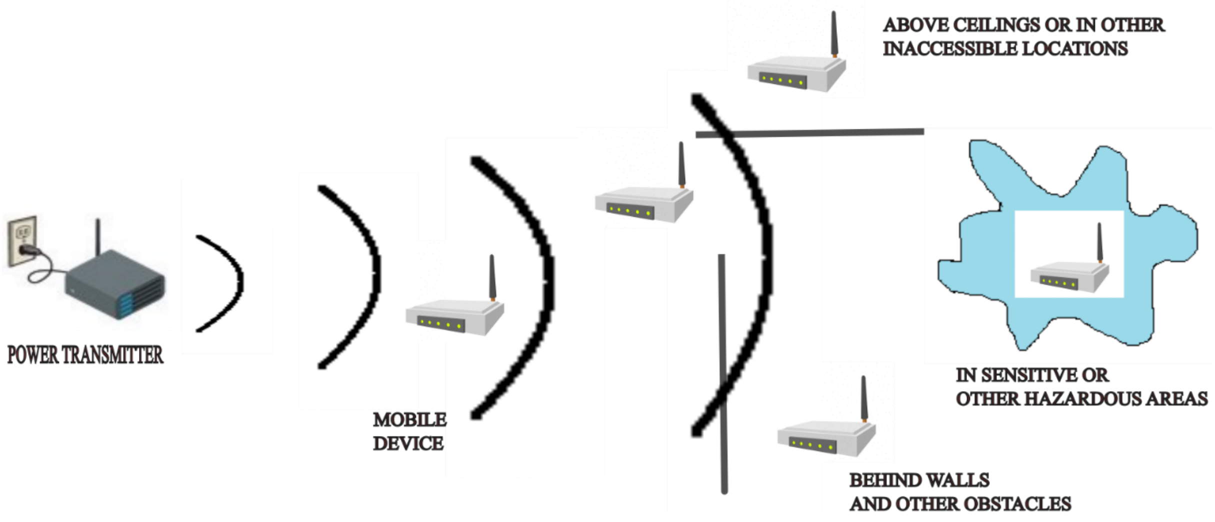

Fig 1.8: Wireless sensor networks responsiveness

Reliability in wireless sensor networks:

Any network must be dependable; this is a basic necessity. In a network structure that is frequently changing, you need reliable data transfer.

In ad hoc wireless networks, scalability and dependability frequently have an inverse relationship [25]. Due to this, maintaining reliability gets more difficult as the network'snode count grows.

If the network is highly scalable and is grown up to a more extensive network than planned,the dependability of data transmission will be strained, and the node's path will reach sooner.

Sensor network mobility:

Mobility refers to a network's capability to manage network nodes in mobility and shift paths. The wireless sensor network must be very responsive to mobility, according to the design shown in Fig.1.10. As a result, designing a large-scale and transportable wireless sensor network becomes more difficult.

1.5.1 CHALLENGES OF WIRELESS SENSOR NETWORKS

Challenges in real-time:

The World Nuclear Society's (WSN) work on real-time sensor monitoring has produced relatively few results. Sensor data must frequently be provided within a specified time frame so that the protocols may take relevant observations or actions. Most protocols either ignore or process data as rapidly as possible in the hopes of meeting deadlines. New findings are necessary to meet soft real-time requirements as shown in Fig.1.9 and cope with the realities of WSN.

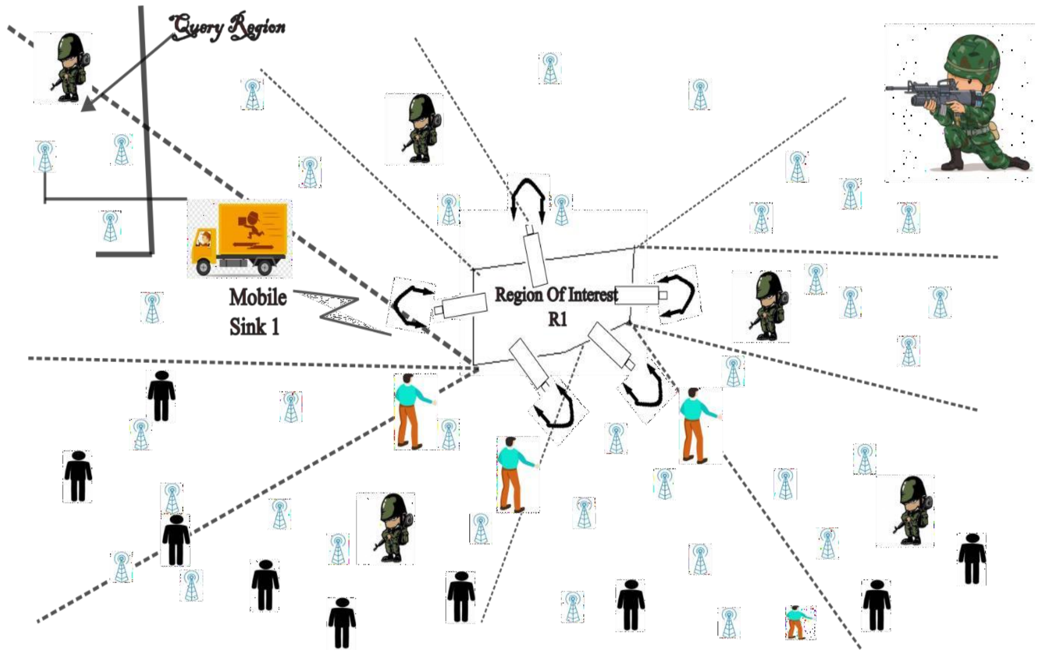

Fig 1.9: Role of WSN in wireless City.

Feedback control looks to be promising for both steady state and transient behavior. Differentiated services are needed to handle different types of traffic, with assurances for crucial and non-crucial traffic.

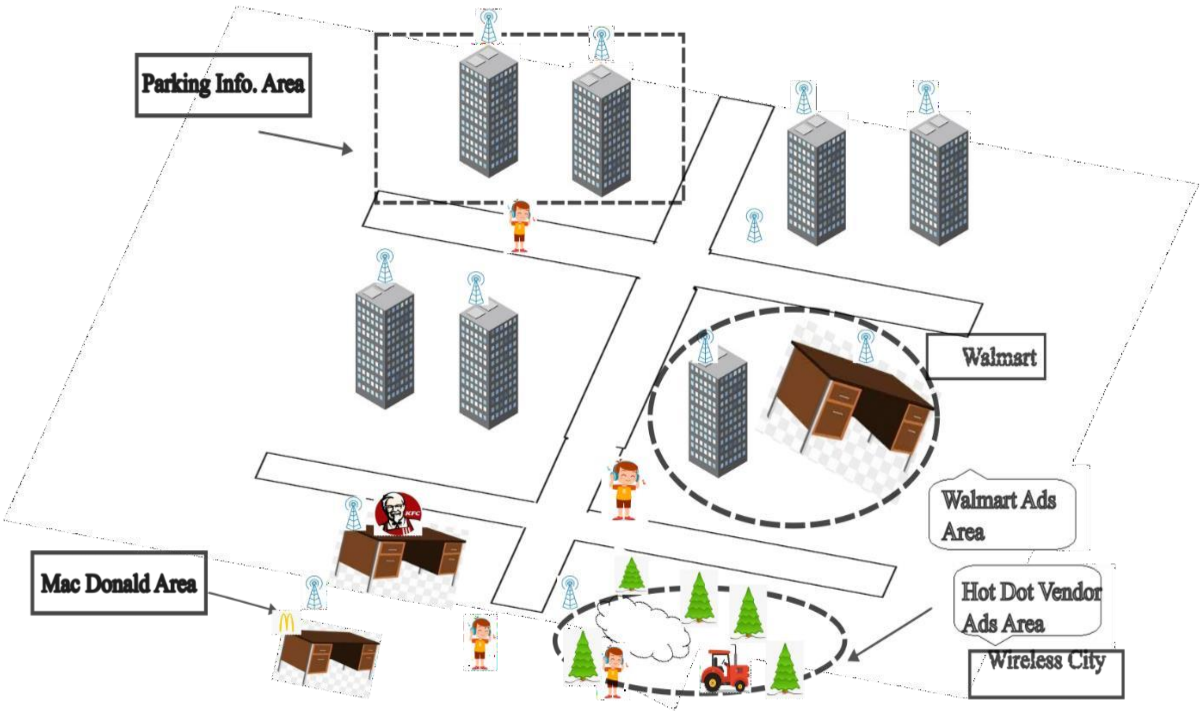

Fig 1.10: Mobility in Wireless Sensor Network during hostile situations.

Challenges in power management:

Sensor networks may be limited by CPU bandwidth and memory, although manufacturers willaddress these issues as manufacturing techniques improve [26]. There is unlikely to be a shortage of energy alleviated vary due to the slow pace of advancement in boosting the battery's capacity. Much of today's research is centered on the best way to supply complete or sensing coverage thatis only partial while conserving energy.

WSN Scale and Time Variability

Nodes of sensors have limited resource capabilities. WSN densities can range from highlysparse to extremely high, depending on the application. In reaction to this, sensor nodes may need to adjust their behavior in response to the irregular behavior of high amounts of noise andradio-frequency interference disrupting wireless connectivity.

Management at a Distance:

Managers or operators must handle their networks directly. As a result, a method for indirect,remote control and administration should be included in the framework. Sensor nodes, such as subway stations, will be deployed in our front field to enable them to be monitored remotely.

1.5.2 VULNERABILITIES IN WIRELESS SENSOR NETWORKS

Sensor networks have to be compared to a vast database. Exclusive access to data is required for users, and data should always be available upon request from an authorized user. Sensor networks and their users are subject to all of these situations. From the user's perspective, the distributed database and the sensor network are treated as one entity. As a result, we refer to these security concernsas "outside security." Outside security includes query processing, access control, and large-scale anti-jamming services.

Internally, a distributed database and a sensor network are quite different. The communication between the internal system components provides the foundation for security from the outside and any other communication between the user and the associated system (servers or sensor nodes, respectively). Such interactions are referred to as security concerns within security. Inside security in sensor networks guarantees that each node's communication is safe,private, and authenticated [27]. A distributed database comprises a few robust servers that are highly shielded from physical and network assaults.

Security techniques developed for distributed databases are incompatible with sensor networks.Sensor networks are a collection of many unmanaged sensor nodes with limited resources and are physically fragile. Aside from apparent resource constraints, single sensor nodeshave a minor impact on the overall system's quality.

To conclude, sensor network security aims are comparable to the distributed database (outside security) and distributed system security goals (inside security). As a result, these can be usedas a starting point. While the criteria are comparable because they consume excessive resources or cannot grow to a large number of nodes, many conventional security solutions (such as public key infrastructures or agreement protocols) are ineffective.

1.6 WIRELESS SENSOR NETWORKING PROTOCOLS

The Ad Hoc routing protocols are responsible for observing how nodes communicate with one another and how data is distributed throughout a network. There are several ways to classify WSN routing protocols. Fig.1.11 shows the basic routing protocols for WSN networksin North America, Europe, Asia, and the Middle East.

Centric on the node

The target node in node-centric protocols is supplied with IDs, and these IDs are numeric,which is not required in wireless sensor networks. Adaptive clustering hierarchy with lowenergy, for example (LEACH).

Low-energy adaptive clustering Hierarchy (LEACH)

LEACH is an algorithm that distributes energy equally among all of the network's sensor nodes.The LEACH protocol creates many sensing nodes clusters, with only one particular node as a head of the cluster and remaining nodes as a routing node in the cluster.

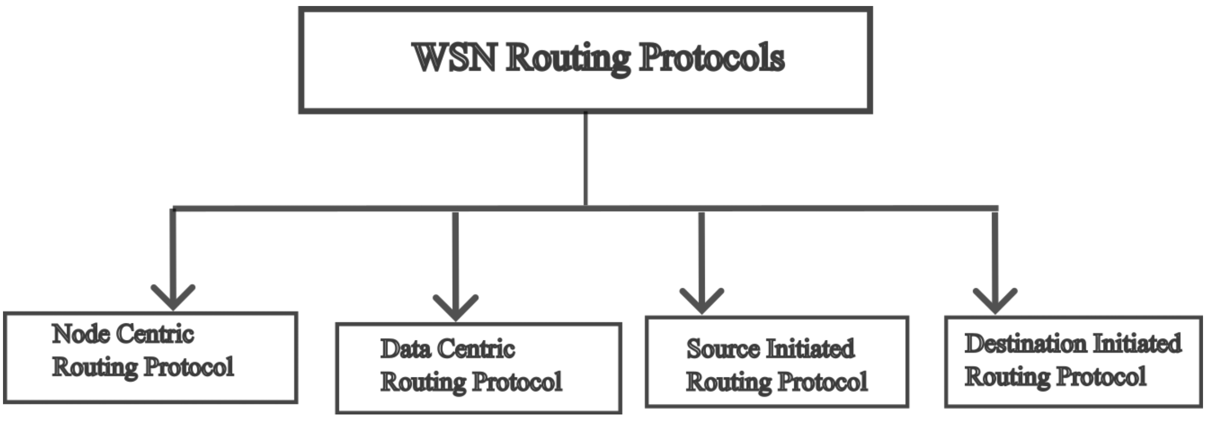

Fig 1.11: Types of WSN routing protocols.

The cluster head is appointed randomly from a set of nodes on a short-term basis so that the protocol can sustain for a longer duration because a single node's battery is not overworked.

Data-centric

Data-centric routing solutions focus on conveying information indicated by specific attributes rather than the physical location of nodes in a network. The sensed data or information is substantially more essential than any physical node in most wireless sensor networks, according to researchers at Texas A&M University.

Because the sink node in data-centric routing searches specific locations for data with particular characteristics, the data quality must be defined using an attribute-based naming scheme. Hereare a couple of such examples:

Information negotiation methods using sensors (SPIN)

Sensor protocol for information via negotiation is abbreviated as SPIN. This protocol is intended to eliminate SPIN for Sensor Protocol for Information through Negotiation, as shown in Fig.1.12. This protocol is developed to alleviate problems in existing protocols, such as flooding and gossiping. Data sharing sensed by a node consumes more resources than sharing meta-data, and it is a description of the data perceived by the node. The resourcemanagement of every node keeps an eye on its resources and makes adjustments as appropriate.

Destination Initiated (Dst-initiated)

The path setup generation occurs when a path is set up from one node to another. The processis called a destination-initiated protocol (DI) and is similar to a direct diffusion (DD) or directed energy exchange (DIE) network protocol.

Directed Diffusion (DD)

Diffusion routing is a data-driven approach. This data-centric technique is used to acquire and disseminate data. The network's lifespan is prolonged since this routing technology is also energy efficient and saves electricity. The directed diffusion routing protocol does not requireaddressing because all communication occurs between nodes.

Initiated by the source (Src-initiated)

When a source node has information to share, it advertises it, and a path is built from that information to the next node in the chain. SPIN is a good example.

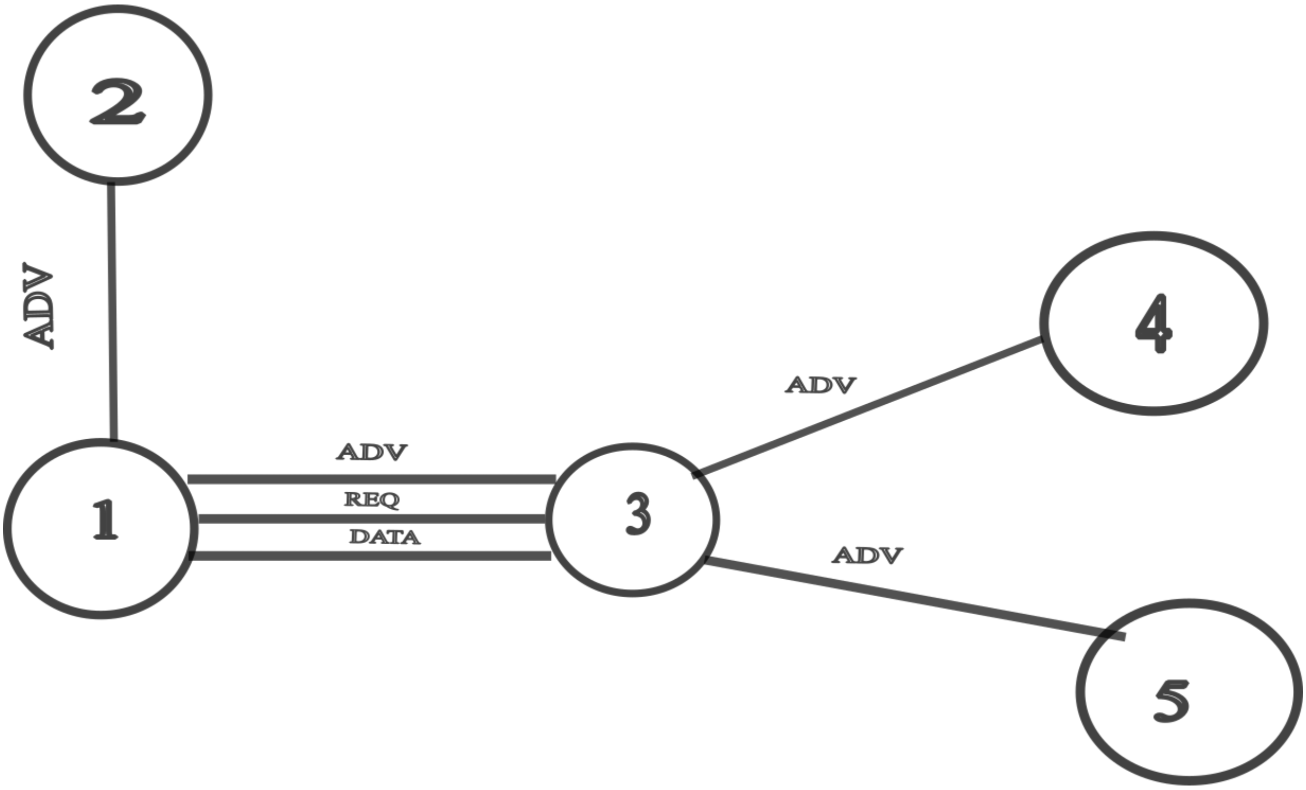

Fig 1.12: shows the SPIN routing protocol in action.

1.7 ENERGY MANAGEMENT IN N MOBILE AD – HOC NETWORKS

Mobile devices in Ad Hoc wireless networks are often battery-powered. Each device's calculation and communication capability are restricted by its energy budget. Within the network, energy resources and compute demands are distributed differently.

When a device has used up all of its energy, it can only be recharged when it is no longer connected to the network. The computing ratio to communication energyusage in wireless networks fluctuates greatly depending on the application type [28]. Communication consumes themajority of energy in some applications, tiny sensor networks, and other uses. In several application fields and applications, such as simulation, artificial intelligence, target detection, handwriting identification, and voice recognition, computational energy consumption frequently outnumbers communication energy consumption.

There are various reasons for energy management in ad hoc networks:

Energy reserves are limited: The Ad hoc networks have a finite amount of energy. Compared to mobile computing and connectivity developments, battery technology is progressing at a snail's pace.

Difficulties with battery replacement: It is hugely. In some cases, replacing and chargingbatteries is challenging, such as on battlefields, natural catastrophes, earthquakes, etc. As aresult, energy conservation is critical in such scenarios.

Inadequate central planning: Ad hoc networks are decentralized networks with no central coordinator. Some of the multi-hop routing nodes should serve as relay nodes. The relay node consumes more power when there is alot of relay traffic.

Battery-related constraints: The battery's weight at each node may cause the node's weight to grow. If the battery's weight is reduced, the battery's power is reduced, and the battery's lifetime is diminished. As a result, energy management strategies must address maximizing the utilization of energy resources and minimizing the battery's capacity.

Choosing the optimum transmission power: As transmission power increases, so does battery charge consumption. Because transmission power determines node reachability, an ideal transmission power reduces node interference, increasing the number of simultaneous transmissions.

1.8 ENERGY MANAGEMENT IN WIRELESS SENSOR NETWORKS

In wireless networks, communication is the principal energy user. In short-range RF communications, it has been shown that a node consumes approximately takes just listening takes just as much effort as speaking, deliver data, Reduced communication and increased computing, powering nodes that cover limited regions, down-select the node's parts or the complete node, and renewable energy sources are all examples of energy management approaches.

Data collection, scheduling, routing algorithms, and MAC (Medium Access Control) protocol study and aggregation have all been influenced by the goal of preserving energy.

The balance between energy conservation and delay is a crucial source of worry. Some time-sensitiveapplications are unable to tolerate packet delivery delays.

Techniques for data reduction

Because transmission costs are considerable, limiting the quantity of data transferred between nodes is essential. The node must share methods to decrease the amount of data and data aggregation.

Leach is a protocol that reduces the amount of collected data from the network's sensors and sends it to the base or central node.

The energy load is equally distributed throughout the network's sensors. Simulations show that it is possible to reduce energy loss by up to eight compared to typical routing algorithms.

Algorithms for determining which cluster a node should join

Some algorithms aim to save energy by directing nodes to the best appropriate collection. The cluster leader gathers data and distributes it throughout the network. Nodes alternate between being active (on) and sleeping (off). There have been several experiments with nodes transitioning between operational and sleep modes.

Among them are how the active/sleep schedule is calculated and how long it takes for each node to reach its maximum possible sleep-wake cycle. Network Nodes must not miss events forthe network to remain dependable.

Communication-based on events

Nodes subscribe to the event kinds they are interested in in this event-based communication architecture. Each node is programmed to receive data, broadcast data, then power down its radio to standby mode.

An event scheduler provides time slots for each sort of occurrence in a dynamic manner. A root node serves as the base station and has more computing, transmission, and storage capacity. Nodes conserve energy by turning off their radios when the events they're interested in aren't happening. The wireless network is organized into a multi-hop network tree using the Topology-Divided Dynamic Event Scheduling (TD-DES) protocol.

Reduce the amount of power used by the sensing operation

A sensor consumes less energy the less surface area it covers. Although the application sets the frequency of detecting activities, power consumption is still possible by reducing each sensor's coverage area [29].

The number of sensors employed by the application has to be raised to cover the region entirely. A sensor's expected lifespan can be considerably extended using this strategy.

Longer lossy links vs. shorter high-quality connections

Many network routing strategies seek to route messages to the sink node's nearest neighbor node. Because fewer hops are required to transport the packet, this appears to be efficient.

When the linkages of These nodes are lossy, which means they lose a lot of data, the problemdevelops. Because the protocol must retransmit packets if wireless networks are unreliable, energy loss might occur.

1.9 Mobile Ad-Hoc Network Performance Metrics

A set of quantitative indicators that the researchers may use to evaluate any routing protocol's performance can be found below.

1. From start to finish, data throughput and latency are vital: Statistical measurements of datarouting performance (e.g., means, variances, and distributions) are essential. These are themeasures for a routing policy's effectiveness as perceived through the perspective of otherrouting rules.
2. Route Acquisition Time: The duration of time needed to build route when requested is an external end-to-end delay measurement of particular significance with "on-demand"routing algorithms.
3. Out-of-Order Delivery Percentage: This is an external statistic of connectionless routing performance that is especially relevant for transport layer protocols like TCP that favorin-order delivery.
4. Efficiency: If you're looking for a way to route data, efficacy is an outward assessment of a policy's effectiveness, and efficiency is an internal metric [30]. Depending on their internal efficiency, two alternative approaches might consume varying amounts of overhead to attain a given degree of data routing performance.

The efficiency of a protocol may or may not have an impact on the performance of data routing.When Control and data traffic must use the same channel, and the node must share the capacity of that channel is restricted, excessive traffic control might slow down data routing.

It's helpful to keep track of a few ratios that reveal a protocol's internal efficiency in completingits task. The ratio of data bits transferred to data bits delivered on average may be regarded as an evaluation of the network's bit efficiency in delivering data [31]. It also offers the average hop count taken by data packets indirectly.

The performance metrics can measure the protocol efficiency based on bit efficiency in spending control overhead on delivering data.

The average number of control bits transmitted/data bits is given. The protocol should include the bits in routing control packets and data packet headers.

In addition, the we must consider the environment in which a protocol's performance is evaluated. The following are essential parameters that should be varied:

1) Node count— in a network, the number of nodes.

2) Network connectivity—a node’s number of neighbors on average.

3) Change in topological rate —how quickly the topology of a network changes.

4) After losses due to multiple access, coding, and framing, link capacity is measured in bitsper second, and other factors are considered.

5) Percentage of unidirectional links —performance of the protocol when unidirectionallinks are present?

6) Traffic patterns—how well does a protocol adapt to irregular heavy traffic patterns?

7) When and in what conditions should you move: is there a topological link between time andspace significant to a routing protocol's performance? What is the best suitable model for modeling a MANET's node mobility in these cases?

8) Sleeping node fraction and frequency—how does a protocol operate when there are sleepingand waking nodes?

There should be a MANET protocol to work in various networking scenarios, ranging from local, more giant mobile, and multi-hop networks to collaborative ad hoc groupings. The properties and assessment criteria discussed before distinguishing MANETs from typical, multi-hop networks using hardwiring Wireless networking is characterized by scarcity rather than abundance, withlimited bandwidth and energy.

1.10 PERFORMANCE METRICS OF WIRELESS SENSOR NETWORKS Coverage, energy usage, and worst-case latency are the three performance measures.

Coverage: Rather than focusing on minimal k-coverage, the algorithm should target the data accuracy for the following sort of application for minimum coverage and inconsistent networks. Using the network's k-coverage map, we examine the exactly k-coverage locations' relative frequency. As a result, the standard deviation of precisely k-covered points and the k-coverage measure.

Energy consumption: - Since the most demanding issue in WSN is energy, and it is essential to maximize energy efficiency in numerous ways [32]. The protocol can reduce energy consumption by using a proper node deployment scheme and enhancing the lifetime of WSN.

Worst-case delay: - in WSN applications, to make time-sensitive functions possible, the maximum acceptable messages transmission delay must usually be defined. Using the sensor network calculus, we assess the worst-case end-to-end latency for each flow and find the most significant worst-case delay in the sensorfield.

1. 11 PROBLEM SPECIFICATION AND MOTIVATION

The following is the result of a comprehensive literature review on energy conservation in mobile ad hoc networks, which allowed us to identify and accurately characterize the difficulties that exist in routing protocols:

a. A protocol must create a sustainable, energy-efficient network to improve the lifetime of individual nodes and reduce routing control overhead and transmission latency.

b. Determination of an optimal path (NP-hard problem) to decrease communication time, improve packet delivery ratio, and achieve reliable network communication.

The life period of a single node in a WSN is defined by its residual energy, which is low in WSNs. Sensor, transceiver, and CPU must utilize the battery's available energy.While the node is alive, the data sensed by the sensor should reach the sink. The node must appropriately use the remaining power available to extend the node's lifespan. As a result, the energy need in WSNs is considered an issue, and strategies for utilizing available energy to extend the life of a WSN are presented in this study effort [33].

The numerous advantages of energy-efficient routing in mobile ad hoc networks encourage researchers to concentrate on decisive and assertive routing approaches to build energy-efficient routing protocols that optimize network lifespan and cope with dynamic networksituations. Wireless ad hoc nodes are distinguished by their compact size, inexpensive cost, and superior communication technology capable of handling limited energy resources. Using a low-energy link regularly depletes the energy of the nodes along itspath, and in the worst-case scenario, it might result in network division.

The challenge ofchoosing an energy-efficient routing path is NP-hard. 11. As a result, an effort has been madeto build energy-efficient routing protocols that pick an energy-efficient path based on theresidual energy of the nodes, so increasing the network's lifespan and the lifetime ofindividual nodes in the network.

Automation focuses on Internet of Things (IoT) and Artificial Intelligence (AI). Automation necessitates the use of sensors to collect data. Sensors alone areinsufficient to meet the demands of automation; processing and transmission are required [34].

The sensor nodes are used for this. A sensor node requires a transmitter and receiver To broadcast and receive data. Each sensor node must communicate with the others To make communication feasible. Wireless Sensor Network is the name of this wireless network (WSN). The energy is available inthe battery powers all of the components of a sensor node. These WSNs are transitory and areonly utilized to get data from the surroundings for a brief duration [35]. According to Ali Hamidianet al., the energy available in the battery impacts the sensor node's lifetime and the WSN's efficacy (2005). a protocol may extend the sensor node's life cycle if energy consumption is reduced.

1.12 OBJECTIVES OF RESEARCH WORK

The following are the goals that focus on decisive and assertive routing approaches to building efficient energy-aware routing protocols to deal with changing network conditions:

- Determine the shortest optimal path for routing with the lowest energy path cost.
- To provide energy-efficient routing by extending the lifetime of individual nodes and,as a result, the network's lifespan.
- To improve the packet delivery ratio and minimize packet transfer latency for a morereliable communication network.
- To reduce the sensor node's energy consumption when transmitting data.
- To control a sensor node from sending data to other nodes.
- Make the sink move in a straight line and collect data from all of the sensor nodes.
- Bring the sensor nodes together data in a single hop to the sink.
- To lower energy use and extend the product life of the WSN by utilizing appropriate data aggregation.

1.13 CONTRIBUTION

- The Mobile Ad Hoc network protocol helps reduce link breakage due to energydepletion.
- The data captured by the sensor nodes directly reaches the sink, which reduces the energy consumed for forwarding the data in multi-hops.
- The data forwarding from the neighbor nodes is eliminated so that the nodes near the sinkdo not suffer energy loss.

1.14 CHAPTER SUMMARY

In this chapter, initially, we have discussed ad hoc network technology and the types of Ad Hoc networks, such as Mesh networks, Wireless Sensor Networks, and Mobile Ad Hoc Networks, and their pros and cons. Next, we discussed the challenges of Ad Hoc networks and the problem of exposed and hidden terminals. Further, the vulnerabilities of Ad Hocnetworks are discussed. This section explains different vulnerabilities faced by Ad Hoc networks.Next, the discussion describes various protocols used in Ad Hoc Networks. Thefeatures of Ad Hoc Network protocols are described. The following section discusses the basic principles of Ad Hoc Networking [35]. The Application areas of Ad Hoc networks and the use of ad hoc networks in military LAN, WAN, PAN, MANET, and WSN are discussed in the next section. The Ad Hoc Network application area Mobile Ad Hoc Networkis discussed in detail. Mobile ad hoc networks following MANET challenges are addressed in detail. The following section discusses the Vulnerabilities of Mobile Ad Hoc networks and Mobile Ad Hoc networking protocols. The MANET protocol DSDV is discussed as an exampleof proactive routing protocols. And, also DSR and AODV are discussed as an example of reactive routing protocols. Also, a hybrid routing protocol is discussed in detail. In the next section, another application area of the Ad Hoc network called WSN is concerned, and its features and challenges are discussed in detail. Vulnerabilities in the Ad Hoc network are discussed in the next section to understand the basic vulnerabilities faced by Ad Hoc Network. In the next section, the protocols of WSNs are discussed. And further, energy management in MANET and WSN, as well as performance metrics used for testing energy efficiency, is discussed.

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CHAPTER TWO

Review of Literature

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2.1 INTRODUCTION

Mobile Ad Hoc networks and Wireless Sensor Networks have seen tremendous researchwork in energy consumption and management. The researchers have developed several protocols to overcome energy-related problems in MANETs and WSNs. The energy-related issues in the MANETs and WSNs are analyzed with the help of different metrics, and many protocols are developed to overcome the problems confronted by the Ad Hoc Networks.

2.2 ENERGY-EFFICIENT ROUTING PROTOCOLS IN MANET

MANET contains several battery-powered communication nodes. The protocols developed to overcome the energy issues are of different types and are designed with additional features to extend the network lifetime. Extensive research hasbeen seen for decades to decrease issues in MANETs.

S. Monapatra et al. (2011) have done analytical work by evaluating the performance metrics of the AODV protocol, and the evaluation metrics used are PDR, average delay, and routing overhead [36]. The evaluation is also performed on DSDV, OLSR, and observation is reported that if data delivery is the priority forany network, DSDV is the more suitable protocol.

Manish Bharadwaj et al. (2013) have proposed a new method to compare various protocols using energy models. The simulations helped to obtain different analytical results [37]. Other protocols are chosen for the investigation of performance. Finally, all the selectedprotocols, like AODV, and TORA, are simulated on different mobility models and found that the TORA routing protocol does maximum energy utilization compared to other protocols. The restof the protocols are analyzed for speed, sent node count, energy overhead, etc.

Rieha Sharma et al. (2015) have performed an analysis to verify the performance of the different routing protocols ADV, DSR, and GOD in different scenarios, either in city scenarios or in highway scenarios. Finally, it is evaluated that GOD is a protocol designed to suit the requirements of the city scenario due to the low network density. ADV is best suitablefor highway scenarios due to the high network traffic and traffic congestion in highway scenarios [38].

Kamalesh Chandra Purohit et al. (2016) have compared existing routing protocols such as AODV, AOMDV, DSR, DSDV, TORA, and ZRP. This protocol evaluates these protocols against VANEt as well as in MANET. Different evaluation metrics, such as delay and PDR, are assessed to get comparative study results with the help of simulations [39].

Leesabanu M Doddamani et al. (2016) have analyzed the DSDV and AODV with an energy model, and the analysis is carried out by changing the topology. The proposed study has examined the protocols in different topologies and concluded that DSDV is comparatively better than AODV and the energy consumption of DSDV is less than AODV [40].

Joseena M Jose et al. (2016) has developed a new smartMAC protocol. And the newly developed protocol and the freshly developed protocol are designed and implementedin NS3, and it is evaluated to be an efficient protocol that saves 98% of the energy comparedto other protocols [41].

S. Russia et al. (2016) have proposed Node Disjoint Energy Efficient Multi-path routing, which is designed for MANET to overcome energy depletion issues in MANETs. This method of improving energy efficiency has used seven scenarios to prove the efficiency of the NDE-MR protocol. The protocol successfully adapted to different topologies by initializing themulti-path [42].

Anne Cecile Orgerie et al. (2017) have developed an Ecofen model, which has a methodology tofill the void of the energy model. Initially, MANET has used in NS2 simulation for wired networks [43].

Girish Paliwal et al. (2017) have developed a comparative analysis in an NS3 simulator to analyzewhether DSDV and AODV protocols will decrease the efficiency during the density. Afterthe simulation, it is analyzed that the throughput increases when the density increases [44].

Sanjeev Sondur et al. (2017) have used the NS3 simulation for analyzing the various protocols under energy models. The authors of this work have introduced individual port levels, power management, node fabric or backplane power management also global controller (GC). Authors used them for monitoring the regular exchange of information for better traffic consolidation with both the endpoints and Local consolidation (LC) so that nodes consolidate the entire traffic alone. The coalition relies on local details obtained [45].

S.R Drishya et al. (2018) have developed an energy-efficient stable clustering algorithm for Mobile Ad hoc networks that choose the efficient cluster head (CH) using the CH selection scheme [46]. The algorithm takes two parameters for determining the cluster head: trust and mobility, and selects the node which can survive for a more considerable duration in the network. This protocol also considers mobility models for choosing the CH node to know the availability of the nodes.

Abdellah Nabou et al. (2019) have evaluated several protocols, such as AODV and DSDV, because both protocols are reactive routing protocols, and separately OLSR and DSDV are analyzed since they are proactive routing protocols. All the chosen protocols are evaluated for the energy needed for transmitting the packets [47]. When the energy necessary for sending data is low, all the protocol performance becomes poor except the AODV protocol. And high transmit power increases the efficiency of almost all the protocols.

Hemin Akram Muhammad et al. (2019) have comparatively evaluated energy consumption in proactive and reactive routing protocols. In their comparative analysis, it is understood that the proactive protocol's energy consumption is higher, and the protocol exhibit a steady state behavior in all scenarios [48]. The proposed work evaluates that the efficiency of the proactive protocol is high in the static network or a network with a minimum movement of nodes. Proactive protocol spends more energy at the application layer due to the energy required to send routing messages. This work analyses that the receiver nodes spend more power at the receiving end because the receiving node obtains data from the neighbors' node, but the sender node transmits data.

Riasuddin H et al. (2019) have developed a new protocol energy-efficient cloud-assisted routing mechanism, the EECRM algorithm. The 5G network uses user Equipment provided by Device-to-Device D2D technology to communicate with other UE’s. D2D is a cloud-assisted MANET, and searching and routing require maximum energy [49]. A backup Routing Table (BRT) is usedto overcome link failure and can boost or enhance the process of recovery from failure. The algorithm improves the quality of the method of energy consumption and residual energy.

Valmik Tiwari et al. (2020) have proposed mobility, contention window, and link quality aware multi-path (MCLMR) routing protocol, which is efficient for maintaining steadiness in the network and maintaining equal load in each node of the network in MANETs. The repeated movement of nodes usually leads to link failure [50]. The other Routing protocolsof MANET choose only a single optimal path, which may lead to network congestion.The MLMR scheme finds multipaths and selects intermediary nodes with routes based on the availability of mobility, the size of the contention window, and the quality of the link values. This protocol considerably reduces end-to-end delay.

Rani Sahu et al. (2020) developed a zone-based efficient energy multi-path protocol, assuming each node has some initial energy [51]. And node can transmit data only when its power exceeds the threshold value. The protocol also selects the leader head from the designated zone; the protocol also knows the details of nodes that propagates the data further within the range of their zones.

2.3 ENERGY EFFICIENT ROUTING PROTOCOL BASED ON AODV PROTOCOL

The Ad Hoc On-Demand Distance Vector protocol (AODV) is energy efficient. It is known to be a leading protocol that gives solutions forenergy-related issues encountered by Ad Hoc Network. Several researchers have done tremendous research in improving the AODV protocol [52].

We Li et al. (2012) have developed a new modified protocol, which includes Geographic Adaptive Fidelity combined with AODV protocol, the expanded protocol incorporates an algorithm to findthe node's position, and each node equipped with GPS gives GIS information forfurther routing. The network lifetime could be increased four times, but the expense is morecomparatively. AODV-GAF protocol is suitable for a network with a maximum number of nodes [53].

Hassan Keshavarz et al. (2013) have developed a modified protocol called smart-AODV, which incorporates the neighbor discovery method by changing the AODV protocol. The smart-AODVoperates based on HELLO messages. Average end-to-end delay is considerably reduced with smart-AODV; several metrics are used to analyze NS-2 and conclude with performance enhancement evidence [54].

Esubalew Yitayal et al. (2014) have developed a balanced-battery usage routing protocol (BBU). This protocol uses the residual energy as a parameter, energy threshold, and hop count to select the optimal path, the disadvantage of AODV related to a recreation of the route during energy loss is solved with the usage of the BBU algorithm [55].

Anita Yadav et al. (2015) have developed a new routing protocol for link breakage prediction, and the protocol can measure the signal strength of three consecutive packets received. It can predict link breakage possibilities, and the threshold signal strength is also evaluated to know the cases of link breakage in the future. Different metrics are used to assess the protocol AODVNLP [56].

N. Apoorva et al. (2016) have developed a new protocol called smart-MAC protocol, and the newly developed protocol has been designed and implemented. NS3 is considered an efficient protocol that saves 98% of the energy compared to other protocols [57].

Priya Seetharaman et al. (2016) have developed a protocol for energy saving called refined trust energy- ad-hoc on-demand distance vector (ReTE-AODV) routing algorithm. This algorithm is compared with existing routing protocols such as AODV, AOTDV, and TE-AODV. The protocol has many advantages over other protocols, and efficiency has outperformed in three different scenarios than other existing protocols [58].

Hassan Faouzi et al. (2017) have developed a protocol called Energy measuring packet delivery ratio, which evaluates total Energy consumption and alive node count. The AODV protocol chooses the shortest route based on the minimum number of hop counts, so load distribution during the occurrence of the congestion is not solved in the AODV. To solve this problem, E-AODV is developed. The simulation results of E-AODV have performed 30% more efficiently than AODV to keep the node alive [59].

Hua Yang et al. (2017) have developed a new protocol called CHNN-AODV. Several routing evaluation metrics are used to compare AODV and CHNN-AODV and result in the quick establishment of the routes from source to destination [60].

Y. Harold et al. (2018) have proposed a Fault Tolerant Multiple Distance Vector Routing Algorithm, which is compared with 2D-AOMDV and AODV with the help of Network Simulator 2. This protocol has networking efficiency in end-to-end delay, PDR. The protocol is evaluated for energy efficiency, and energy efficiency issues in MANET is considerably reduced. In this protocol, when the threshold limit exceeds a node, 2D-AOMDV will send a message toall the nodes to find an alternate path. The routing table is maintained to store information suchas mobile nodes, their adjacent nodes, and residual energy [61].

Nandanwar Chethan Damodar et al. (2018) have developed energy and load-based routing protocol, a newly updated protocol from the protocol AODV. ENL-AODV evaluates the remaining power, the load situation, and the random delay. A new concept called delay is introduced in this protocol to avoid collisions [62].

Aksh Soni et al. (2018) have evaluated the AODV protocol in different mobility models such as Random Way Point Mobility Model, Mass Mobility Model, and Linear Mobility Model. The mobility is assessed in three other regions where high mobility is found and less region slow. Moderate and fast. The control packets used are more in areas where highmobility is found and less in the part where mobility is slow. The more control packets, the more the entry is used, so the RWP requires fewer control packets in the slow mobility region, and Gauss Markov requires less in the fast mobility region [63].

Usharani C.M et al. (2019) have developed an Energy Efficient Modified AODV, compared with the AODV protocol. This proposed scheme is efficient over QOS parameters like PDR and Delay [64].

H K Sampada et al. (2019) have developed M-AODV, which is set by modifying the popular AODV protocol. M-AODV protocol is proven more efficient than AODV and increases efficiency by improving the network's longevity. M-AODV uses a specific control packet called HELLO packet by including two parameters: trust and residual energy. The parameters evaluated by the ns2 simulator and the willingness ranges from 0 to 7, and trust ranges from 0 to 1 [65].

2.4 ENERGY EFFICIENT PROTOCOLS FOR WIRELESS SENSOR NETWORK

Andrea Munari et al. (2009) have developed a new protocol for routing the packets from an endless information source to portable sinks via a multi-hop wireless sensor network. Thenodes can identify their location by Kalman Filter and then send status update messages back to the source with the information. The STATE UPDATE messages will help the nodes to predict the sink location, and the protocol uses geographic data to anticipate wherethe sink will be. The overhead frequently prevents the STATE UPDATE messages from being sent, which are created in the network. The difference and error can be calculated using the Euclidean error norm, and Kalman surpasses a predetermined threshold. With the help of simulation, the efficiency of the proposed scheme is described [66].

Ming Tao et al. (2010) evaluated the wireless sensor network with the help of a Radio Model. The researchers also analyzed two protocols for comparing energy dissipation,the first protocol is direct interaction, and the second protocol is a multi-hop routing protocol. They developed a new protocol, and it is called Adaptive Energy-Aware Multi-path routingprotocol with load balance (AEMRP-LB). This protocol sends and receives interest messages to the intermediate node from the sink in the right direction using the direction angle concept [67].

Tzung-shi Chen et al. (2015) have developed a new protocol, Object Tracking Sensor Network (DTSN). This protocol efficiently tracks the locations of the sensor node within the network with the help of the velocity, trajectories, and other helpful information of the sensor node. Wireless Sensor Networks have more components to find the sensor nodes' position than GPS. The elements that help the sensor nodes find their locations are infrared, ultrasonic, electromagnetic, and Laser. Another analysis donein the proposed work is that GPS can find sensor node locations in outdoor scenarios more accurately. Still, WSN can find the location in outdoor and indoorscenarios. This object tracking protocol is mainly used to discover the sensor network's trajectories and deeply analyze the trajectories pattern. The analyzed pattern is then transferred into the form of a tree, and the tree can then use to predict the next phase. Most of the time, the protocol helps the entire network to be either in a sleep state or in an active state [68].

Shekar Kumar et al. (2015) have developed a protocol called Enhance Threshold sensitive (ESSEX), compared with the traditional protocols DI, MTE, and LEACH. The proposed protocol takes two parameters, the stability and instability periods. A protocol can measure strength by finding the time interval from the beginning of the network up to the time of death of the first node. The time interval can identify another parameter in a stable protocolperiod from the first node death to the last node death. And thisperiod is known as an unstable period.

Ghufran Ahmed et al. (2016) have developed a protocol called APCEER is mainly related to the power control method, which controls power dynamically. This protocol can be used in urban areas to control power consumption dynamically based on the cost field [69].

Hye Young Kim et al. (2016) has developed an algorithm to balance the energy load with the help of analyticalmodels [70].

Dibakar Saha et al. (2016) have developed a technique called a self-organized node placement algorithm to cover a particular area of interest. Also have developed a self-organized node placement algorithm to occupy a fascinating region. The selected area is subdivided into hexagonal tiles known as an origin. The entire hexagonal area must obtain coverage. Theseveral target points are placed inside the hexagon and are unique, and this particular node is placed accordingly at the target point. This appointment of a node will result in minimum displacement of the node and leads to increased development in energy saving to expand the network's lifespan [71].

2.5 ENERGY-EFFICIENT CLUSTER-BASED PROTOCOLS FOR WIRELESS SENSOR NETWORK

Feilong Tang et al. (2010) have developed a chain-cluster mixed routing that uses LEACH and PEGASIS. The entire network is organized by this protocol as a chain and categorized into two types horizontal chain and vertical cluster. The protocol again performs the data routing with the help of two different phases. In this protocol, in the first phase, the chain head receives data from each chain and uses the chain-basedrouting protocol to perform this operation. The advantages of PEGASIS and LEACH are extensively utilized in CCM protocol, and several issues encountered in PEGASIS and LEACHare resolved by CCM. The overhead created in LEACH for voting and the PEGASIS is suffered by the problems related to delay in transmission [72].

Huei-Wen Ferng et al. (2011) have developed a route that uses little energy structures called Static Clustering and Dynamic Structure (ERP-SCDS) protocol, in which the researcher has concentrated on dividing the entire network into evenly distributed clusters. The protocol arises to adapt a static cluster, but the network structure is dynamic. The protocol ensures the optimal path selection by selecting the nodes with maximum remaining energy and choosing the node near the cluster's center. By doing this, the protocol enhances the network lifetime.
This protocol does not employ any route discovery algorithm to select the relay node with the highest energy. It avoids a certain amount of complexity within the network [73].

S. Siva Ranjani et al. (2013) have developed a protocol, Energy Efficient Cluster Based Data Aggregation (ECBDA) scheme for sensor networks. The protocol messages to its local cluster to overcome the overhead. The protocol has used the data aggregation method [74].

Ren Cheng Jin et al. (2013) proposed a protocol that can reduce energy usage with the help of hierarchical management strategies. In the first round, it uses passive clustering, and in the second round, it uses active clustering. In other rounds, the protocol targets improving energy efficiency and QoS [75].

Hesham Abusaitukh et al. (2014), the entire WSN is organized into groups in this work called clusters. During the cauterization process, the protocol groups the nodes into a cluster depending on the energies of the cluster heads and the sensor nodes. The entire cluster creation depends on the cluster; also, the whole network depends on the power remaining within the cluster head for the survival of clusters. The WSN network lifespan simulation results are conducted using the NS-2 simulator [76].

Heework Shin et al. (2014) has developed a balanced clustering algorithm. This algorithm aims to find the cluster head for a cluster that can decide to become the cluster head by analyzing the sensor count [77].

Payal Khurana Batna et al. (2015) have tried to improve the LEACH protocol by reducing the problem of randomness in the protocol, and this will help the network to maintain a stable cluster head count. The work also has compared several protocols such as LEACH, LEACH-MAC, BLEACH, and LEACH-DCHS protocols. The number of clusters is counted to know the efficiency of the network since the cluster head count highly affects the network's lifetime. Because of a more significant number of clusters, less space is required to connect the cluster head to the network node. Suppose the network has a smaller number of cluster heads, and the distance between the cluster head and cluster members becomes more. So, the utilization becomes more complex due to the fewer cluster heads [78].

A Muthukrishnan et al. (2021) has introduced the concept of multiple mobile sinks for heterogeneous networks. The protocol is evaluated based on the performance metrics such as data packets received, the lifetime of the network, and residual energy [79].

Alfredo Navarna et al. (2015) have focused on latency bounded data collection approach for WSN. The main goal is to reduce data collection latency [80].

Rashmi Ranjan Sahoo et al. (2015) have included a trust model for the energy-efficient protocol and used a protocol called honeybee mating to avoid the entry of malicious nodes. Thisprotocol is used to select the most appropriate node as CH. Protocol selected the CH based on the threshold percentage [81].

Straight Shiokawa et al. (2015) have proposed a strategy for choosing CH to make all the nodes in the cluster sleep, so the new sleep control mechanism is introduced. It has been proved that when the mobility speed of the node is low, the protocol is more successful than during high mobility [82].

Efren L Souza et al. (2015) have proposed a protocol called APCEER to overcome interference and maintain routes with energy efficiency among the nodes. This work used alpha, beta or particle filters for the easy and efficient prediction of the position of the target [83].

Mohammad Gholami et al. (2016) have proposed a mechanism for inter and intra-cluster data transformation Java Agent Development Environment) JADE is being used by the proposed tool to compare different older versions [84].

E. Golden Julie et al. (2016) have developed connectivity cost energy virtual Back Bone protocol. This protocol is compared with the LEACH protocol. The main drawback of the leach protocol is that despite considering the distance and residual energy value, the LEACH protocol will find the path. The mechanism used in the proposed protocol CCE sends broadcast messages, and after the broadcasted message, each node's current status is updated into the sink node. The protocol also counts the number of successful messages and sent Message Success Rate (MSR) by seeing the sent count and received count of the messages. So, the CCE is well known as a Virtual Backbone protocol and is used to increase WSN's energy effectiveness. The protocol uses a method for choosing the CH using the Message Success Ratio. It has the maximum connectivity ratio among all the nodes and is eligible monthly to be a cluster head [85].

B. Siva Kumar et al. (2016) have developed a protocol called Energy Efficient clustering with Delay Reduction Approach in Data Gathering (EE-CDRDG) technique which can improve the duration of a network, throughput, and success rate of data delivery. The protocol also gathers data from such clusters, which has low energy than other cluster head, so this is an efficient way to decrease data loss [86].

PC Srinivasa Rao et al. (2016) have developed a novel chemical reaction optimization (CRO) Paradigm, and this protocol chooses cluster heads near the Base Station more and comparatively less in other areas of the network. This protocol also calculates the cost factors of conversion from non-CH to CH. Also, this protocol is compared with PSO, EBUCF, FBUC, and EPUC using different performance metrics [87].

Hui Xia et al. (2016) have developed a UCCGRA protocol to form the clusters and their area in unequal to balance the energy [88].

Ibtissem Zaatouri et al. (2017) have compared heterogeneous and homogeneous clustering algorithms [89].

K Laxmi Joshitha et al. (2017) have developed a technique for improving the network lifetime called linear iteration regression-based cluster network. The algorithm developed in this work can allocate the member nodes of a cluster to another cluster head in the case of energydepletion within the cluster head of the same cluster. At this moment secondary cluster can performdata aggregation [90].

Mohammed Alaei et al. (2019) have developed a new clustering technique called Energy Efficient Load–Based Clustering Method for wireless Mobile Sensor networks. The protocol considers the network and sensing areas as a circular field. And the base station is situatedin the middle of the network region [91].

2.6 ENERGY-EFFICIENT MOBILE SINK-BASED PROTOCOLS FOR WIRELESS SENSOR NETWORK

Yijun Mo et al. (2013) have proposed a Sink Oriented Layered Clustering protocol. Even if the distance from the sink to the node is more, this particular protocol can send and receive messages withpower efficiency. The protocol has divided the entire network into concentric rings, so this protocol has to do intra-ring clustering and inter-ring routing. The clustering chooses a node fromthe same ring. The size of the ring is less when it is near the sink, and when it is far from the sink, it is significant. In this case, the energy is used less for data processing between clusters and more power for data relays between clusters [92].

Hongliang Lie et al. (2015) have analyzed the wireless sensor network to prevent coverage gaps and production of coverage by employing a static sink node and a non-uniform node orientation strategy. A new protocol IDMSN has been developed to avoid coverage holes and redundancy [93].

Kalpana Murugan et al.(2015) developed a new protocol LETCSN, LETSSN and are compared in the proposed work. The protocols are simulated using NS2. LETSSN has a low packet loss ratio compared with other single and multi-sink routing algorithms. The LETCSN algorithm is compared with the PEGASIS, TEEN, LEACH, and LETSSN. Similarly, the LETSSN algorithm was compared with EMCA, LEBDPC, and RPL. LETSSN has proved that it will result in a low packet loss ratio [94].

S.M Amini et al. (2016) have developed a clustering mechanism using a hexagonal beehive network area, and this hexagonal network area can be further divided. And the hexagonal division is based on the radius of the circle. The mobile sinks are given movements in this protocol for covering all the clusters in the hexagonal area of the network. The protocol developed by this work is known as IMECA, which is the modified protocol of improved Multi Sink energy-efficient clustering algorithms. So, the protocol selects the normal node at the cluster's center as a cluster head [95].

Fatma Hanafy et al. (2016) have proposed a new protocol, Reliable Energy Balance Traffic Aware Greedy Algorithm (REBTAM) in multi-sink WSNs and compared with one more similar work previously developed called DTAR, NBPR, and MSDDGR protocols. This protocol gives high preferences to the extension of network lifetime. Also, the Imust deliver the data sensed to the selected sink without any interference and with the lowest buffer overflow [96].

Suraj Sharma et al. (2016) have developed a routing protocol that relies on a rendezvous point, and this protocol uses two methods for data transmission. Establishing ameeting spot in the network's center is created, and then the protocol uses two ways to transmitthe data with the help of a tree that is established inside the rendezvous area. Transmission method one is data transmission from the source node to the sink via a tree. The location of the sink node is transmitted to the tree using a second approach, and some node obtainsthe sink node's location with the help of the tree, and then it can send the data straight to the sink. The protocol is then compared with the HBDD protocol for efficiency [97].

Mukul Alagiri Samy et al. (2017) have created an inequitable clustering mechanism (EEUC). The main issue faced by the WSN is the equal size of the clusters formed within the network. The equal-sized clusters require more power to send data from the source node tothe sink [98].

Xu-Xing Ding et al. (2017) have developed a protocol called Dynamic K value LEACH (DK-LEACH), designed to decrease the power usage in WSN. The DK leach protocol proved more efficient than the LEACH protocol used in Wearhouse and agricultural management [99].

Ammar Hawbani et al. (2017) have developed Sink-Oriented Tree-based data dissemination (STDD) protocol that creates one data dispersal tree for entry mobile sink. This tree helps to give the updated location of the nodes. The dissemination tree is formed immediately after the appearance of the sink. Two different methods are used to improve the duration of the network. The first strategy for data forwarding is independent path data forwarding and mergepaths data forwarding. STTP protocol cannot support the nodes with mobility [100].

Xiodong Liv et al. (2017) has developed a virtual uneven Grid -based routing protocol (VUGR). This protocol aims to overcome the network's lifespan while addressing energy problems with the help of a dynamic partition of the network into multiple grid cells [101].

Kumar Nithesh et al. (2017) have developed a new technique for WSN, where the mobile sink trajectory is designed, which is delay efficient. The protocol also decides the rendezvous points for the mobile sink based on the Voronoi diagram. The recovery technique for cluster member nodes is also involved in this technique to recover the nodes which have become orphans due to the energy depletion of the cluster heads [102].

Sudhakar Pandey et al. (2017) have proposed a new method for picking a cluster head, the selectionrelies on residual energy in the node, and for the distance pre – clustering is applied in the clustering phase. The load balancing feature is also included in this algorithm to change the location of the sink node when energy depletion issues occur in the nodes surrounding the sink node [103].

Amer O Abu Salem et al. (2018) proposed a work that improves the lifetime and energy, which can resolve the drawbacks of the LEACH protocol. A simulation is performed for the analysis. It has been proved that the proposed method is more potent than LEACH [104].

Djamila Mechutu et al. (2018) have developed a new protocol called TMSRP2, which gives improved and efficient outcomes in the case of the packet received. The protocol has also successfully kept the network nodes alive for extended periods. And the time required for delivering the packets is considerably reduced by the protocol. The location of the mobile sink is identified with the help of a routing tree to decrease the amount of time needed for data delivery [105].

V. Saranya et al. (2018) have developed a new protocol called Energy Efficient Clustering Scheme (EECS). The work helps to improve the number of packets delivered to the sinknode. Estimates are made of the protocol's effectiveness using different metrics, and its efficiency is compared with Modified -LEACH (MOD-LEACH) [106].

2.7 CHAPTER SUMMARY

This chapter discusses many of the foundational theories related to Ad Hoc Networks and their principles, application, MANET protocols, energy evaluation by different protocols, Wireless sensor technologies, and WSN protocols. The in-depth theories and research contributions provided by other scholars to the various phases stated in this research framework like Energy Efficient Routing protocols, energy-efficient routing protocols based on AODV protocols, energy efficient protocols for WSN, Cluster based WSN protocols, and mobile sink-based protocols are covered in the chapter after this one under the heading Review of Literature.

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CHAPTER THREE

Research Design and Methodology

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3.1 INTRODUCTION

The Ad Hoc network has several branches, in which Mobile Ad Hoc Network and Wireless Sensor Network are mainly focused in this research study. The Mobile Ad Hoc Network is battery-powered, and instant creation of the network is possible at any location as per the requirement [107]. The protocol called ORES-AODVis introduced in this work and evaluated with other similar robust protocols such as Ad Hoc On-Demand Distance Vector (AODV) protocol, Modified AODV(M-AODV),Intelligent Routing AODV (IRAODV) protocol, Energy and Load-Based Protocol (ENL-AODV). The evaluation process among the protocols is performed with the helpof metrics such as packet loss, packet delivery ratio, and throughput.

3.2 OBJECTIVES OF THE RESEARCH

The Ad Hoc networks are independent nodes equipped with a battery, and the node size is much smaller to move from one place to another. Due to the high mobility and size constraints of the ad hoc network, considerable research has been carried out to improve energy efficiency, which can increase the network's lifetime. Theproposed research also has coined its contributions to improve battery efficiency bydeveloping and modifying the protocols and has the following objectives.

1. Study the working of Existing Energy Efficient Protocols, such as Ad Hoc On-Demand Distance Vector (AODV) protocol, and analyze using simulation tools.
2. The existing Energy Efficient Protocol AODV is then compared and analyzed withthe proposed Modified protocol, Optimized Residual Energy Selection AODV (ORES-AODV) protocol.
3. The network is examined under different mobility models using the ORES-AODV protocol
4. to analyze the energy variation in Mobile Ad Hoc networks. To study the working of Existing Energy efficient routing protocols for Wireless Sensor networks such as the Low-energy adaptive clustering hierarchy (LEACH) protocol and its variant, Mobile-sink based energy-efficient clustering algorithm (MECA).
5. To analyze the Multi MECA protocol and similar protocols such as MECA and LEACH protocols for energy efficiency.

3.3 SCOPE OF THE RESEARCH

The increasing popularity of wireless technology has seen a tremendous increase in the number of mobile devices among users. This revolutionary technological improvement has boosted the inventions relating to Ad Hoc Networks [108]. The scope ofthe Ad-Hoc network in several application areas requires a communication network withminimum cost and time. The following are some of the essential application areas of Ad Hoc Networks.

1. Medical Applications
2. Environmental Applications
3. Industrial Applications
4. Military Applications
5. Personal Area Network
6. Provincial Level Communication Network
7. Business Applications
8. Educational Service Applications
9. Sensor Applications
10. Backup Service Applications

3.4 PROPOSED METHODOLOGIES

The methodology used in this proposed work is by profoundly analyzing and comparing the proposed protocol in the NS3 simulator also MATLAB R2021a. The NS3 simulator is usedto analyze and compare the efficiency of the ORES-AODV protocol with other leading protocols such as AMODV, M-AODV, ENL-AODV protocols, and the AODVprotocol [109]. The Ad Hoc network, WSN-based protocol proposed in this work called Multi MECA protocol is also analyzed for its efficiency. Its efficiency is compared with other well-known protocols such as LEACH and its base protocol MECA. The methodology used is described for both protocols, as given below.

3.4.1 Mobile Ad Network

3.4.1.1 Method-1

The proposed study has used three methods to solve the issues in Mobile Ad Hoc Networks, and method 1 is Energy Efficient Routing in Mobile Ad Hoc networks.

Energy Efficient Routing in Mobile Ad Hoc Network

The Energy Efficiency of the Mobile Ad hoc networks is essential for prolonging the network's life. The energy optimization technique within the network has to take several energy-saving and enhancement mechanisms [110]. The network has several nodes, in which all are battery-powered, so if a node fails in the network, the entire network will halt, resulting in network failure. The advancement in mobile technology has enhancedbattery efficiency and issues such as more energy requirements for specific applications, andit is tackled efficiently in the proposed work.

The proposed work focuses on reducing energy-related issues by developing an improved protocol. The proposed work deeply analyses the working of the AODV protocol because AODV is considered a popular energy-efficient protocol by several researchers after the deep analysis of the protocol [111]. The AODV protocol has certain drawbacks, and the proposed work has identified the defects and has included remedial aspects to overcomethe issues.

The AODV protocol uses the control packets to identify the optimal path for a journey from oneplace to another. The control packet known as Route Request is broadcasted across the network to select the optimal way. The RREQ packet contains fields such as Broadcast ID, Destination IP address, Source IP address, Destination Sequence Number, andSource Sequence Number.

The fields of the RREQ packet help obtain precise information about the participatingnodes in the path and choose an optimal path from source to destination by AODV protocol.The AODV protocol uses an RREQ packet for path selection.

On receival of the RREQ packet,each participating node forwards it to the neighbor node because it realizes it is not theintended node. Each time the participating node receives the RREQ, it keeps track of the hop count and the sequence number [99]. The RREQ packet is propagated until the destination node is reached. On receival of the RREQ packet by the destination node, aRoute Reply packet is created as an acknowledgment. Once the source node receives the RREP, the data packets will begin their transmission.

The AODV protocol selects the quickest route possible for data transmission. The AODV protocol always choosesthe shortest path for data transmission [112]. The selection of the shortest path will result inlink breakage and also results in packet loss. Selection of the shortest route will dent the quality of transmission and the efficiency of the Ad Hoc Network. In this research work, AODV and other protocols such as ENL-AODV and M-AODV are analyzed and compared with the AODV protocol using different metrics, and also the AODV protocol, ENL-AODV, and M-AODV protocols are deeply studied with the help of Network Simulator NS3.

3.4.1.2 Method-2:

Optimized Residual Energy Selection – Ad Hoc On-Demand Distance Vector Protocol

The development of an improved AODV protocol has implemented the energy efficient Power-saving techniques also identified the problems in the AODV protocol during the optimal energy-efficient path selection. So, the proposed work has developed a new protocol called Optimized Residual Energy Selection ORES-AODV protocol. The main goal of this protocolis to overcome the problems experienced in the AODV protocol [113]. The proposed algorithm ORES- AODV is designed with a mechanism to identify the low-energy node. The proposed algorithm chooses the path with high energy in its participating nodes to propagate data packets. Path selection is always based on the hop count, and hop count is discounted from sourceto destination. The shortest path has the minimum hop count. Still, if only the minimum hop count is taken as the parameter for path selection, then the participating node may have low energy, and it causes link breakage in the network.

So, the proposed protocol has developed a cost metric to avoidfuture link breakage in the path. The AODV protocol uses specific necessary parameters in the RREQ packets, as sown in Table1.1. These parameters play an essential role in path selection in AODV. The ORES-AODV uses additional parameters to select the path, so an energy-efficient path is chosen for the data transmission. The different parameters are Least Residual Energy and Total Node.

Table 3.1: Necessary parameters in the RREQ packets of AODV

Broad Cast ID
Destination IP
Source IP
Destination Sequence Number
Source Sequence Number

Residual Energy is added to the table1.1 its mean value is calculated for the selected optimal path, and in Table 1.2, new parameters are added. The two new parameters are added to the route table each time the data transmission is requested.

Table 3.2: New parameters in the RREQ packets ORES- AODV

Broad Cast ID
Destination IP
Source IP
Destination Sequence Number
Source Sequence Number
Least Residual Energy
Total Residual Energy of Nodes

Some metrics, such as the difference between the path with the most significant average residual energy and the path with the highest threshold, are used for the path selection.

Another method is finding the difference between the highest average of minimum residual energy and the threshold to select the path [114]. Finally, the path selection with equalcost factors will again rely on minimum hop count.

3.4.1.3 Method-3

Mathematical Model for ORES-AODV

The mathematical model of ORES-AODV denotes the optimal route as Rt, where Rt=rt1,rt2,rt3,……,rtn, here the rt1 is the beginning point of the path, i.e., source, and the redis the endpoint in the path, i.e., destination. rt2 and rt3 are the participating nodes in the path. Each node is measured for its residual energy, and it is denoted as rt(ei), the equation to get the average of least residual energy is,

The mean of the least amount of residual energy $Rt = \left(\min_{\forall ei \in Rt} rt(ei)\right)/h$

Average Total of the node Residual Energy $aRt = \left(\sum_{\forall ei \in Rt} rt(ei)\right)/h$

The ORES-AODV protocol makes use of two different types of cost metrics. Both of the cost metrics are used to find the optimal path as well as the energy-efficient path.

The first cost metric finds a path with residual energy, which is always more than the least residual energy.

$$\underset{ei \in A}{ALRE}(Rt) * h \geq Thr$$

Each node's residual energy is summed in the path in the second cost metric. Once the summation is obtained, the difference between the threshold of each node is calculated i.e

$$Op(Rt) = \max_{ei \in A}(ALRE(Rt)) - Thr$$

The path can alternatively be chosen using the mean value of most minor node residual energyand threshold.

3.4.1.4 Method-4

Algorithm for RREQ handling in ORES-AODV

Step 1: The RREQ packet is received. Each time RREQ is received, the Broad Cast IDis searched in Routing Table.

Step 2: If the path is already established earlier, only updating the routing path entryis insufficient. Otherwise, a new entry has to be created.

Step 3: In the case of receiving a new RREQ packet, determine each node's energy leveland then calculate the difference in energy levels of nodes.

Step 4: The obtained energy level is measured and compared with the intended value to select a participant node. If the energy level is below the intended value, discard the RREQ.

Step 5: Each time the new node is selected for the path with enough energy levels,the difference in energy is updated in the route table.

Step 6: Checking whether a path has survived for an intended period. If not, then readthe route table for a new path.

Step 7: Wait for the Additional Route request.

3.4.1.5 Method-5

Flowchart defining the operations of ORES-AODV

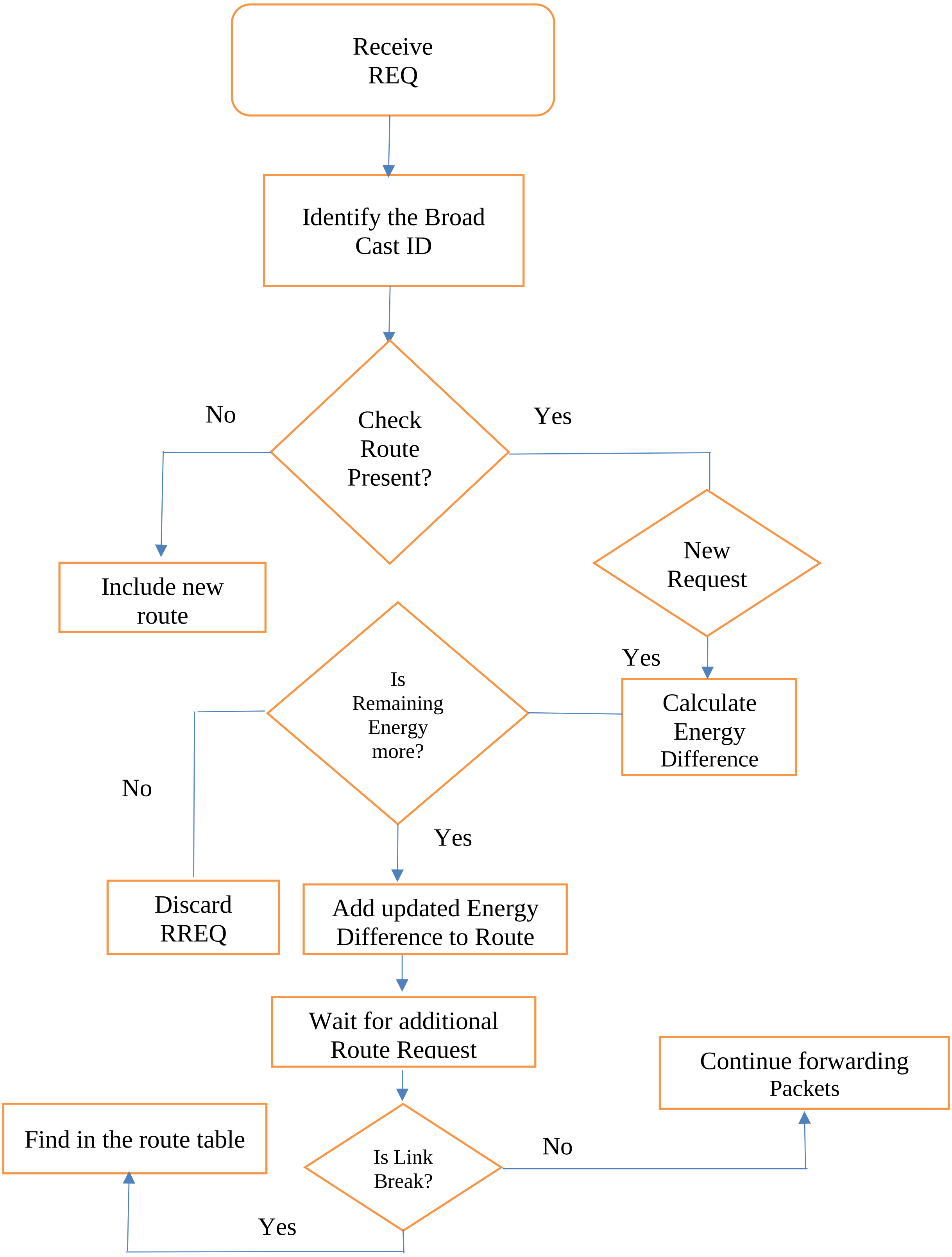

Fig 3.1: Flowchart defining the operations of ORES-AODV

3.4.1.6 Method-6

Understanding and Analyzing the Operations of AODV and ORES-AODV

The AODV and the ORES – we can deeply analyze AODV operations with an example case study. The analysis assumes that each node has a threshold of 6 Joules.

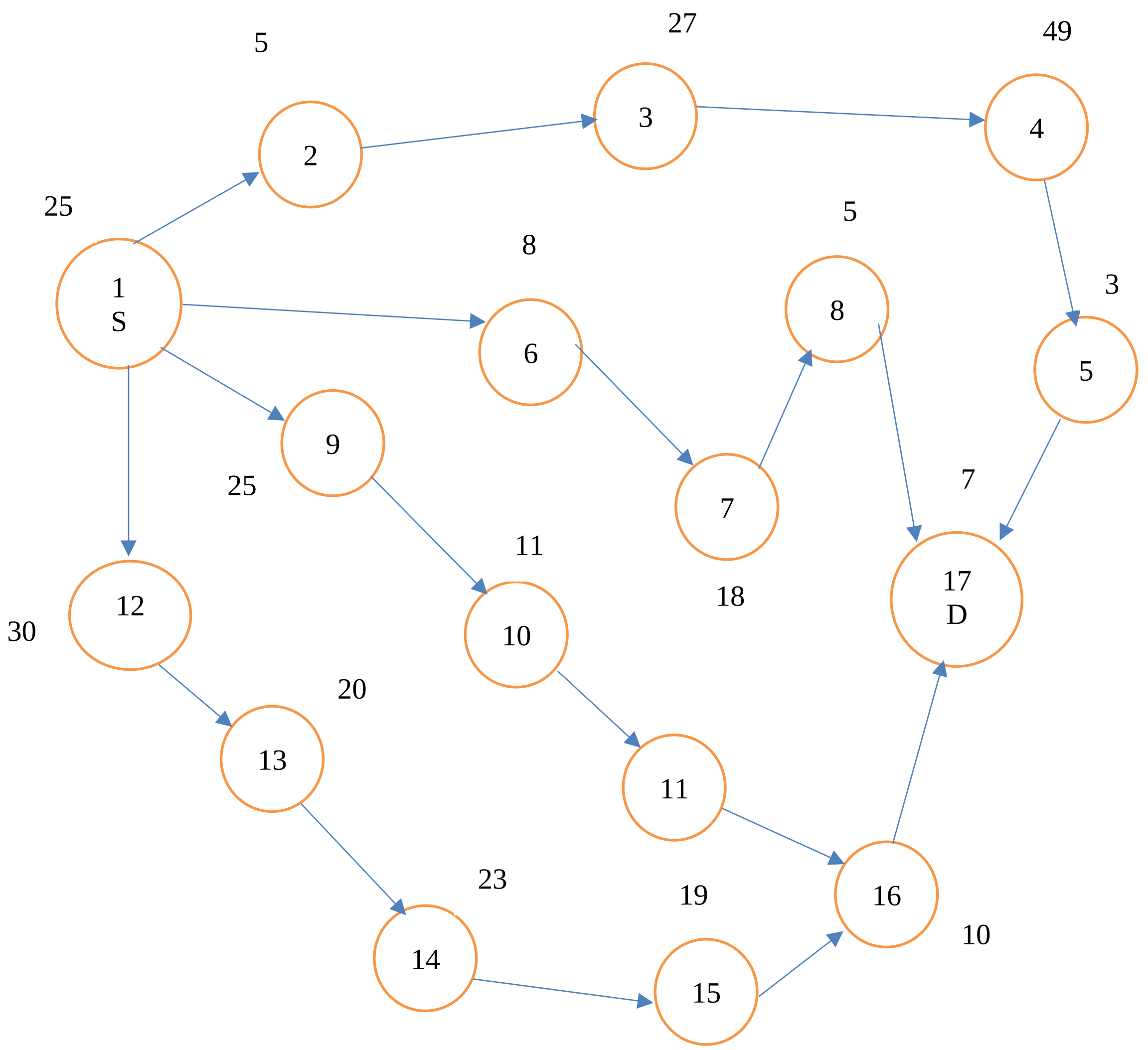

Fig.3.2. Operational analysis of ORES-AODV

Case 1: The AODV protocol typically chooses the path with a smaller number of hops, and as shown in Fig.5, the AODV protocol chooses the path <S: -6: -7: -8:-D>, The number of hops on the specified path is three.

Case 2: The ORES – AODV is proposed will find the direction between the source and the destination, such as <S: -6: - 7: -8:-D>, <S: -9: -10: -11: -16:-D>, <S: -12: -7: -8:-D> and here the algorithm finds the sum of the nodes residual energy and chooses the path with highest of the mean value of a sum of residual energy.

Case 3: The ORES – AODV will use another step to choose the optimal path by selecting a path, such as <S: -12: - 13: -14: -15: -16:-D>, <S: -9: -10: -11: -16:-D>, <S: -12: -7: -8:-D> with a minimum hop count, and if Case2 does not apply to any path, then the protocol will choose the path with the highest mean value of the sum of minimum residual energy.

3.4.2 Wireless Sensor Network

3.4.2.1 Method-1 System Model for WSNsBasic assumptions

- The selected network zone has a sink node that moves within the network area and several static sensing nodes that do not have mobility. Still, all the sensing nodes share similar characteristics.
- The network's sensor nodes are spread out and equipped with enough storage.
- Depending on how far they are from the receiver, the sensor nodes' broadcastingstrength can be changed by themselves.
- Although they can move in opposition to one another, sink movements are synchronized.
- The sinks go along a pre-determined path, arrive at a meeting place, and can communicate their locations to their close neighbors.

3.4.2.2 Method-2 Movement Strategy

The Multiple Mobile-Sinks-Based Energy-Efficient Clustering Algorithm (Multi-MECA) employs a naturalistic movement technique. Networks can use triangle forms for various purposes because of their advantages. Below are the benefits of choosing twosymmetrical triangles inside a circle [115].

Symmetrical triangles arranged closely together have fewer open areas than other forms do.This approach can cover more sensor nodes than previous versions since it covers a broader area per perimeter.

This work presents an energy-efficient cluster-based routing technique based on many mobile sinks [116]. The suggested strategy's main objectives are to solve the cluster head sinking issue and enable cluster heads to approach portable sinks.

Every cluster could have a sensor node near two mobile sinks. Cluster heads consequently utilize less energy when transmitting data. Mobile sinks may cover each part of a cluster at once to enhance network performance.

The suggested system is divided into three phases: initial sink placement and movement strategy, energy-efficient hierarchical routing, and sink halting stations. Sensing nodes can transfer information to the nearest mobile sink as cheaply as feasible by using a range of communication channels that are available to them.

The circle form is considered the sensing region in the suggested method due to its benefitsfor sensor nodes. Mobile sinks in Multi-MECA move down the sides of both triangles in the opposite direction at a fixed speed [117]. Figure 4 illustrates how the sensing nodes can use less energy when relaying data tothe closest sink.

The suggested method entails deploying a network of portable sinks to collect data from newly added sensor nodes. Each sink stops at a halting station, where it should only broadcast its location once. Broadcasting is done before any relocation or change in location.

The stoppage time option on each mobile sink controls how long it will wait to collect data from other sensor nodes [118]. A stoppage time frame was used to collect data. Each iteration of the data collection procedure occurs within a period of "stoppage time."

As soon as they receive the message, sensor nodes locate themselves concerning the right sink. Because each node knows the quantity and location of neighbors adjacent to the sinks, it will be easier for other sensor nodes to relay their data to the nearestsink. Each sink node goes on to the next stoppage station after the stopping interval has ended.

3.4.2.3 Method-3

Hierarchical routing algorithm with low energy consumption

The following guidelines must be followed by a sensor node when it employs the suggested hierarchical routing mechanism to send data packets to a nearby sink. M-MECA is explained below.

8. The nearest sink or cluster head is the direction in which the node's data are routed as affordably as possible.
9. The node may be close to the sink as the mobile sinks migrate over long triangular diagonals.
10. In this case, the node may determine which sink is closest by measuring the distance to the nearest sink.
11. One of the routes a node can take to determine how much it will cost to run it: the quickest way to the nearest CH, the route to the CH via several hops, the CH's path, and routing to its CH across several hops.

12. As a result, the node must send its data along the least energy-consuming path possible. To manage the energy used for data transmission, the sensor node in the network must assess the best relay node (Kj) in the multi-hop routing process.
13. Each sensor node that participates in the multi-hop routing operation can preserve data about the location of the sinks nearby and the ID of Kj as the best node for subsequent data transmission at each rendezvous point based on Kj's remaining energy to save energy consumption.
14. The node must choose a new relay node if Kj's remaining energy is below the threshold.

Algorithm:

Step 1: Initialize all the parameters, Sink Node1 and Sink Node2 is moving at predefined path.

Step 2: Invoke Cluster creation and cluster Head election procedure.

Step 3: Appoint central node as Cluster Head.

Step 4: Broadcast the advertisement to member nodes.

Step 4: Wait for Acknowledgment.

Step 5: Prepare a TDMA schedule and encourage other nodes to become new cluster heads.

Step 6: Select the new cluster Head based on Residual Energy and Threshold value.

Step 7: Send message with time slot and new CH details to member nodes.

Step 8: CH begins data aggregation from member nodes.

Step 9: CH calculates the distance from the sink node 1 and sink node 2.

Step 10: When sink node 1 and sink node 2 reach the rendezvous point, and if the distance of

CH is near to the Sink, send CH_DATA to the Sink. Else, wait.

Step 11: If remaining energy of CH is below the threshold.

Repeat the steps, and invoke cluster head creation procedure.

Step 12: Restart the broadcasting procedure.

Flowchart:

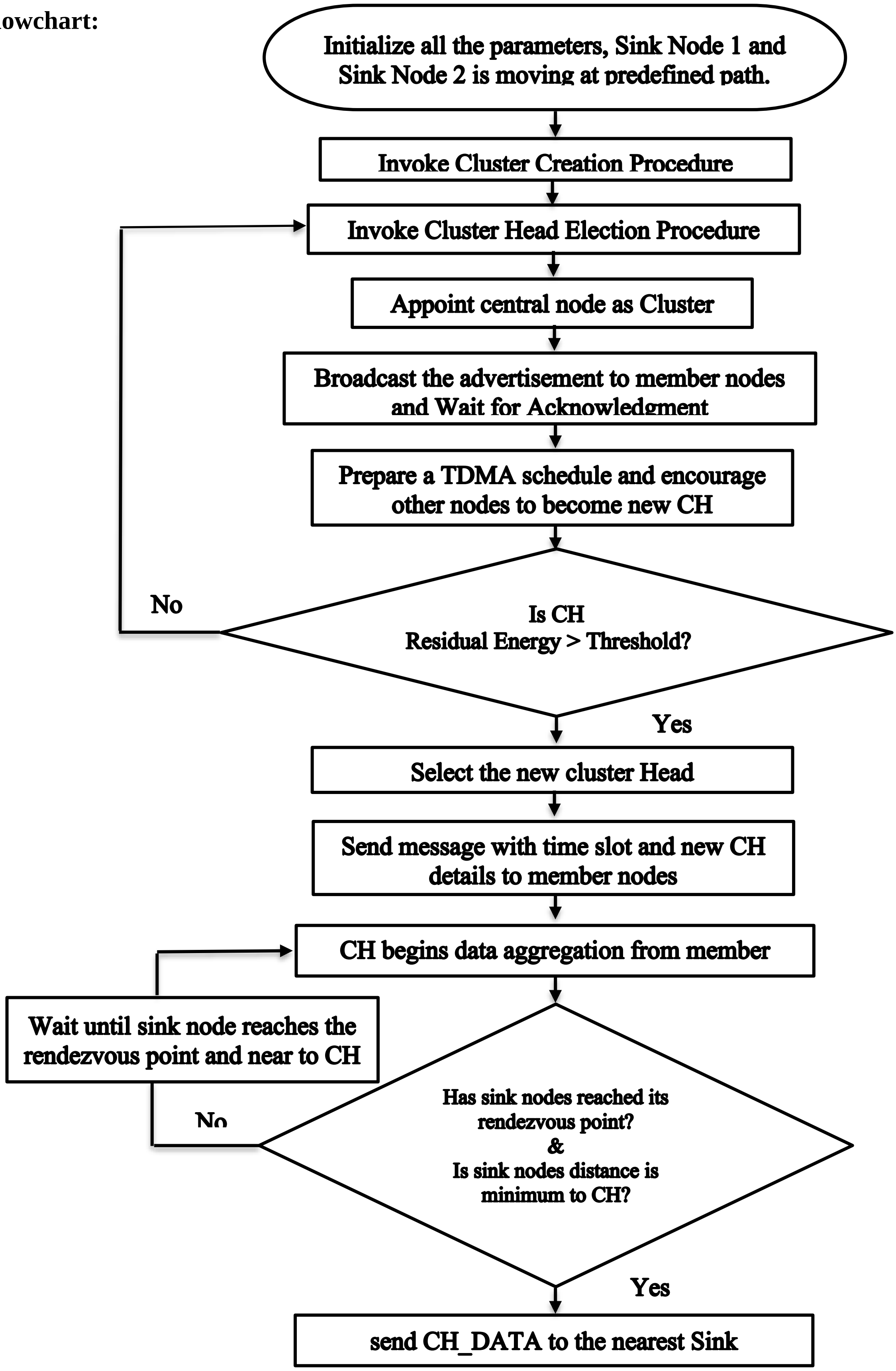

Fig 3.3: Flowchart defining the operations of Multi-MECA

3.5 Chapter Summary

The objectives of the planned study have been described in this chapter, followed by the scopeof the research work. In the next section, the methodologies used in the proposed work are discussed, and algorithms used to implement the protocols are described and discussed. Initially, the methods used in the MANET for the proposed algorithm are discussed, and then in the next section, the methodologies used in WSN for the proposed algorithmare discussed.

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CHAPTER FOUR

Energy Efficient Routing Protocols for Ad-Hoc Network

Contents	Page No

4.1 INTRODUCTION

Network nodes utilize Energy Efficient Routing Protocols for Ad Hoc Networks for effective communication. In an ad hoc network, nodes talk to oneanother when they are within radio range. To create an Ad Hoc Network, they alsostart communicating with other nodes in their radio range [119]. The Ad Hoc Networkis becoming more popular because the network created can be easily deployed with several different types of networks such as Wi-Fi, WiMAX, and Cellular networks.

4.2 Mobile Ad Hoc Network Routing Protocols

The proposed research work has selected several energy-efficient routing protocols for evaluation. The Ad Hoc On-Demand Distance Vector Protocol (AODV) and its variant and modified protocols are analyzed. The chosen protocols are evaluated against the ORES-AODV for energy efficiency [120]. The protocol ORES-AODV is the proposed protocol in this research work. The AODV protocol, ENL-AODV protocol, IR- AODV protocol, and M-AODV protocol are compared and evaluated with ORES-AODV.

4.2.1 Ad Hoc On-Demand Distance Vector Protocol

Some of the characteristics of the Dynamic Source Routing DSR and Destinated Sequenced Distance Vector (DSDV) protocols have been included in the AODV protocol. The On-demand demand routing scheme of AODV avoids unnecessary broadcasting of control packetsin the network. The AODV uses similar route maintenance and routes discovery methods adapted in the DSR protocol. AODV uses a sequence number after each hop count of the Route Request Packet, this sequence number is helpful to get the path with a minimum hop count, and AODV adapts this feature from the DSDV protocol [121]. The AODV is quick because it isa reactive protocol, and during the link change, if a path already exists and if it is a valid route, then the packet is transmitted between the source and destination. Otherwise, By delivering the RREQ packets, a Route Discovery procedure is started. A receiving node's new entries in the routing table will rebroadcast the RREQ packets. Timeto Leave (TTL) is used to control the propagation of the RREQ packets. The participatingnodes, neighbors of the source node, will discard and drop the RREQ packets once the TTL field is equal to or greater than its limit and rebroadcasting of the control packets is halted. The destination node sends a Route Reply control packet to the sender of the RREP packet upon receiving the RREQ packet, and for an intended period, the path is maintained and data packets are transmitted along the path [122]. And if any issues occur, such as location change by a source or destination node, then the Route Error RERR is sent by the participating nodes until the source node receives it. Immediately, the source node stops the propagation of data packets and will perform the route discovery.

4.2.1.1 Limitation of AODV

The AODV protocol has some limitations that hinder its performance, mainly its path selection techniques, which emphasize a path with a minimum hop count [123]. Considering hop count only as a parameter for path selection will create issues when the network becomes more extensive. So, additional parameters are the critical requirements of the AODV protocol to solve the nodes' link breakage and energy depletion. So, considering parameters such as threshold and remaining energy of the node is an additionalrequirement of the AODV protocol to lengthen the network's lifespan. Another modification that has to be included in AODV is the load balancing among the nodes. The route established with the load balancing technique increases the efficiency of routing.

4.2.2 Modified - AODV Protocol

The Modified AODV protocol includes an additional field in the RREQ and RREP packets. The new field throughput is added to the RREQ and RREP and then used to compare the performance of a node. The outcome of the comparison is used for the selection of a participant node [124]. The modified AODV makes some changes to the AODV protocolby adding a throughput field to the RREQ packet, and then the beginning of the route discoveryis allowed in the network. The throughput saved in the RREQ is the throughput of the source node, and the route discovery looks for the path with a minimal hop count, and the throughput is also compared. Suppose the visited node has a throughput value lesser than the source node. In that case, the node is discarded and considered inefficient to be selected as an intermediate node from source todestination.

4.2.3 Intelligent Routing AODV (IR-AODV)

The Intelligent Routing AODV protocol uses Received Signal Strength Indication (RSSI), andthe RSSI is technology to identify the node's location. It is invisible to the users of the device containing the receivers. The RSSI is well known to the users of the IEEE 802.11 protocol family. The RSSI calculates the distance from one node to another using the FRIIS formula.

Receiving power is denoted as Pr; in the formula, Pt represents the remaining energy.

$$P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi)^z d^2 L}$$

The node's energy and Gt save the distance value captured between two nodes. And the Grdenotes the value from receiving antenna. And the Gr is the measurement of the gained energyradiated from a direction in space.

The wavelength is indicated using the λ, the system loss factor isdenoted using L, and the distance is shown using D, and D is the distance between the antenna. In IR-AODV, two Network nodes exchange messages, and the mobile Ad-Hoc networkis created with N nodes. Ai is the set of neighboring nodes, where distance is kept minimumand is only one hop distance.

The neighboring nodes are with two hop distances and denotedas Bi, and all the distance is denoted as Di and the and set the axis line for X and Y. Followingthe previous step, the protocol selects the node with the same distance.

4.2.4 Energy and Load Based Routing Protocol (ENL-AODV)

The ENL-AODV is another enhanced protocol from AODV. This protocol considers load balancing and remaining energy during the route-finding process. The flooding of RREQis another step initiated by the protocol for route discovery. Once the flooding of RREQ is triggered, a reverse path is formed [125]. The ENL-AODV considers delay or jitter as a parameterfor energy loss in the nodes.

The delay is due to minimum residual energy in the node for datatransmission between nodes. Also, load balancing amongthe nodes can minimize energy loss. ENL- AODV also introduces the delay model to overcome the energy depletion issues in the nodes.

4.3 Mobility Model and its Impact on Efficiency

The ad hoc network is formed in scenarios where the deployment of network topology formation does not require any preparation. We can instantly form a network any hostile environment where the radio range of cellular network service providers is unavailable.

The network's topology is created in real-time and is helpful in several scenarios where nodes are in mobility and want to communicate with other nodes immediately.The network is decentralized, and every node can act as a router, intermediate node, transmitter, or receiver [126].

The ad hoc network keeps two neighboring nodes in its vicinity so that it can communicate with them and form an ad hoc network quickly. The nodes that make up the network can move unpredictably. Some of the migration of nodes is faster. This quick movement of the node changes the ad hoc network topology, a few nodes may move lessfrequently, and slow mobility is observed.

Therefore, the unpredictable node migration from one site to another is another challenge faced by ad hoc protocol other than the battery constraint. In an ad hoc network, the mobility models used will determine the behavior of themobility of nodes in the ad hoc network.

The two different used mobility models in the network Scenarios are the Gauss Markov Mobility model and Random Way Point Mobility Model. Thenetwork nodes can move in any random, unpredictable direction. The proposed protocol ORES-AODV is compared in Random Way Point Mobility Model and Gauss Markov Mobility Model. The mobility model will describe the movement of a node in the network, location,velocity, and acceleration.

The mobility model does a random walk and is classified into two types—first, Indoor MobilityModel, and Second, Out Door mobility model.

In Indoor Mobility Model, an Indoor scenario is chosen, where nodes randomly travel from one locationto another. This model identifies three types of mobility: randomwalk, random waypoint, and random direction. For example, consider two individuals within aroom walking and moving from one place to another, holding a cellular phone.

In this scenario,participating node1 can visit the location of participating node two and vice versa. In the indoor mobility model, randomly selecting the direction and speed, the mobile node goes from its current site to its new one. This method is known as a random walk. The attributes usedhere are minimum speed and Maximum speed [127]. Direction [0,2π], which means it can movein 360 Degree—the parameters constant time interval and distance 'd' are also used.

In random walk mobility, the direction, speed, and acceleration are dynamic. In a pause, time is zeroand does not store its status in memory, known as a memory-less pattern. Also, the current speed does not depend on the past rate of the node. It's also difficult to forecast the movement of nodes because of their rapid turns.

The second classification of the indoor mobility model is Random Waypoint Mobility Model. The difference between the Random Mobility and Random Waypoint Mobility Models is that the Random Way Point Mobility Model stops the transition between speed and direction change. Mobile Node stays for a certain period before making the next move.

The third classification of the indoor mobility model is the Random Direction Mobility Model, in which the probability of a new destination is always in the simulation area's center, and the path passes the simulation area's center [128]. A protocol will form a cluster in the middle ofthe network area. In the Random Direction Model, thenode selects a random direction and velocity from the ranges [0,2π] and [0, Vmax]. The node will then slowly reach the border of thesimulation area.

When the node hits the edge of the simulation area, it waits for the pause period. When the pause timer expires, the node chooses a new path from [0, π] and begins approaching the boundary.

In the outdoor mobility model, the protocol Gauss Markov mobility model, this protocol was suggested for simulating personal computers and their mobility. The Gauss Markov mobility model has several features, such as easy adaption to random mobility.

The nodes are assigned by current speed and direction in the Gauss Markov mobility model. Since the mobility is outdoor, the simulation area is infinite, and there is no initial point. It randomly takes some direction. The instantaneous speed and direction values are calculated using thefollowing equation.

$$K_n = \alpha K_{n-1} + (1-\alpha)\,\bar{k} + \sqrt{(1+\alpha^2)\,Kx_{n-1}}$$

$$Dt_n = \alpha Dt_{n-1} + (1-\alpha)\,\bar{Dt} + \sqrt{(1-\alpha^2)\,Dtx_{n-1}}$$

In the above equations, K_n and Dt_n are the random variables of gaussian distance, α is the randomness index, k is the average speed, Dt is the middle distance, Kn is a new speed Dt_n is the new direction. If the new rate and direction must be assigned, equation (1) is employed to determine the unique speed and movement [129].

The nodes are mostly expected to beinside the simulation area if there is any possibility that any node crossing the boundary of the simulation area, then by using the equation and a specific mean value, the node can be pushed inside the simulation area.

Another protocol in the outdoor mobility model is the Random Walk Mobility Model in Probabilistic Form. A probability matrix is used in this mobility model to calculate the positionof a specific Mobile Node in the next step.

In the probabilistic matrix, state 0 indicates the mobile node's current location, state 1 denotes the mobile node's previous location, andthe node's next position is indicated by state 2.

$$Pr = \begin{pmatrix} pi(0,0) & pi(0,1) & pi(0,2) \\ pi(1,0) & pi(1,1) & pi(1,2) \\ pi(2,0) & pi(2,1) & pi(2,2) \end{pmatrix}$$

Based on the probabilistic matrix given, the mobile node's current, previous, and subsequent moves are determined in the Random Walk mobility model with a probabilistic twist.

As shown in the matrix, the movement of a node from the next state to the previous state is directly impossible, and the node will remain in its current form. Mobile nodes can move from the last state to the next only once they reach the current state.

The wireless Sensor Network is another Ad Hoc Network, an information-gathering network from sensor nodes throughout the network. The wireless sensor network is also suitable for a hostile environment, where quick adaption is necessary [130].

The proposed protocol highlights the benefits of using multiple sink nodes for gathering data to overcome the issues such as sinkholes and the methods for creating cluster heads to avoid thehot regions near the base station.

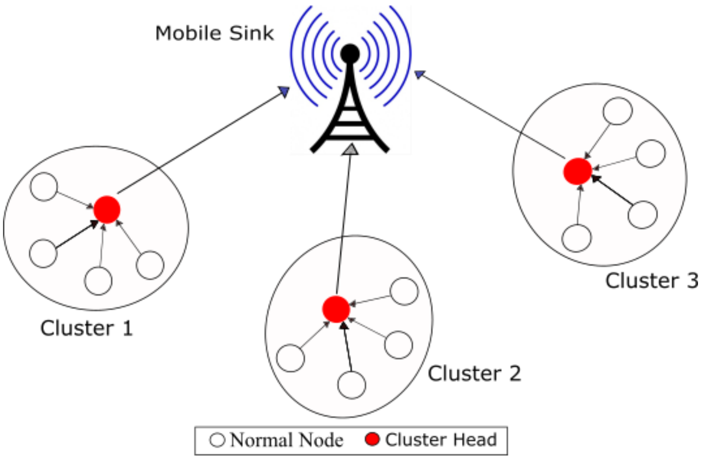

Fig.4.1. Wireless Sensor Network with Sink node.

The proposed protocol creates a virtual star cell within a circle formed using two symmetrical equilateral triangles, where two mobile sinks move to reduce the communication overhead and energy hotspot near the sink.

4.4 Wireless Sensor Network Routing Protocols

The Wireless Sensor Network uses an energy-efficient routing protocol to route the data fromone sensor device to another. The network contains nodes equipped with a battery having limited battery power, the protocols used to form the network have to use methods to overcomethe energy dissipation. One of the most robust protocols is LEACH, and in this research work,LEACH and its variants are evaluated against a modified protocol, Multi-MECA, for energy efficiency [131]. The Multi-MECA is a proposed protocol assessed for efficiency with LEACH and MECA routing protocols.

4.4.1 LEACH Protocol

In this study, we have focused on the issue of network hotspots or energy holes and tried to solve the problem of energy holes utilizing mobile sinks. Before the network even starts, some presumptions are established [132].

The sink node is expected to have enough energy to travelat the center of the network and is assumed to be moving from one position to another.

The suggested research will be based on the LEACH protocol, which has multiple problems due to the fact that it is a hierarchical cross-layer protocol.

To address the issue of energy dissipation,the LEACH protocol uses a hierarchical approach, which requires numerous iterations.

The bulk of iterations consists of preparation and sustained data transmission phases. The protocolwill dynamically establish the cluster, and randomly chosen cluster heads will be selected during the preliminary stage.

In the steady data transmission phase, the cluster heads are swapped after erounds, and the selection of the cluster heads depends on the percentage R-value and thethreshold value, as shown in the following equation.

$$P(m) = \begin{cases} \dfrac{R}{1 - R * \left(e \bmod \frac{1}{R}\right)} \end{cases} \quad if\ m \in Q\ otherwise$$

When deciding whether a cluster head belongs to Q—the number of nodes that nodes didn't have cluster heads in the 1/R rounds prior—the LEACH algorithm utilizes the threshold value. After beingselected as the cluster head node, it will send all other cluster members a message informing them of its selection. Each member node is given a transmission slot, which indicates when to transmit when a node is chosen to act as the cluster head. This scheduling and assignment are done via TDMA. If one of the nodes has served as a cluster head in the past and has been selected for each iteration, P(m) is set to zero, and the protocol won't select the same node or the 1/R iterations.

The primary problem with the typical LEACH approach and the wrong selection method is thatit does not consider the base station's location and the amount of remaining energy when choosing Custer Head.

The intended study uses residual energy and a threshold value to select the cluster head.When a node's mobility is activated, its motion is monitored. Since every node in the networkis aware of its neighbors' movements, route discovery and maintenance are started [133].

The packets are transmitted once the route has been established using the route discovery method, which finds the shortest path between the source and the destination. The procedure fordiscovering routes is used to complete the work when the source node's route is unknown whenit transmits packets. The route discovery process can be used more than once to fix the unsuccessful routes, and it is feasible to reconstruct the pathways from point A to point B.

4.4.2 MECA Protocol

The Mobile-sink based Energy-efficient Clustering Algorithm (MECA) is based on the LEACH protocol. The MECA uses an energy balancing technique with the help of a mobile sink node at the detecting location. The MECA appoints a sink node with a fixed movement track, andthe nature of the sink node is predictable. A clusterhead is selected for each network partition, and cluster heads assemble data andgradually propagate to a moving sink node by Partitioning the network into equal parts. When the mobile sink node reaches therendezvous point, cluster heads transmit data to the sink node.

4.4.2.1 Network Model

In MECA, the network contains network nodes, and the number of nodes is pre-determined asper requirement and denoted by N, and the member nodes of the network are denoted as {Sr1, Sr2, ...Srn}.

The MECA considers its network area to contain sensors dispersed within a circle Radius.

R. The sink is decided to be placed at the edge of the circle, and the movement of the sink nodeis pre-determined to be counterclockwise. The movement follows a necessarily required velocity, the direction of the sink is upon the arc, and a fixed track is used [134]. The protocol can predict the sink movement and its exact location on the arch.

Some of the assumptions made by the MECA protocol are:

1. Each node within the network has unique characteristics
2. The sink node occupies the pre-determined location at the network's edge.
3. The sensor nodes within the network can regulate their power requirement for thetransmission based on the transmission distance from the sender to the sink node or base station.

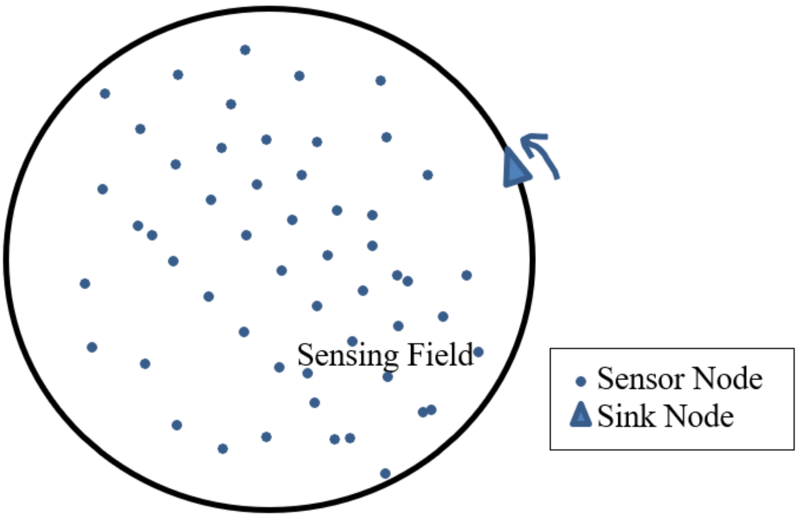

Fig. 4.2: Network Model of MECA

4.4.2.2 Energy Model

A free space (d^2 power loss) or multi-path fading (d^4 power loss) channel model is utilized in MECA, and a comparable energy model considers the distance between the transmitter and receiver. Each sensor node will need to expend the corresponding ETX amount of energy to broadcast an l-bits packet over a distance of d:

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

Where the Elec is the amount of energy used to operate a transmitter or receiver circuit per bit.,$l\varepsilon_{fs}$ and $l\varepsilon_{mp}$ indicate the effectiveness of the transmitter amplifier and the channel circumstances. Radio needs the power to receive a packet:

$$E_{RX}(l) = lE_{elec} \quad (2)$$

4.4.2.3 Relocation of the Sink

The sink or base station moves at the edge of the network, and this scenario of the network helpto increase the network lifetime. The earlier researches on the same area assume that each nodeknows the location and current condition of the sensor nodes within the network. And every sensor node can predict the current location of the other node.

Location prediction needs to broadcast additional control packets, which requires additional energy consumption [135]. In the MECA protocol, the mobile sink node's direction can either be clockwise or opposite as shown in Fig.4.1. In the MECA protocol, the sink node is the only node responsible for sharing its location with other sensor nodes in the network only once.

At the later stage of the network, sensor nodes can calculate the current location of the sink node by adding θ to the initial location of the sink node after Δt interval of time as shown in Fig.4.3. The initial area of the sink is P0, and it isknown to all the nodes in the network [136] by sensor node can implement the method shown in the figure to find the current location of the sink node.

Once the broadcasting is completed, the sink node is responsible for collecting data from the sensor nodes. Another assumption is that the sink node will remain moving within the network until the completion of data gathering. After retrieving all the data, a sink node can move to the following site.

4.4.2.4 Cluster Formation and Cluster Head Selection

The MECA protocol divides the entire network area into c number of clusters, and c is assumedto be 5 in the MECA protocol, the following figure shows the clustering formation of the sensor network. As shown in Fig.4.4, each cluster head is selected via the MECA protocol, and only one clusterhead is allocated to each established cluster. The Cluster head combines data and transfers it to the sink after data fusion [137]. The algorithm MECA has several advantages, suchas the MECA protocol could overcome the traffic load due to its data aggregation feature.

The secondadvantage is that the MECA protocol can appoint cluster heads more uniformly, whereas the LEACH protocol randomly selects cluster heads. Another advantage of the MECA protocol is the sensor nodes are not performing communication in the MECA protocol, and the sink node does it. Sink node communication capability will enable the network lifetime to be extended.

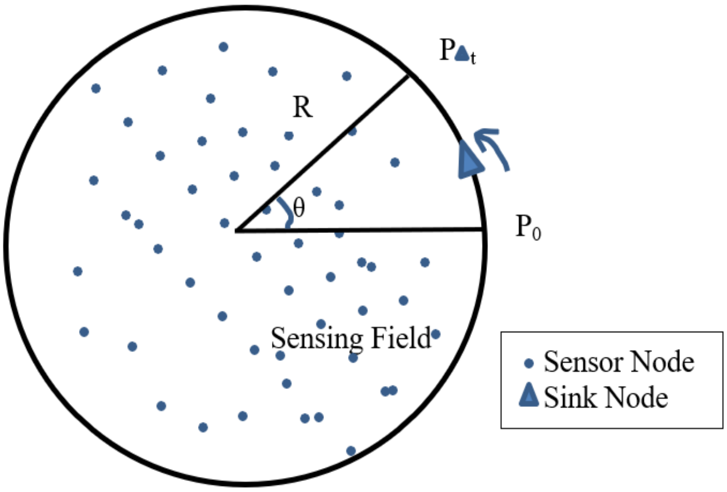

Fig. 4.3: Relocation of the Sink in MECA

The MECA protocol chooses the cluster heads based on remaining energy. The cluster head selected for the sensor node is recommended to be in the middle of the network area because the node which is at the center of the network itself is preferably suitable for chosen asthe cluster head, denoted by Si, Si then broadcasts an alert message within radius R to encouragethe sensor nodes which are interested in becoming the cluster head [138].

Near neighbors only receive the posted messages, and the rest of the nodes are not triggered by the alert sent by Si. the broadcast message contains the ID and Residual energy of Si. and on receipt of the broadcasted message, the other neighbor node Sj compares its residual energy with residual energy value sent through the message. If Sj's residual energy is more than Si's, Sj is activated as the cluster head. Once a new cluster head is selected, it will senda new message to its neighbors.

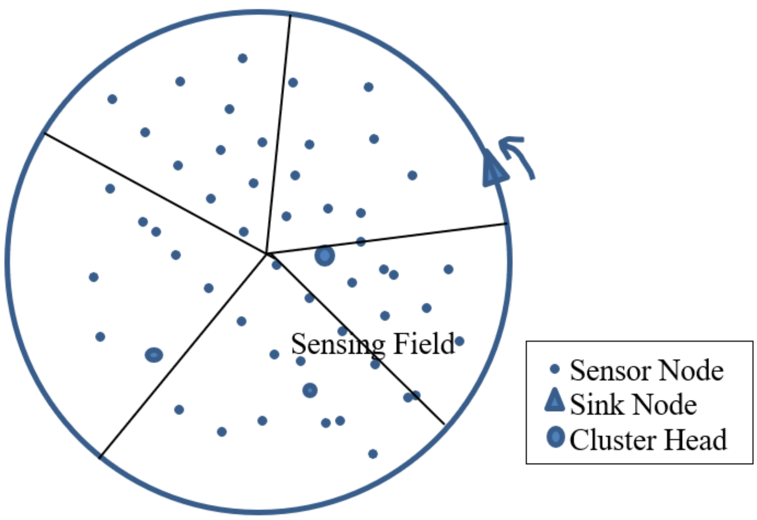

Fig.4.4: Cluster formation and Cluster Head Selection in MECA.

4.4.2.5 Routing Procedure

Several clustering techniques, including LEACH, allow the sensor nodes within a cluster to share data directly with the cluster head. Due to the location's inflection, some sensor nodes may expend much energy during long-distance transmission. As a result, we established a multi-hop intra-cluster routing protocol.

4.4.3 Multi-MECA Protocol

The Modified Mobile-Sink-based Energy-efficient Clustering Algorithm (Multi-MECA) is based on the MECA protocol, and the MECA protocol is modified from the LEACH protocol. The Modified MECA protocol multi-MECA is proposed in this research work and uses multiple sink nodes to equalize the network's energy load. The multi-sink nodes used in the Multi-MECA protocol move at a predefined path in the opposite direction of each other. The movement of sinks is predictable by other sensor nodes in the network [139]. As shown in fig., the network isdivided into partitions, and the direction of the sink node is on the edges of the shape as given in the figure. The divisions are created by the intersections of the two symmetrical triangles and called clusters, and Multi-MECA appoints a cluster head for eachcluster.

The Multi-MECA considers its network area containing sensors within the two symmetrical triangles as shown in Fig.4.5. The sink node can also communicate with the sensors outside the boundary if they are near neighbors of the clusters within the triangles [140]. The sink node1is placed at the edge of the first triangle, and sink node two is placed at the second triangle, as shown in Fig. The M-MECA protocol appoints a cluster head in the middle of the two symmetrical triangles, known as the central cluster head. It is responsible for propagating control messages to other clusters in the network. The central cluster head sends a message.

Which is received from both the sink nodes, sink node one and sink node 2. The message contains the sink node's initial location, the central cluster head's residual energy, and the major cluster head's threshold value [141]. The central cluster head encourages other clusterheads also to become the cluster head. Its residual energy and threshold are compared, and the node with the most excess energy is selected as a cluster head. If the node's thresholdvalue is below a specific limit, then the node is discarded from comparison for a particular time interval. The central cluster head triggers other sensor nodes to become cluster heads. The selected cluster heads are responsible for gathering data from a sensor within the network and propagating it to sink nodes one and 2. The cluster heads can transmit data to any sink node when they reach rendezvous points. The location of the sink nodes can be calculated by their initial location and with the help of the distance formula.

$$d = \sqrt{[(x22 - x11)^2 + (y22 - y11)^2]}$$

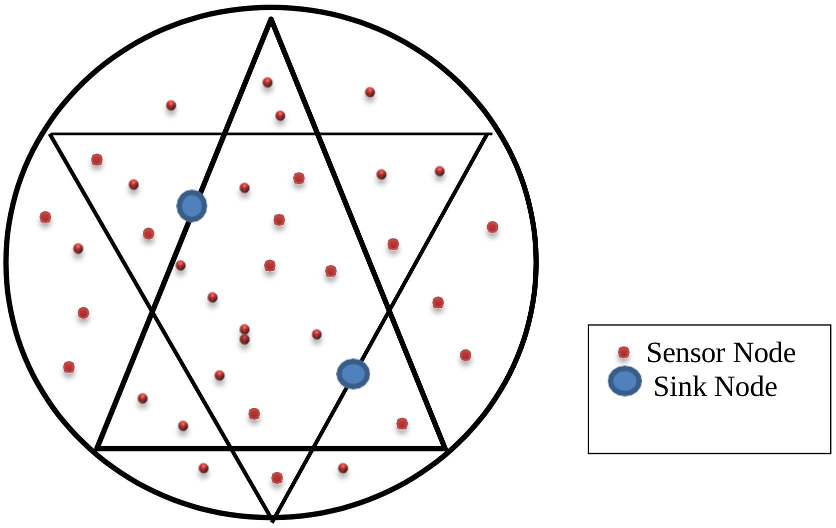

Fig.4.5. Multi-MECA Network Model

4.5 Chapter Summary

This chapter discusses Energy efficient routing protocols for Ad Hoc networks. Initially, Energy Efficient Protocol for Mobile Ad Hoc Network is concerned. The discussed protocols are based on the AODV protocol. The AODV protocol is discussed in the next section, following its limitations. And other advanced protocols based on AODV, such as M-AODV, IR-AODV, ENL-AODV, and proposed protocol ORES-AODV, are discussed. In the next section, the energy-efficient protocols of WSNs are discussed, and the protocols are based on the LEACH protocol. The following section describes the MECA protocol, a variant of the LEACH protocol, and also newly proposed protocol in this work called Multi-MECA is also discussed.

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CHAPTER FIVE

Simulation Design and Results

Contents	Page No.

5.1 INTRODUCTION

The research uses Simulation tools to attain the results from the proposed methods usingNS3 simulator for Mobile Ad Hoc Networks and MATLABR2021a for Wireless Sensor Networks. The network simulators help analyze the various network protocols and generate comparative analyses. The study uses different performance metrics and graphs to analyze the result. The simulation analysis is performed initially for two protocols, the base, and the modifiedprotocols. A detailed comparative analysis is performed between the energy-efficient protocols [142].

In the Mobile Ad Hoc network, a well-known energy-efficient protocol, AODV,is used. The research is carried out to understand the behavior of the AODV protocol withthe help of a simulation tool. The simulation tool used for the analysis is NS3, and the AODV protocolis compared with varying numbers of nodes.

Initially, performance metrics are compared for fewer nodes and gradually increasing the number of nodes for the simulation. After the evaluation AODV protocol, the protocol is evaluated with the protocols modified and proved by the researchers that are more efficient than the AODV protocol. Some of the protocols compared with the AODV protocol are ENL-AODV, M-AODV,and others [143]. After evaluating the protocols in NS3, the results are plotted using graphs and analyzed to understand the protocols deeply.

In the second step,a modified protocol is developed in the proposed work and evaluated. Then, a comparative analysis is performed using the NS3 simulator, and the proposed protocol ORES-AODV is proven more efficient than the AODV protocol. After comparing ORES-AODV with AODV and other modified protocols such as ENL-AODV and M-AODV. Also, the ORES-AODVis evaluated in different mobility models to test its energy efficiency in different mobility models, such as Random Way Point Mobility Model, Gauss Markov Mobility Model, and Constant Mobility Model.

In the case of Wireless Sensor networks, MATLAB is used to evaluate the energy-efficient wireless sensor network protocols, such as LEACH, are, are considered. The modified M-MECA protocol is proposed in this research, and MECA and M-MECA are compared for their efficiency.

5.2 Protocols Selected for Simulation in MANET

The proposed research work has selected a protocol,and it is a Reactive protocol. AODV AODVprotocol is then compared with leading protocols such as OLSR, DSDV, and DSR and proved that AODV is efficient. Then, the AODV protocol is modified as the ORES-AODV protocol and evaluated in NS3 with several parameters such as energy consumption, end-to-end delay, throughput, and packet loss ratio assessed using an NS3 simulator [144].

The protocols compared with AODV and ORES-AODV are ENL-AODV and M-AODV. The ORES-AODV takes some additional parameters, such as residual energy and threshold, to solve the problem ofenergy evaluation.

5.3 Protocols Selected for Simulation in WSN

The energy-efficient LEACH protocol is used for evaluation using the MATLAB simulation tool. The MATLAB simulator evaluates the LEACH variant MECA for its efficiency against energy.

The modified protocol called Multi- MECA is proposed to overcome energy depletion issues.

5.4 Performance Evaluation

5.4.1 AODV protocol

Open-source simulator Network Simulator 3 (NS3) allows simulations with discrete nodecounts. In the simulation of the proposed work, 100 nodes are simulated, and there are ten sinks. The constant Speed Propagation Delay propagation model is used in the suggested work.

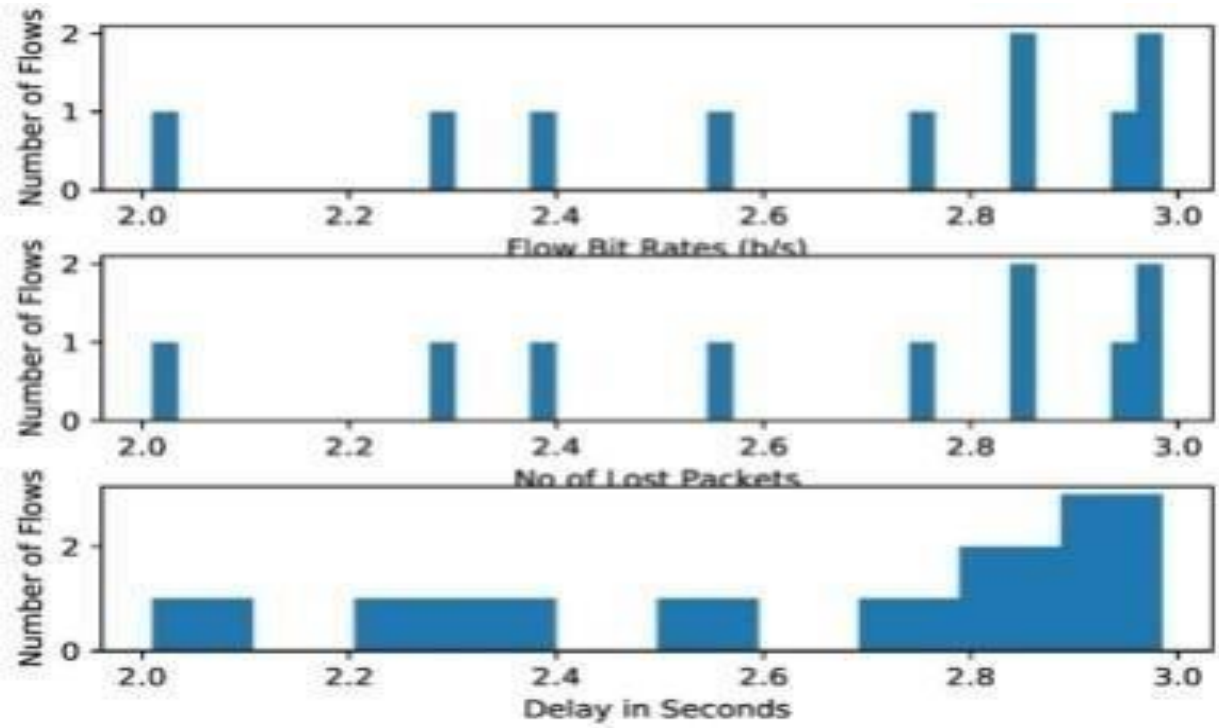

Fig. 5.1: No of Lost Packets and Delay in seconds in AODV protocol.

Initially, the simulation analyses the AODV protocol for bit rate flow, packet loss rates, and packet lag times in seconds. According to the total flow count, Figure 5.1 displays the bit rate flow, the number of packets lost, and the delay in seconds to receive packets.

This simulation's total number of discharges is 2, and the flow bit rate in AODV is good at bitsper second. Figure 5.1 also examines the quantity of transmission-related packet losses. Additionally, the time it takes to receive the packets is in seconds.

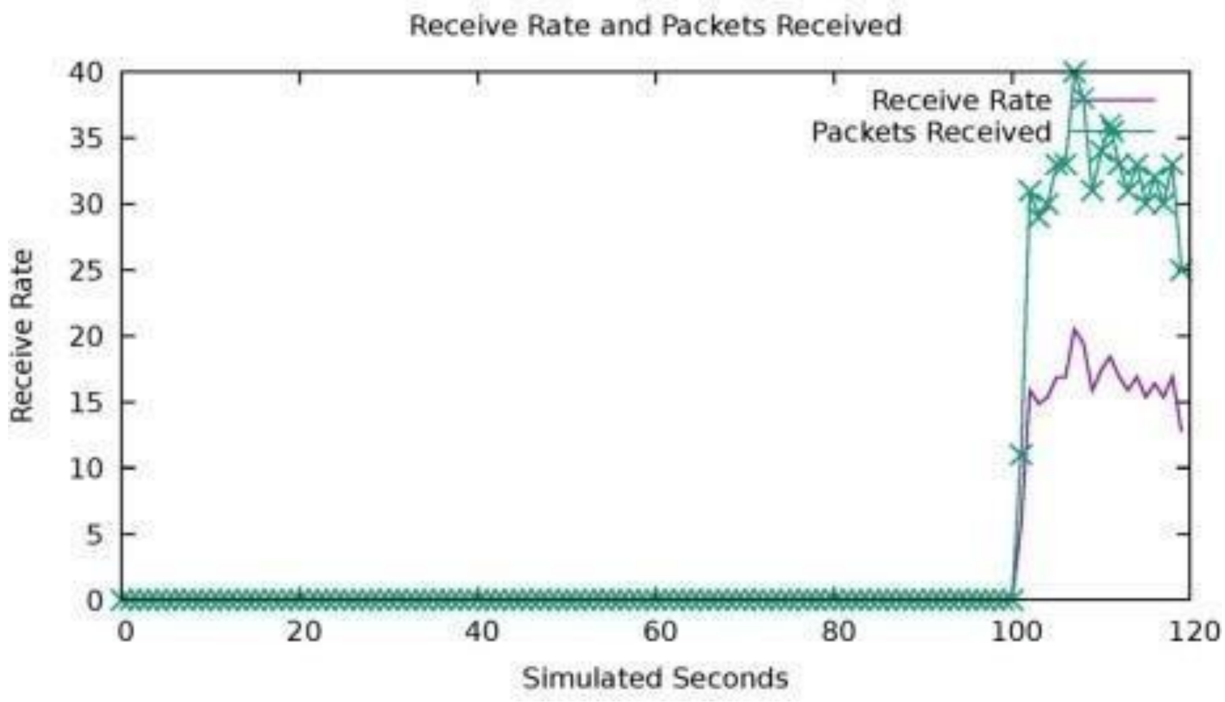

Fig. 5.2: Rate of received packets and Packets Received analysis in AODV protocol.

At the end of transmission, the packet's delay gets longer. Figure 5.2 displays the AODV protocol's received packet rate and packet count. The simulation's final diagram reveals that theAODV protocol's receive rate suddenly increases after being stable for the first 100 seconds. This increase indicates that the protocol needs 100 seconds to broadcast packets before receiving a destination.

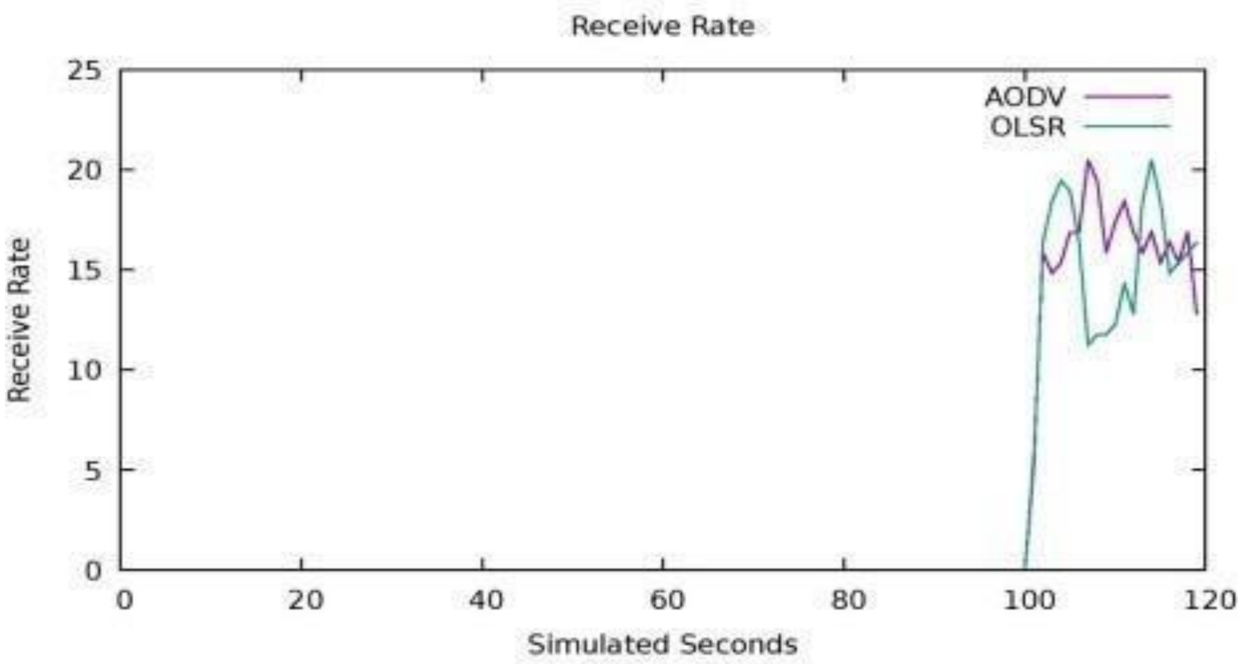

Fig. 5.3: Comparison of AODV and OLSR protocol based on Receive Rate.

Fig. 5.3 shows the comparative analysis of AODV and OLSR protocols on receive rate.The accepted rate of both protocols is stable.

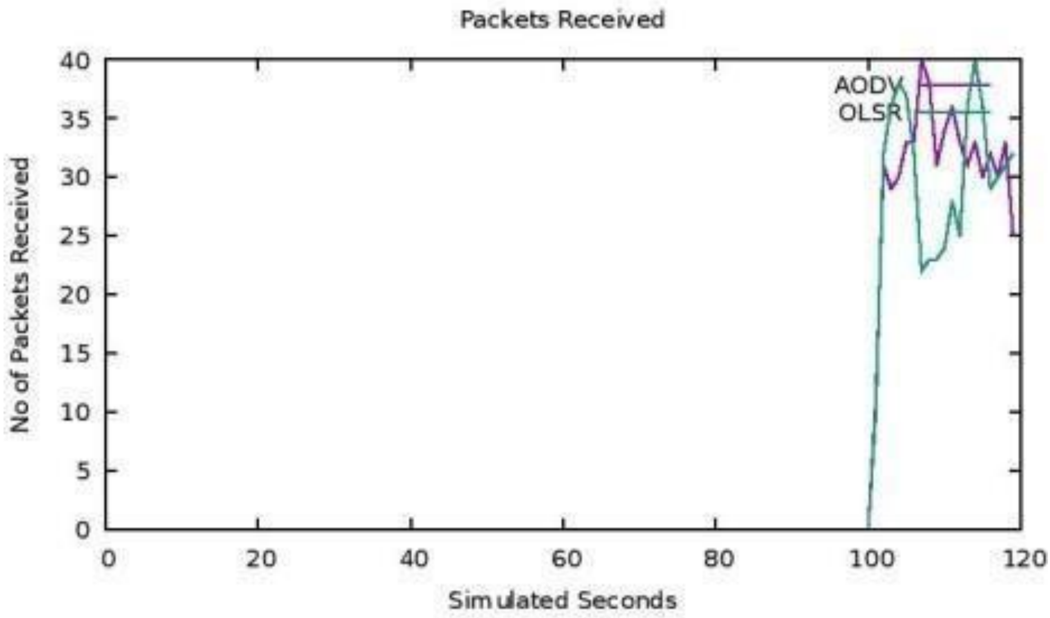

Fig. 5.4: Comparison of AODV and OLSR protocol based on No. Of packets received.

The comparison of the AODV and OLSR protocols receive rates is shown in Figure 5.4. Both protocols' reception rates are consistent.

5.4.2 Comparison of AODV with other MANET protocols

We assessed and compared the performance of the MANET routing protocols and the differentmetrics of the routing protocols. We have analyzed four routing protocols in network simulation, and their simulation parameters are reported in Table 5.1.

Table 5.1: Simulation Parameters.

Parameter	Value
Area (m*m)	300 x 1500 m
Simulation Time(s)	500 Seconds
Speed (m/s)	20 m/s
MAC type	802.11 p MAC
Traffic type	Two-Ray Ground
Packet size	64-byte packets
Protocols	OLSR, AODV, DSDV, DSR, M-AODV, IR-AODV, ENL-AODV, ORES-AODV
Mobility Model	Random Waypoint Mobility Model

The rate of packets received varies from protocol to protocol, the simulation is performed for27 vehicles for 500 seconds, and Fig. 5.5 shows how to receive rate differs from one protocol to another. The simulation result shows that after 200 seconds, the protocol DSR's receivesrate is stable, and AODV has high performance compared to other protocols. In this result, the simulation can also conclude that the performance of the AODV protocol is remarkably high.

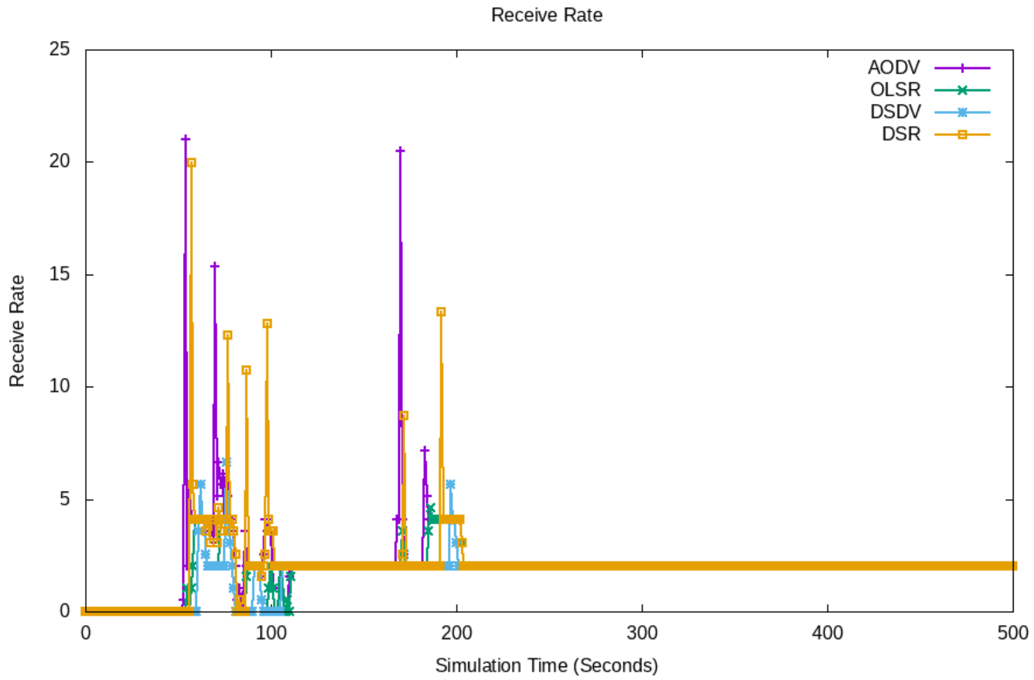

Fig. 5.5: Received rate of OLSR, AODV, DSDV, and DSR protocols.

A comparison of the distribution packets received to all four protocols shows that all three protocols' packet delivery ratio is good at the simulation, as shown in Fig.5.6, except for the DSR protocol.

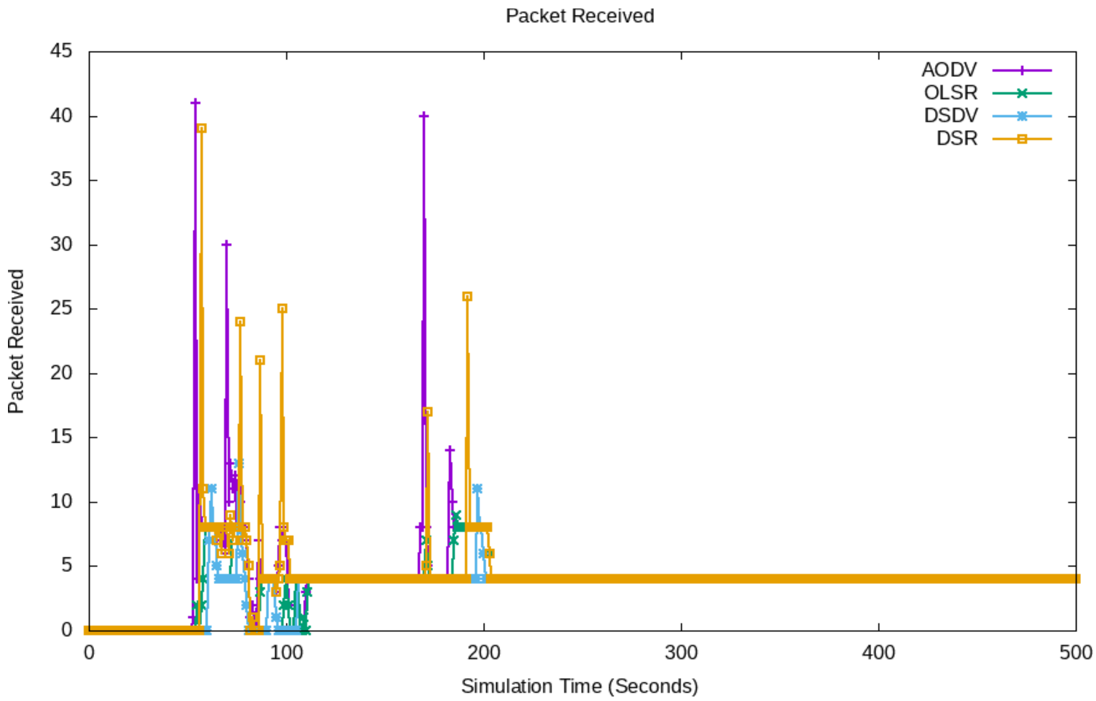

Fig. 5.6: Comparison of Packets received of OLSR, AODV, DSDV, and DSR protocols.

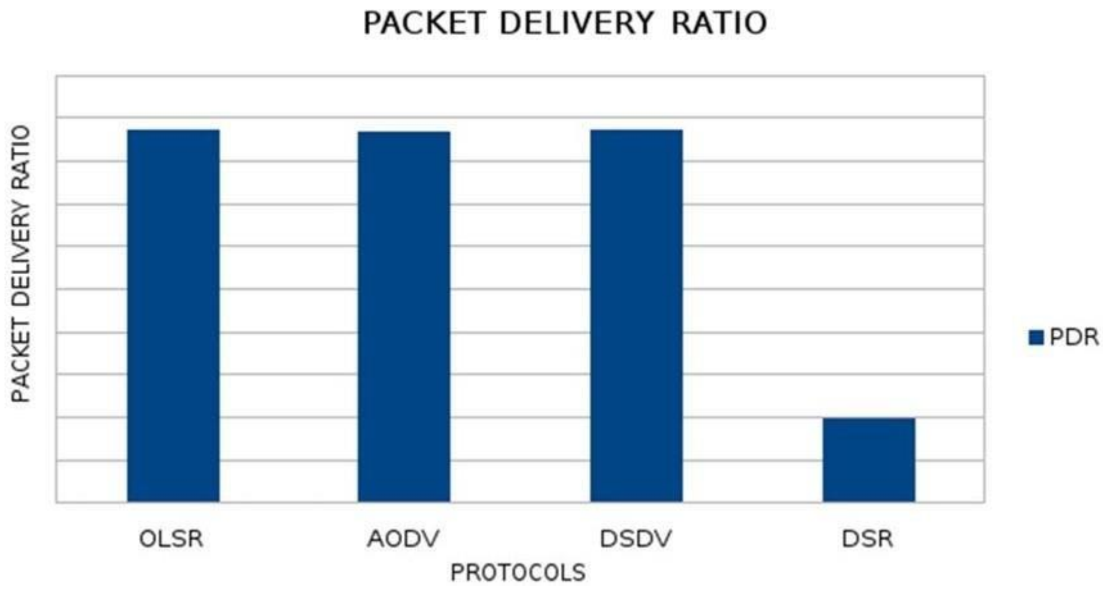

Fig. 5.7: Comparison of Packet delivery ratio of OLSR, AODV, DSDV, and DSR protocols.

A comparison of the distribution ratio of packets to all four protocols shows that all three protocols' packet delivery ratio is good at the simulation, as shown in Fig.5.7, except for the DSR protocol.

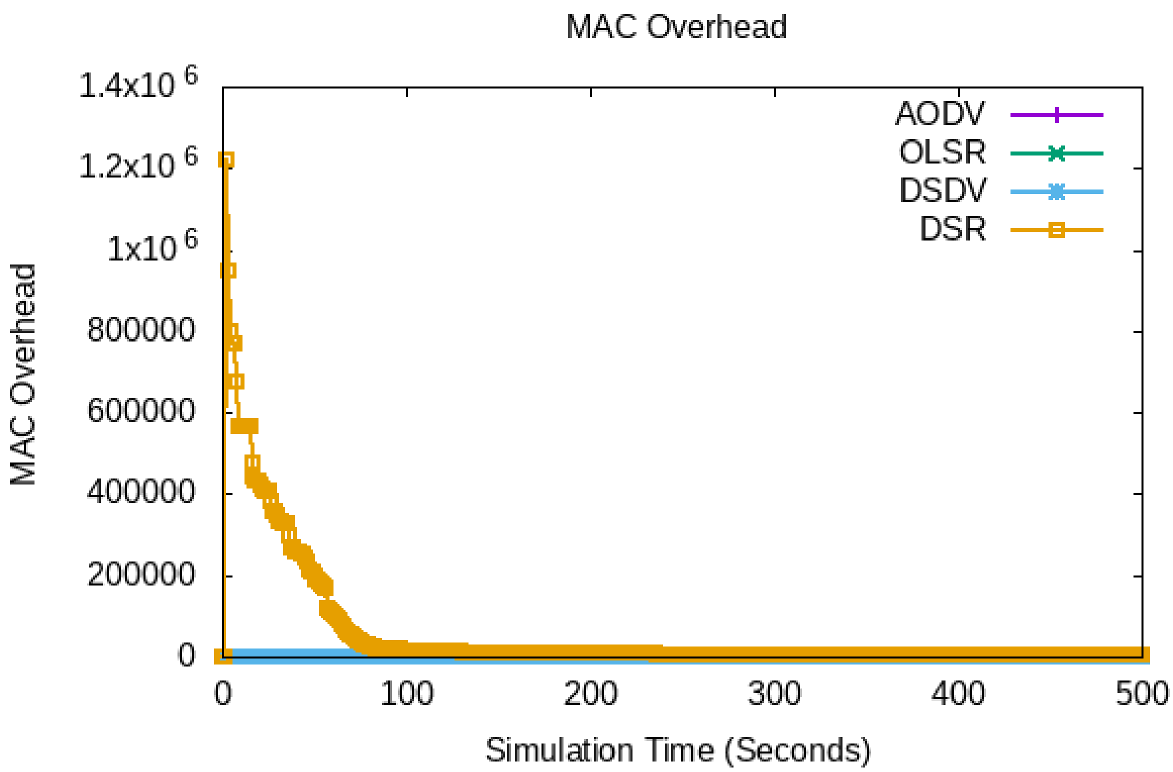

Fig. 5.8: Comparison of MAC/PHY Overhead of OLSR, AODV, DSDV, and DSRprotocols.

MAC/PHY Overhead is related to the practical usage of the bandwidth, MAC/PHY Overhead is less, and nodes can send more data in each packet in our simulation. It is shown in Fig. 5.8 that the protocols AODV, OLSR, and DSDV have less or zero MAC/PHY Overhead compared to the DSR protocol.

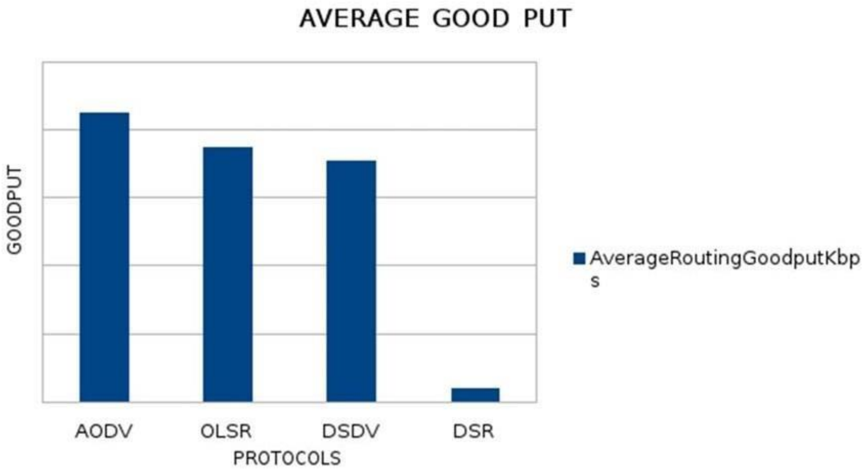

Fig. 5.9: Comparison of Average Routing Good put of OLSR, AODV, DSDV and DSR.

Typical Routing Good put differs from throughput since only the necessary information is contained in goodput, but throughput includes information like retransmission and overhead. Fig.5.9 illustrates how, in our experiment, AODV has a higher average Routing Good put than other protocols.

5.5 Performance Evaluation of AODV with simulation Metrics

The AODV protocol is simulated for 200 seconds, and a total of 350 flow ID has been generated due to the simulation. The fig shows the number of sent packets when AODV is used as a protocol.

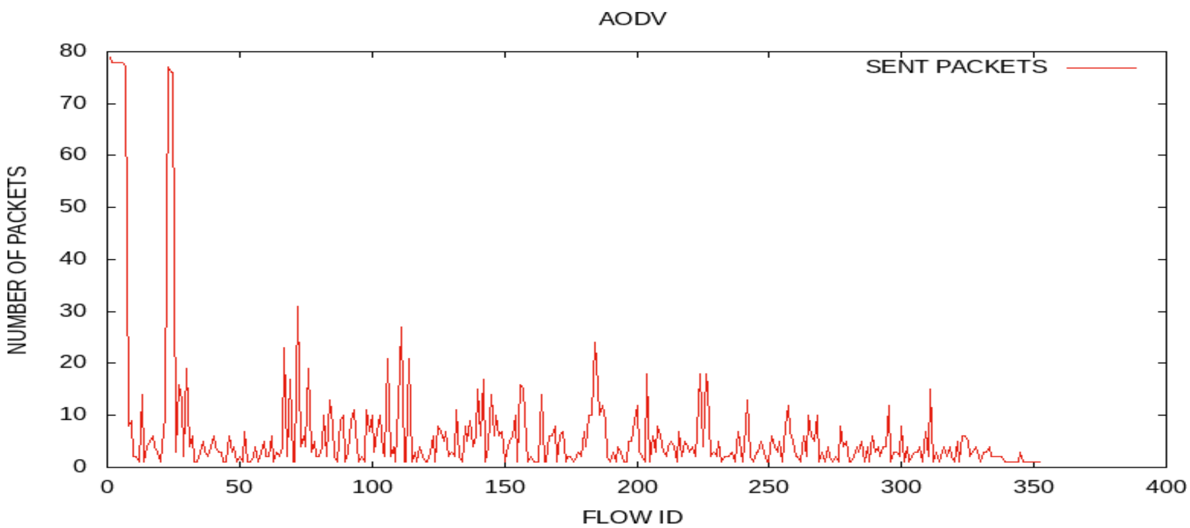

Fig. 5.10: Sent Packets.

From the result, we can analyze that the maximum number of packets are sent during the beginningof the simulation as shown in Fig.5.10.

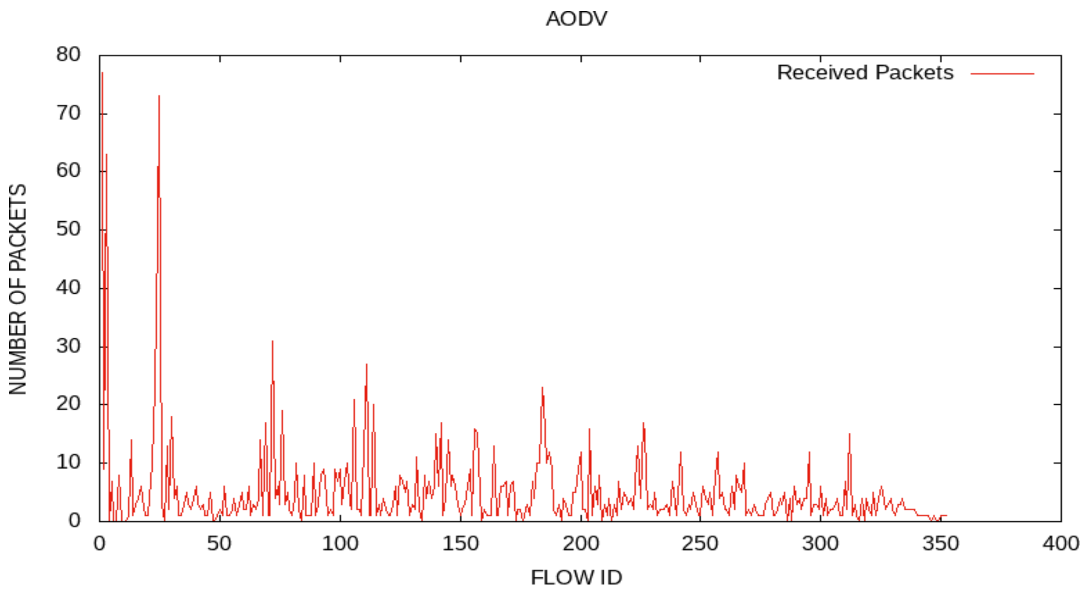

Fig. 5.11: Received Packets.

The AODV protocol is simulated for 200 seconds, and a total of 350 flow ID has been generated due to the simulation. The Fig.5.11 shows the number of received packets when AODV is used as a protocol. From the impact, we can analyze the maximum number of packages received during the beginning of the simulation.

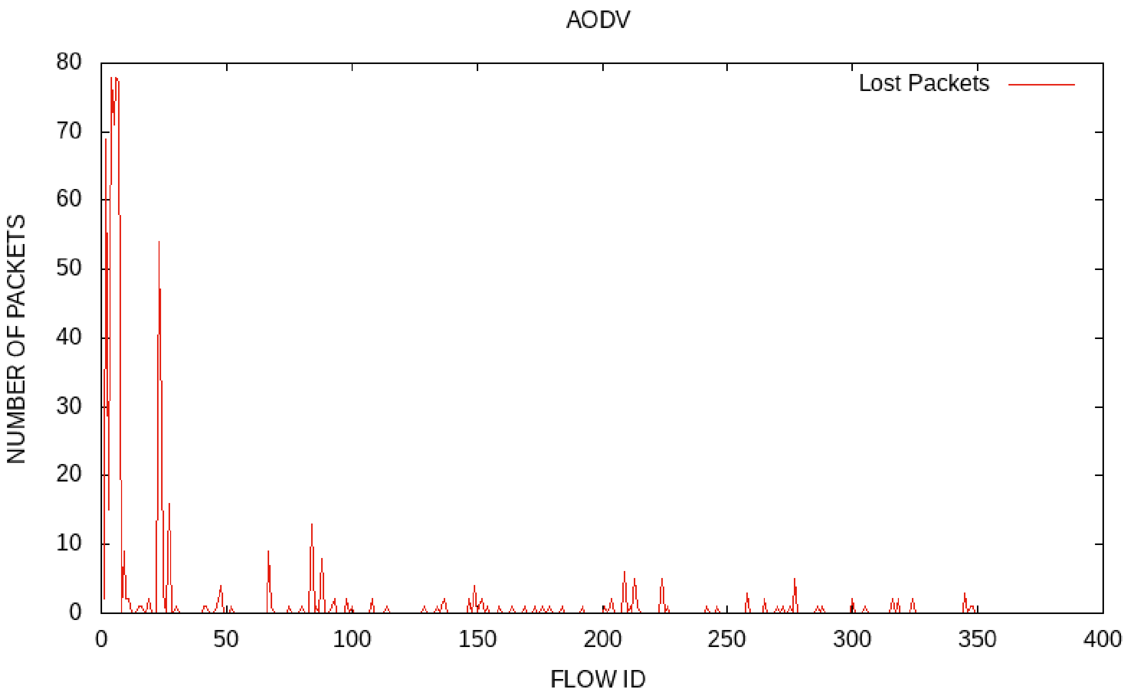

Fig. 5.12: Lost Packets.

From the result we can analyze, the maximum number of packets are lost during the beginningof the simulation as shown in Fig. 5.12.

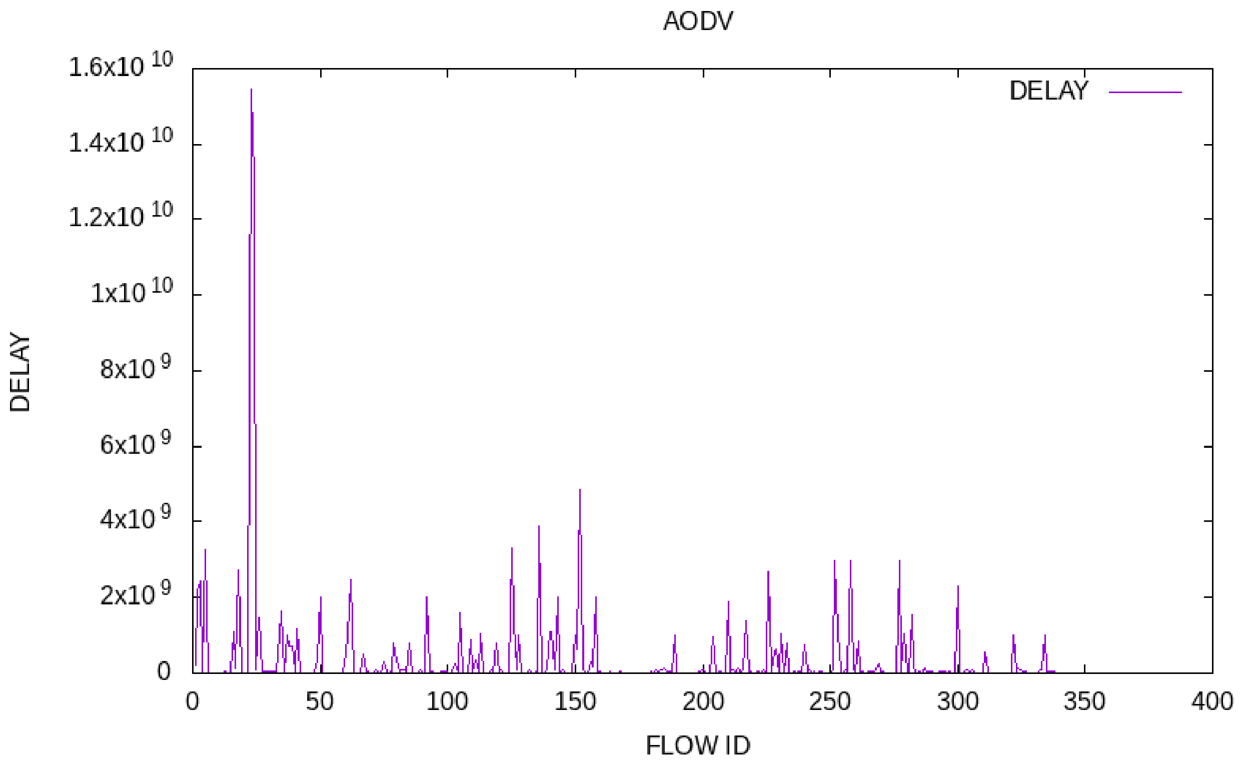

Fig. 5.13: Delay in AODV.

From the result, we can analyze that transmission delay is high at the beginning of thesimulation as shown in Fig.5.13.

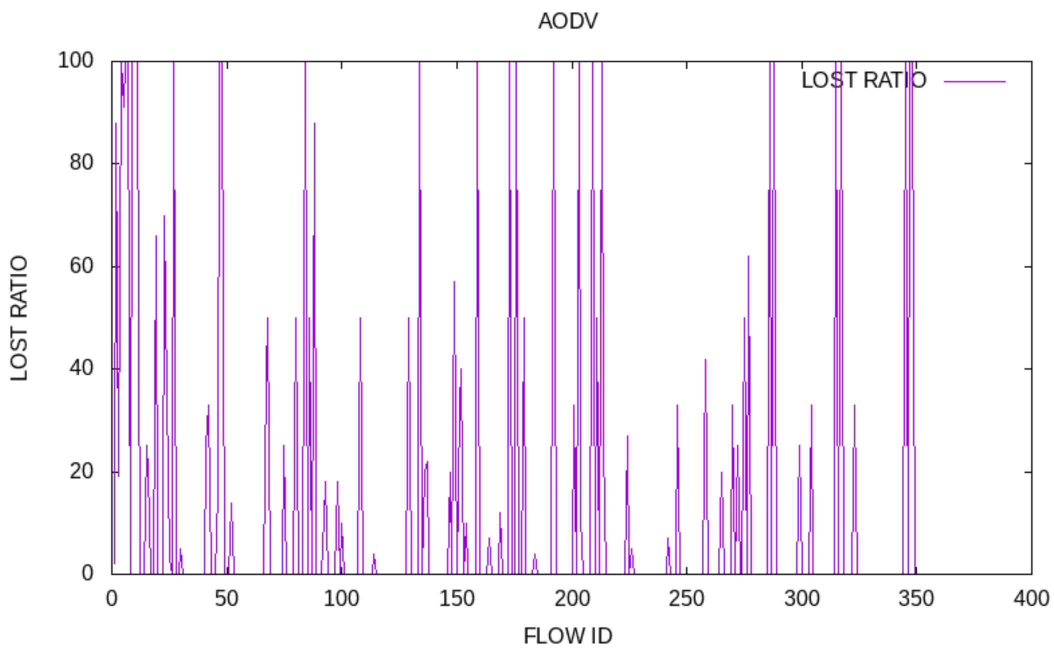

Fig. 5.14: Packet Lost Ratio in AODV

From the result, we can analyze that the maximum number of packets are lost during the beginningof the simulation, and an increase can be again as shown in Fig. 5.14.

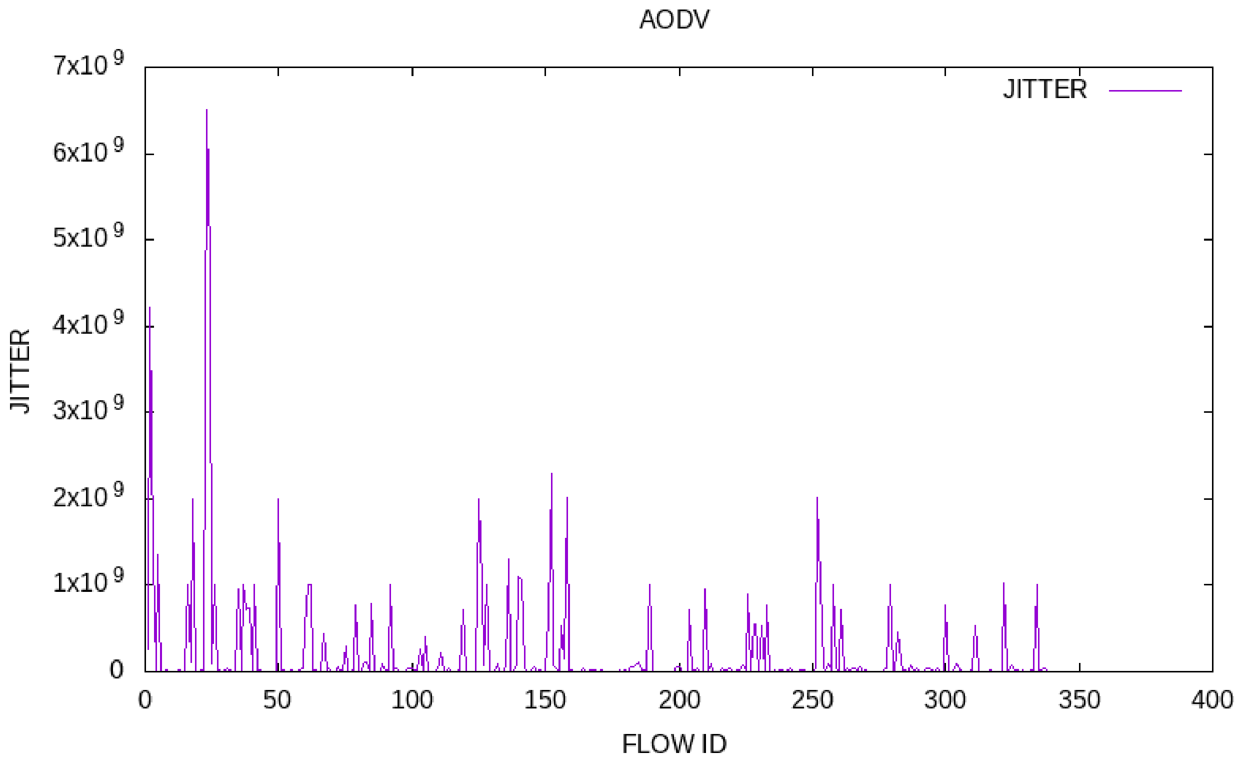

Fig. 5.15: Analysis of Jitter in AODV protocol.

From the result, we can analyze that jitter is high during the beginning of the simulation.Gradually the jitter gets decreases as shown in Fig.5.15.

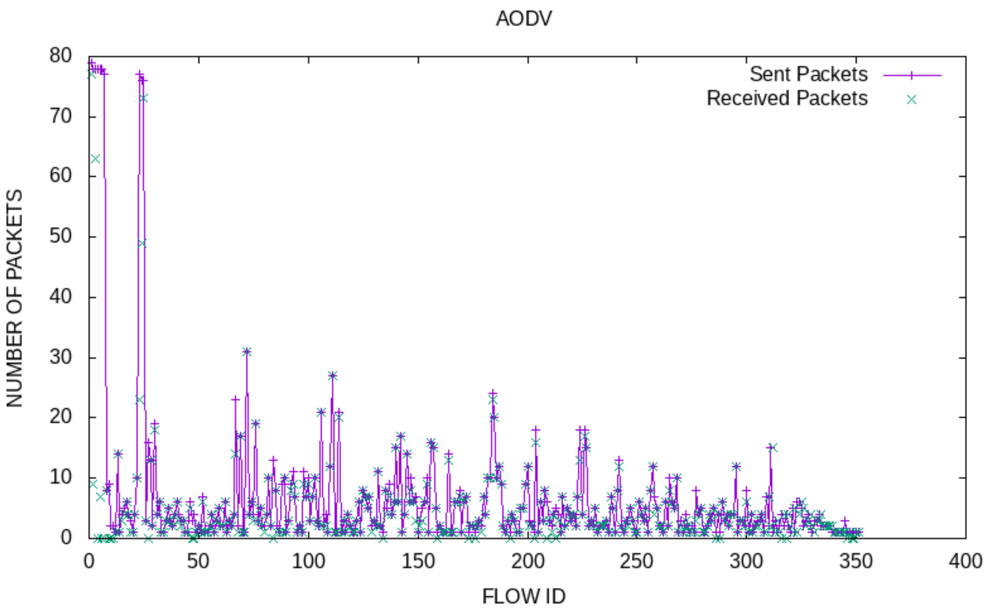

Fig. 5.16: Comparison of Sent and Received packets in AODV protocols.

We can analyze the result that sent packets are high at the beginning and receivedpackets are low as shown in Fig.5.16.

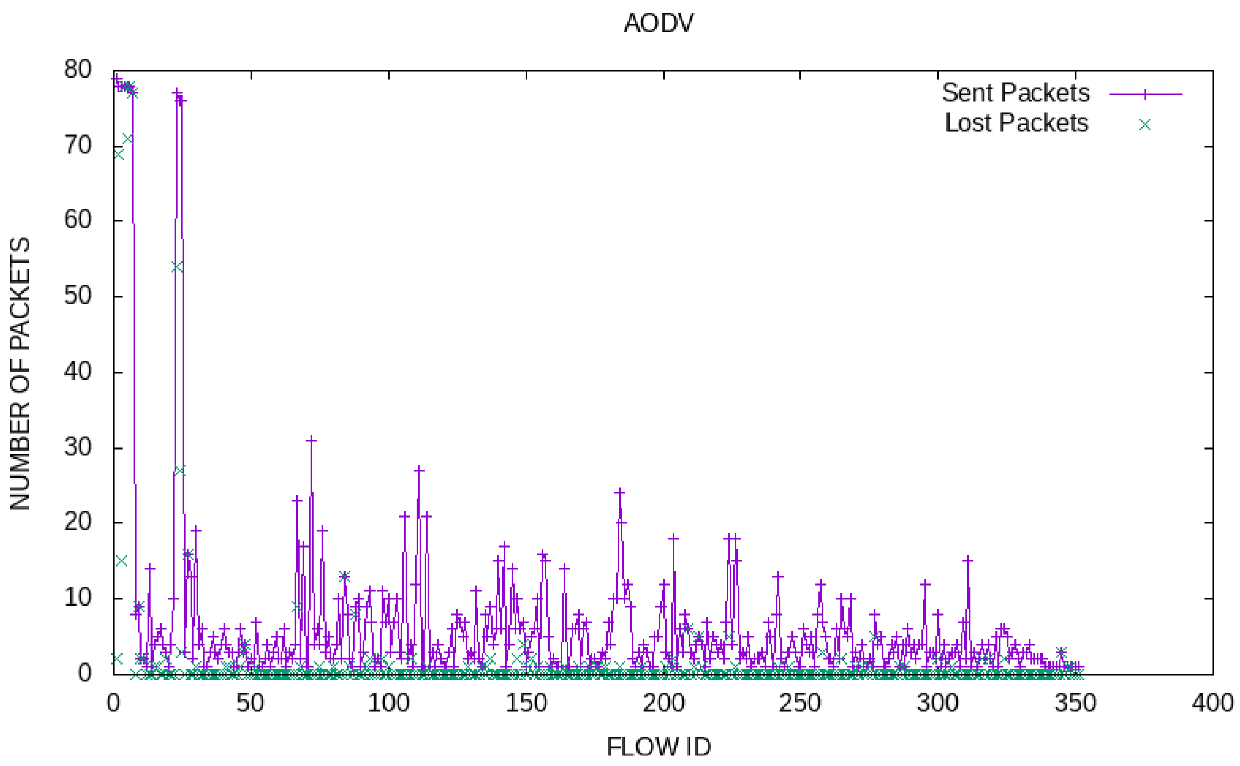

Fig. 5.17: Comparison of the number of Sent and Lost packets in AODV protocols.

We can analyze the result that lost packets are less and sent packets are more as shown in Fig.5.17.

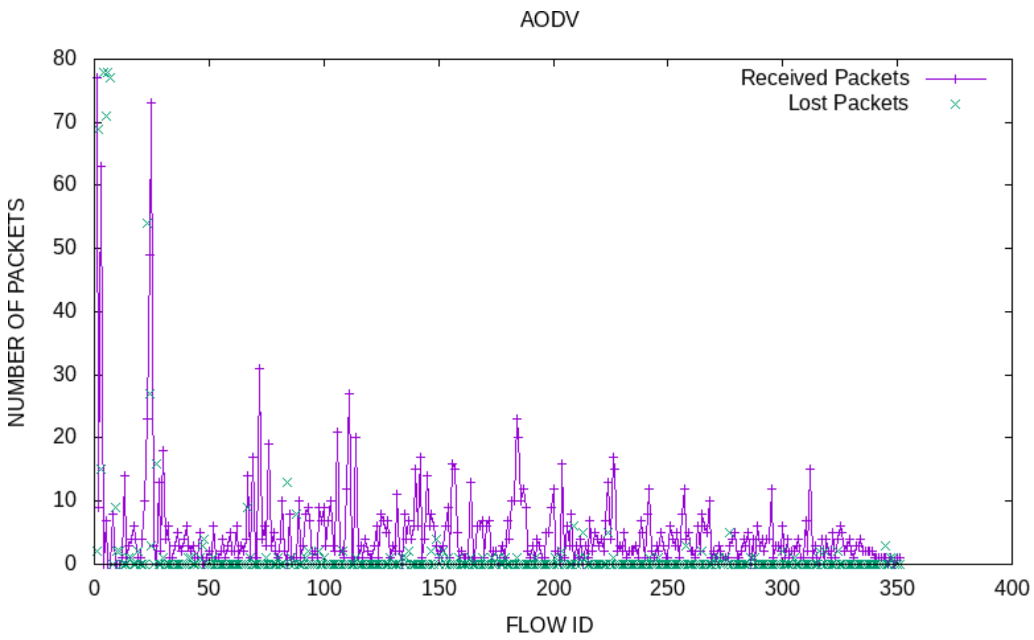

Fig. 5.18: Comparison of received and lost packets in AODV protocols.

From the result, we can analyze that the maximum number of packets is lost during the beginningof the simulation as shown in Fig.5.18.

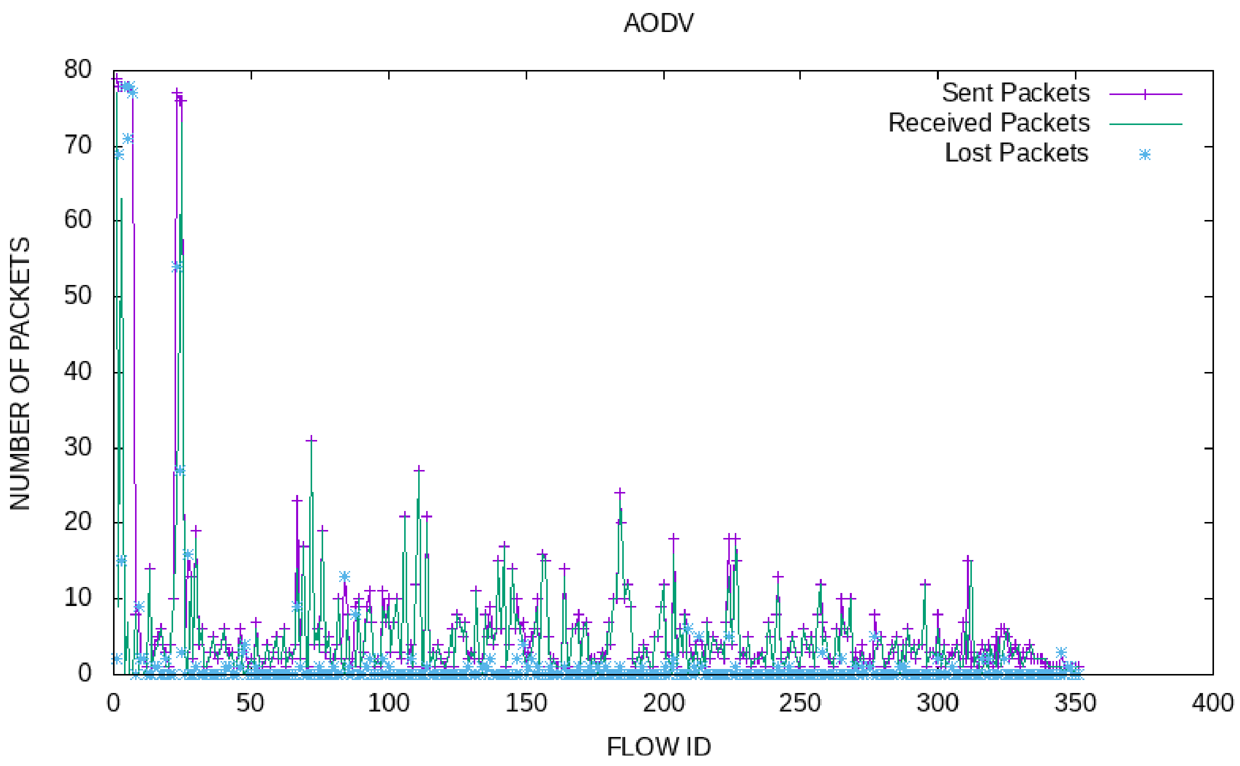

Fig. 5.19: Comparison of Sent Packets, Received Packets, and Lost Packets in AODV.

From the result, we can analyze that the maximum number of packets are lost during the beginningof the simulation, and the maximum number of packages received at the beginning of thesimulation, lost packets are minimum as shown in Fig.5.19.

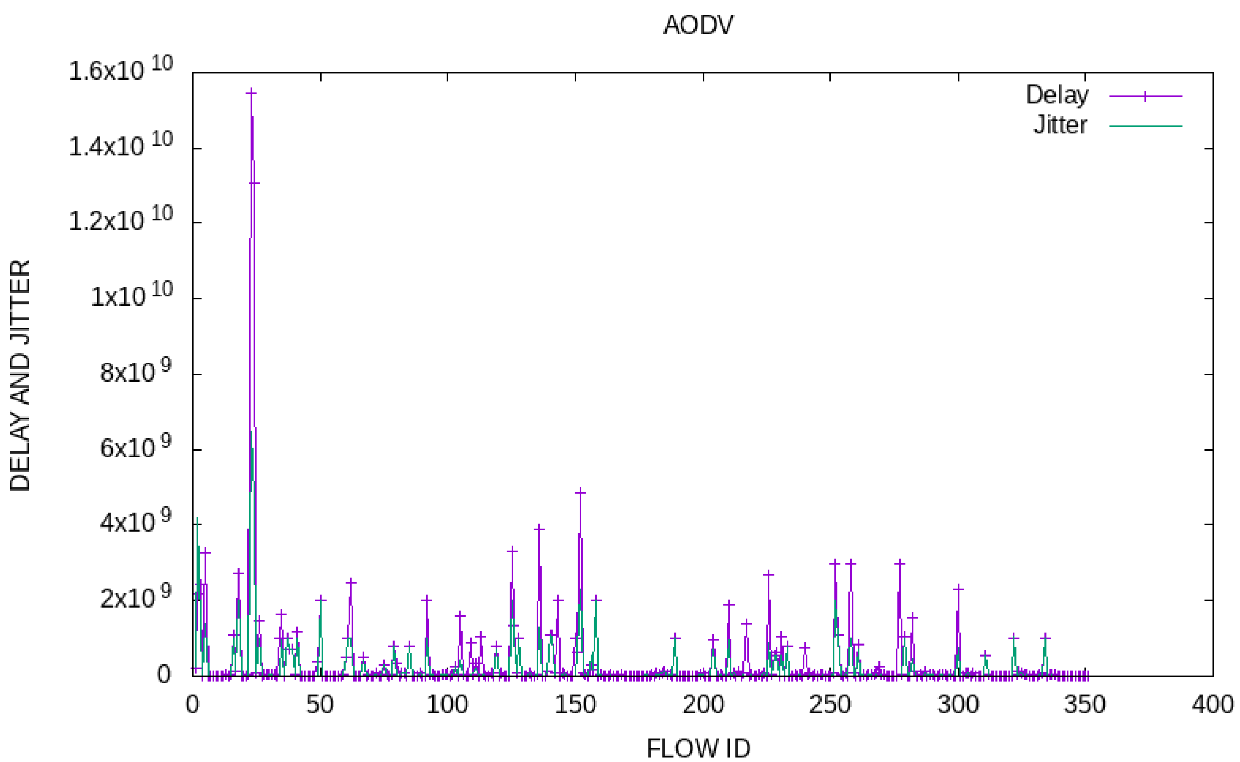

Fig. 5.20: Comparison of Delay and Jitter in AODV protocol.

From the result, we can analyze that the maximum number of packets is lost during the beginningof the simulation as shown in Fig.5.20.

5.6 Performance Evaluation of ORES-AODV with simulation Metrics

The analysis for ORES-AODV is performed, and a thorough evaluation is done on the requiredmetrics.

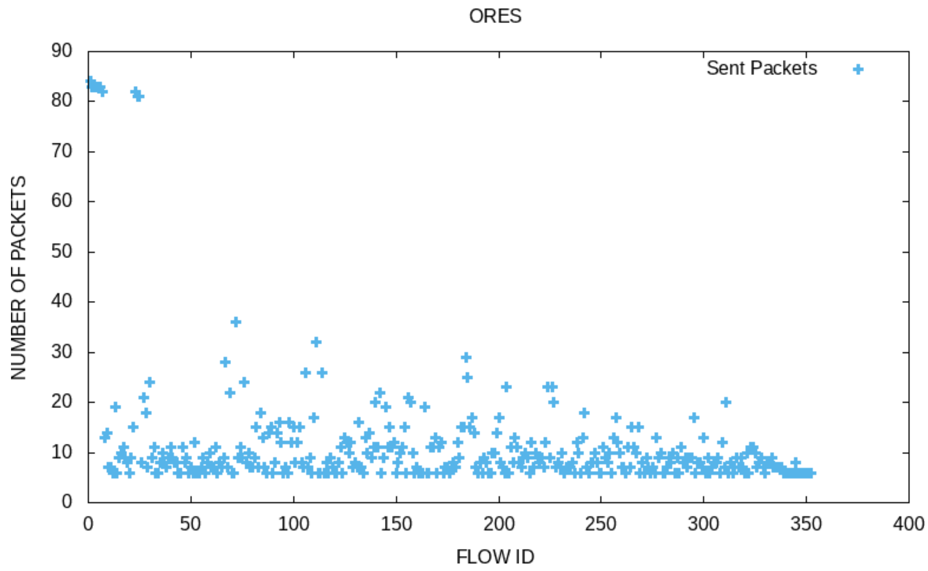

Fig. 5.21: Analysis of Sent Packets in ORES-AODV

From the result Fig.5.21, we can analyze that the maximum number of packets are lost during the beginning of the simulation.

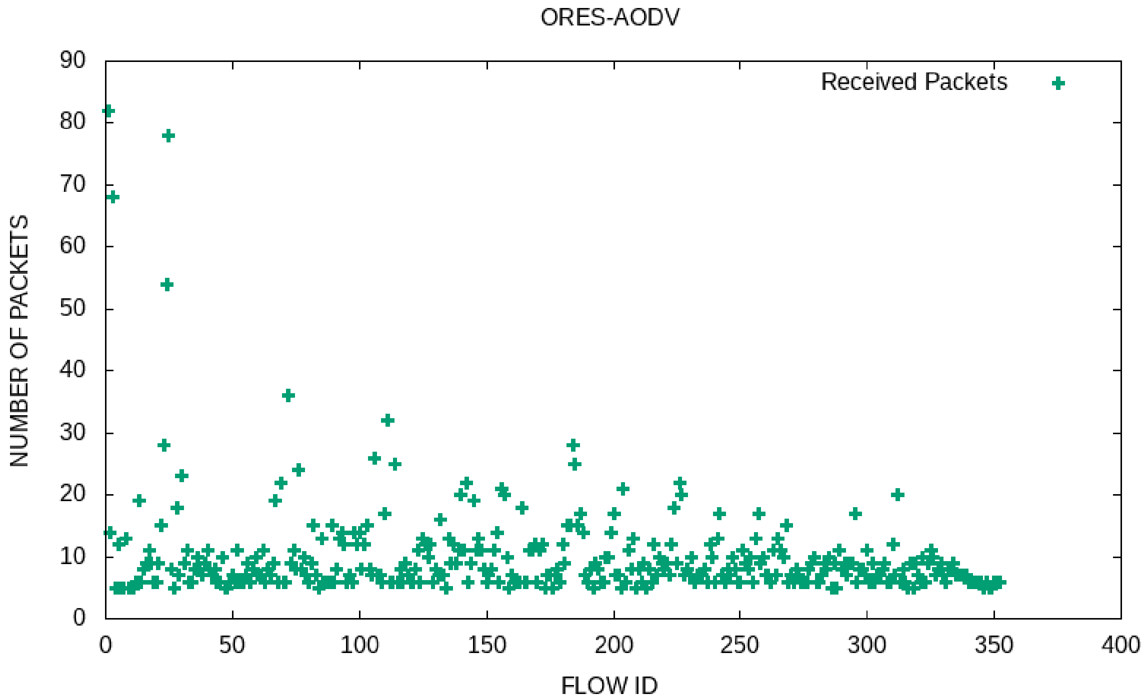

Fig. 5.22: Analyzing received packets in ORES-AODV protocol.

From the result, we can analyze that the maximum number of packets are received during thebeginning of the simulation as shown in Fig.5.22.

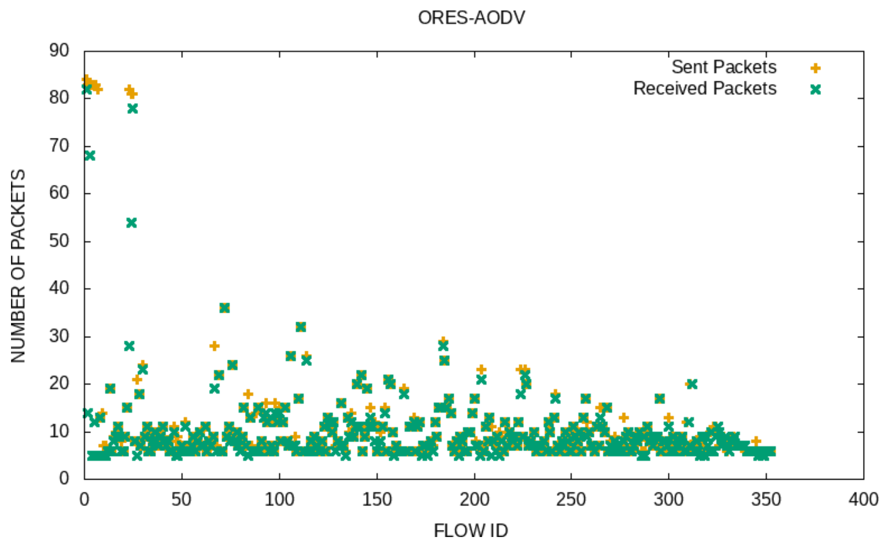

Fig. 5.23: Comparison of sent and received packets in ORES-AODV protocol.

From the result, we can analyze that the number of transmitted packets is high at the beginning of the simulation as shown in Fig.5.23. Eventually, the number of sent and received packets become the same.

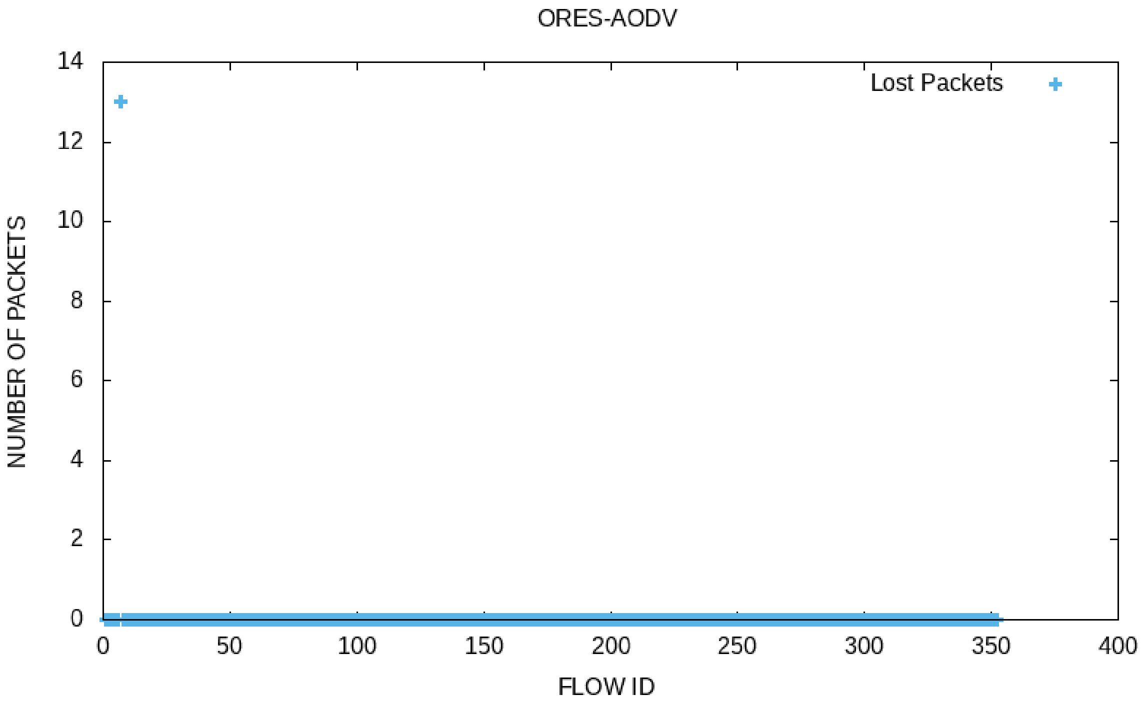

Fig. 5.24: Analysis of Lost packets in ORES-AODV protocol.

From the result as shown in Fig.5.24, we can analyze that the number of lost packets is approximately equal to zero inthe ORES-AODV protocol.

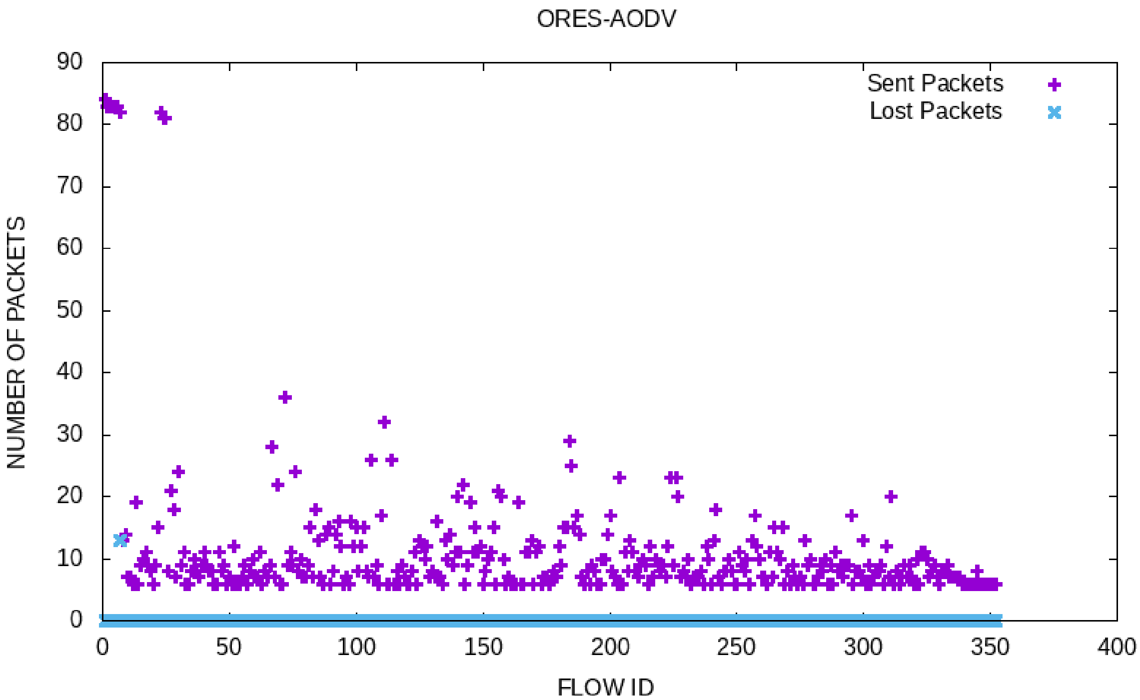

Fig. 5.25: Comparison of the number of Sent and Received packets in ORES-AODV protocol.

From the result as shown in Fig.5.25, we can analyze that the number of lost packets is less than the sent packets.

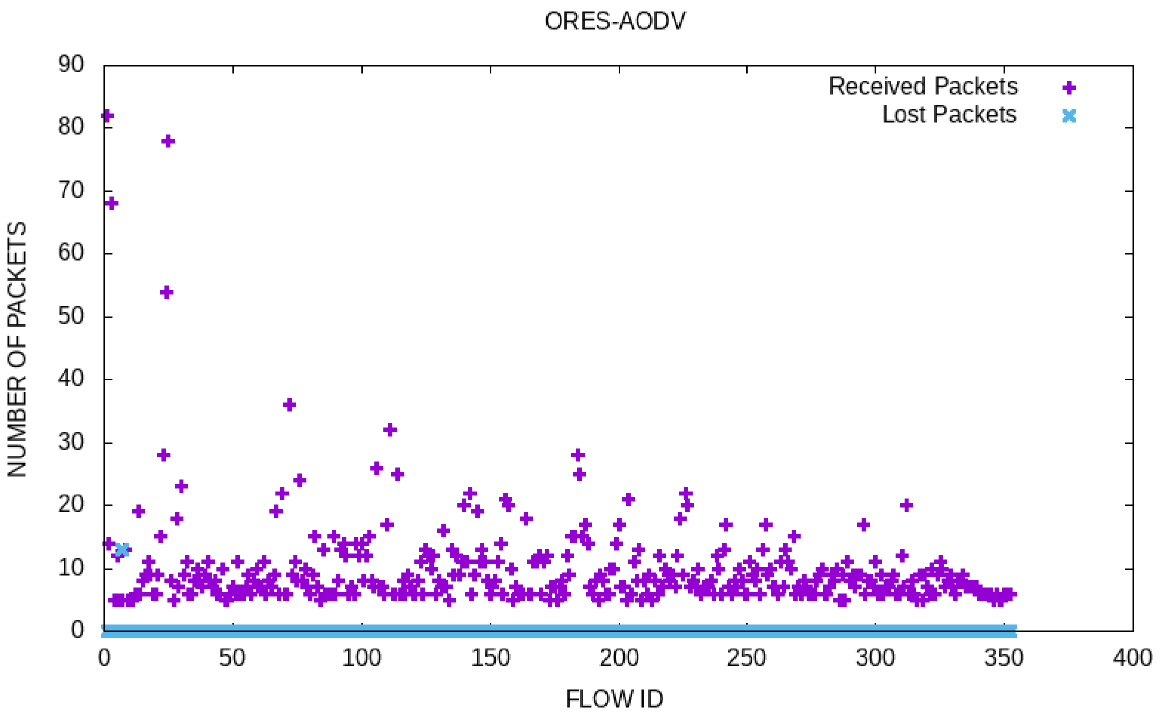

Fig. 5.26: Analysis of Received packets and Lost Packets in ORES-AODV.

From the result as shown in Fig.5.26, we can analyze that number of received packets is more than the number oflost packages.

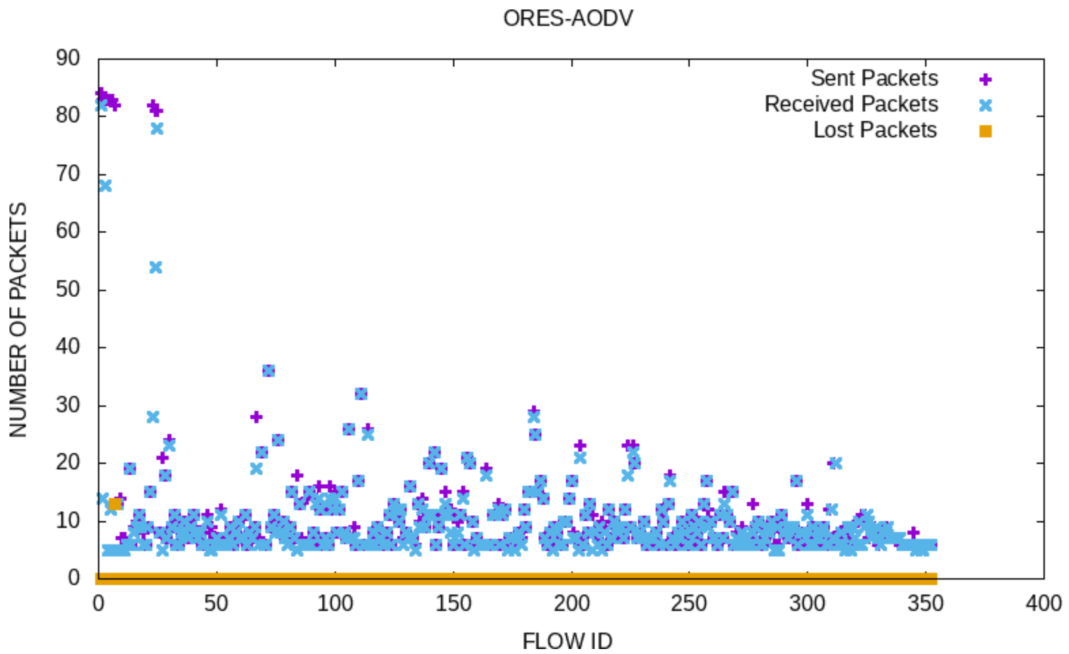

Fig. 5.27: Analysis of Sent Packets, Received Packets, and Lost Packets in ORES-AODVprotocol.

From the result as shown in Fig.5.27, we can analyze that lost packets are comparatively low than receivedpackets and lost packets.

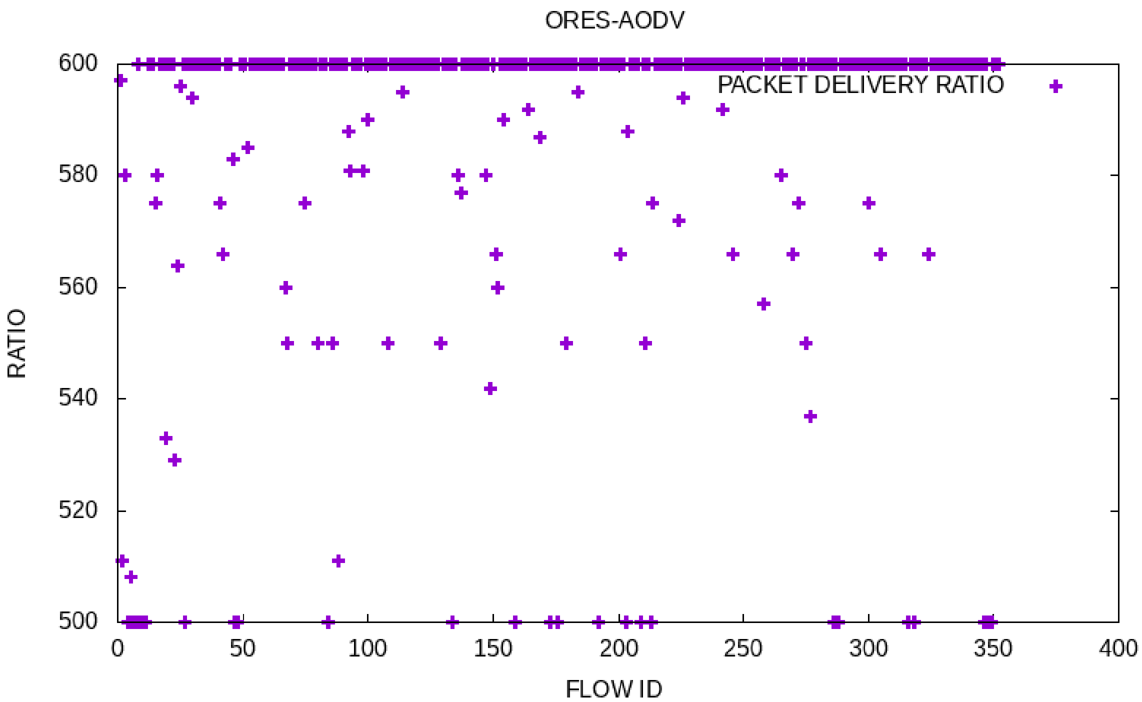

Fig. 5.28: Analysis of Packet Delivery Ratio of ORES-AODV protocols.

From the result as shown in Fig.5.28, we can analyze that the packet delivery ratio of ORES-AODV is maximum.

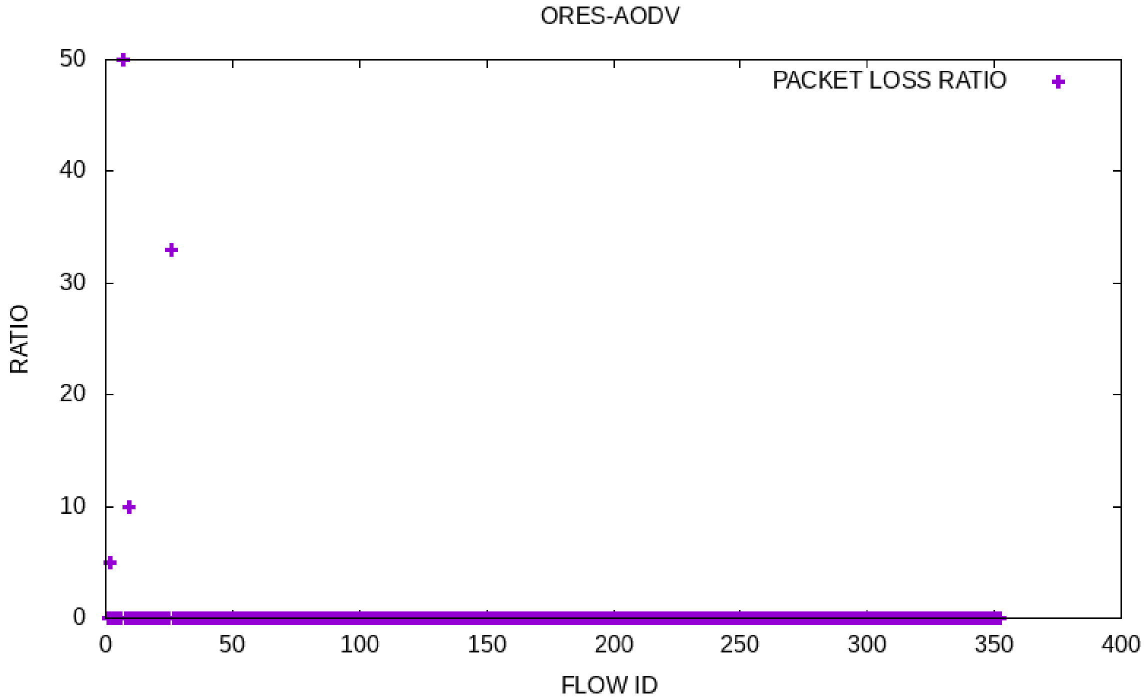

Fig. 5.29: Analysis of Packet Lost Ratio of ORES-AODV protocols.

From the result as shown in Fig.5.29, we can analyze that the maximum number of packets are lost during the beginningof the simulation in ORES-AODV.

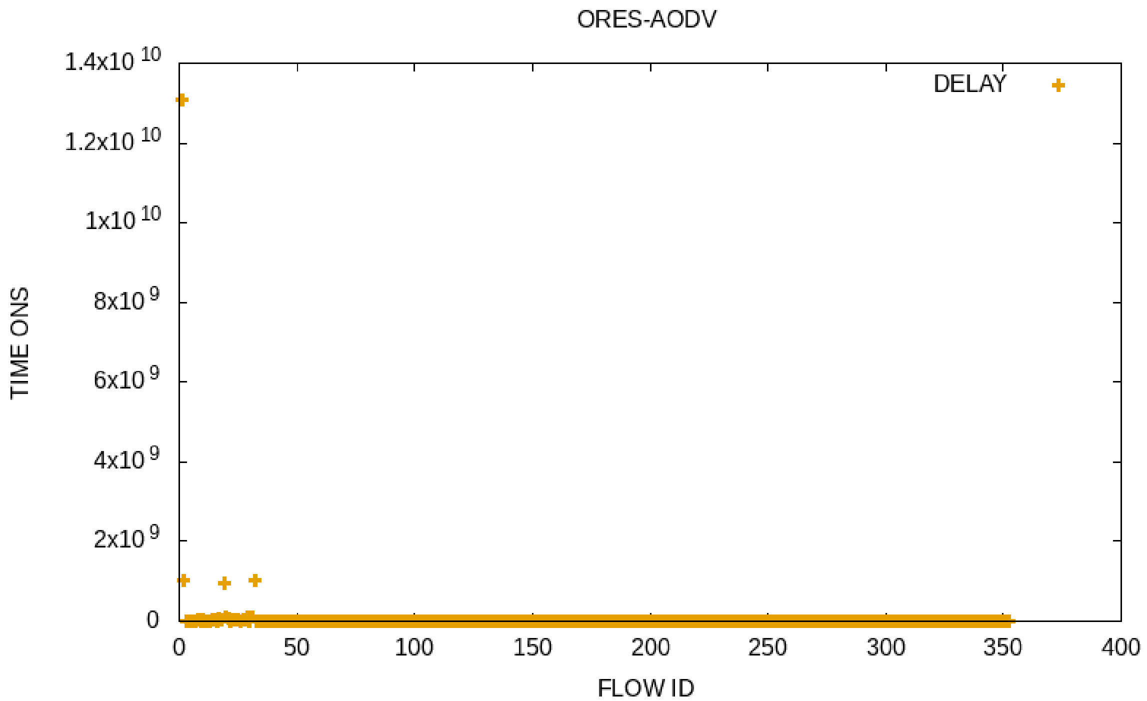

Fig. 5.30: Analysis of Delay in ORES-AODV protocol.

From the result as shown in Fig.5.30, we can analyze that delay in packet delivery is investigated, and we found adelay at the beginning of the simulation.

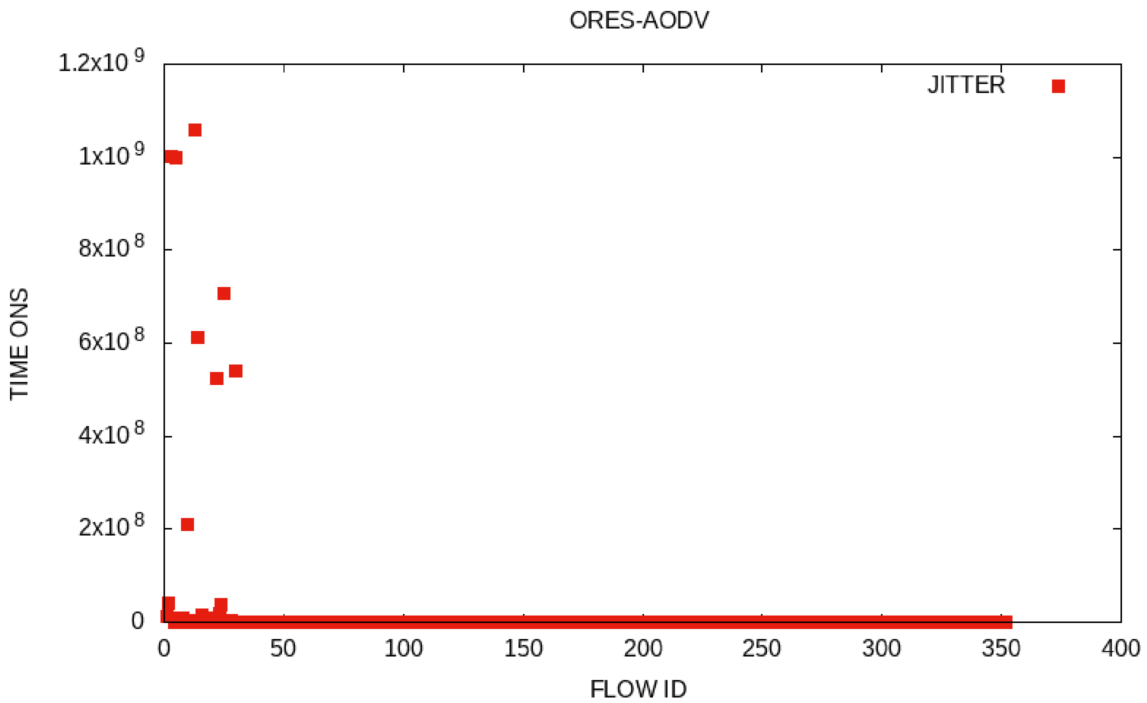

Fig. 5.31: Analysis of Jitter in ORES-AODV protocol.

From the result as shown in Fig.5.31, we can analyze that delay in packet delivery is investigated, and it is observed thatjitter is found at the beginning of the simulation.

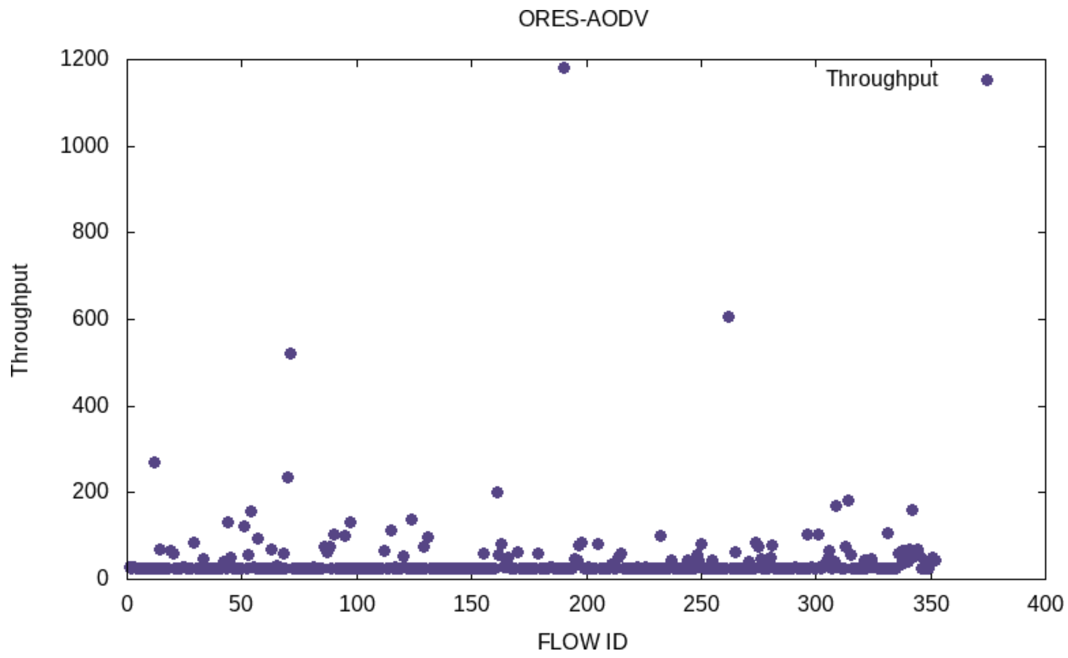

Fig. 5.32: Analysis of Throughput in ORES-AODV protocol.

From the result as shown in Fig.5.32, we can analyze, the maximum number of packets are lost during the beginningof the simulation.

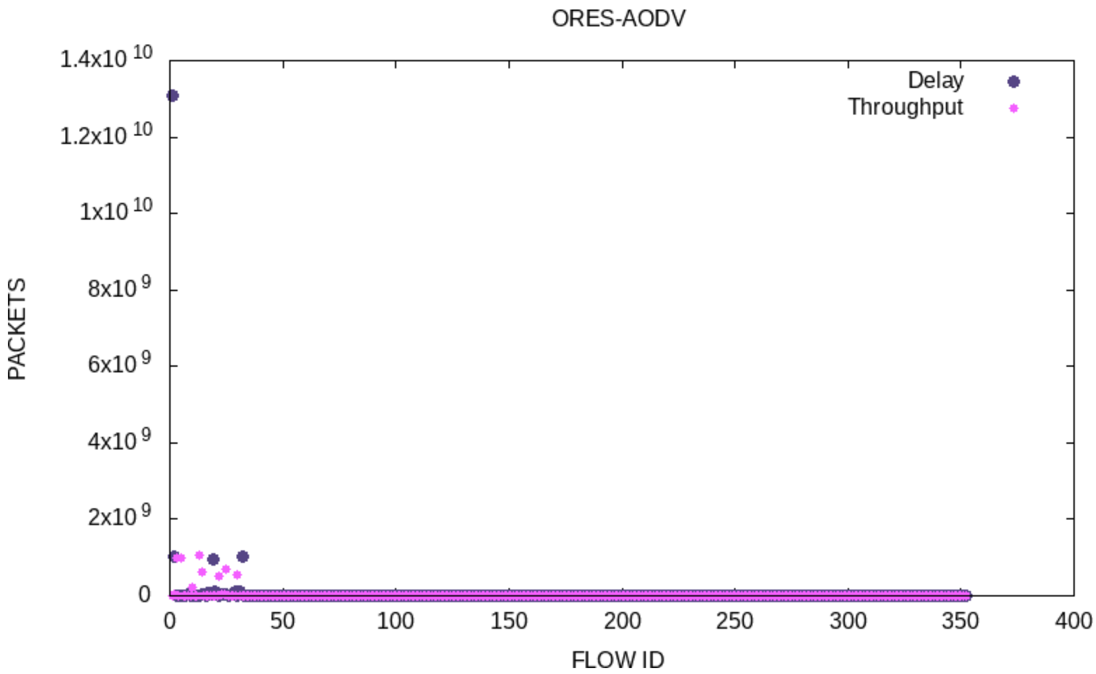

Fig. 5.33: Comparative Analysis of Delay and Throughput in ORES-AODV protocol.

From the result as shown in Fig.5.33, we can analyze that a maximum number of packets is delayed at the beginningof the simulation.

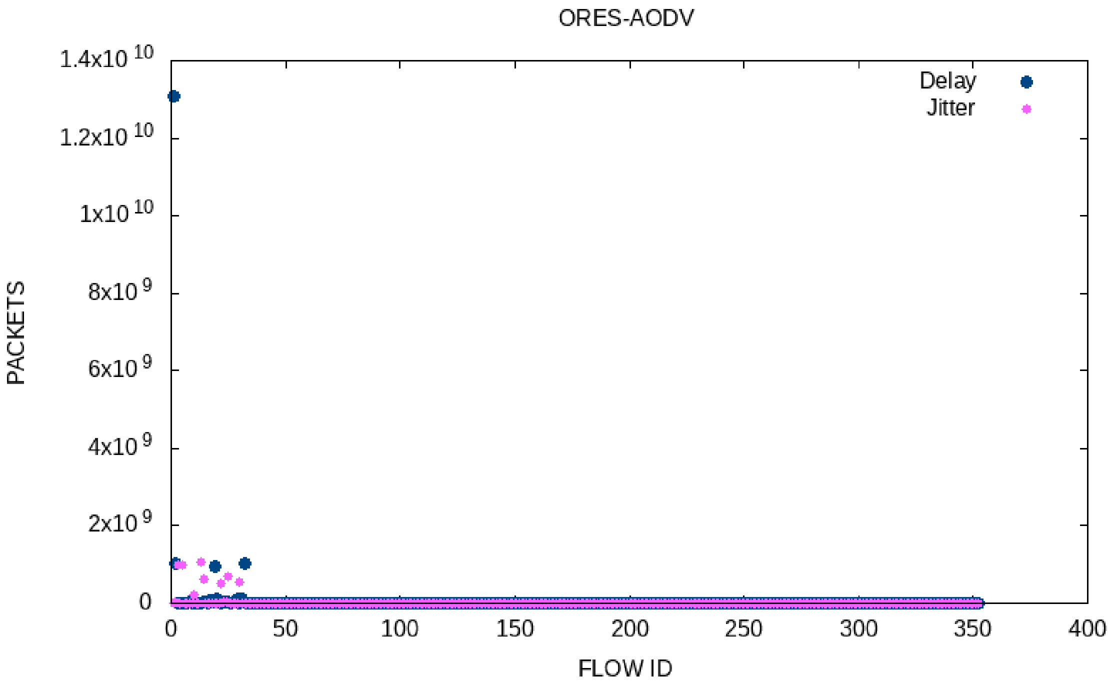

Fig. 5.34: Comparative Analysis of Delay and Jitter in ORES-AODV protocol.

From the result we can analyze as shown in Fig.5.34, the maximum number of packets are lost during the beginningof the simulation.

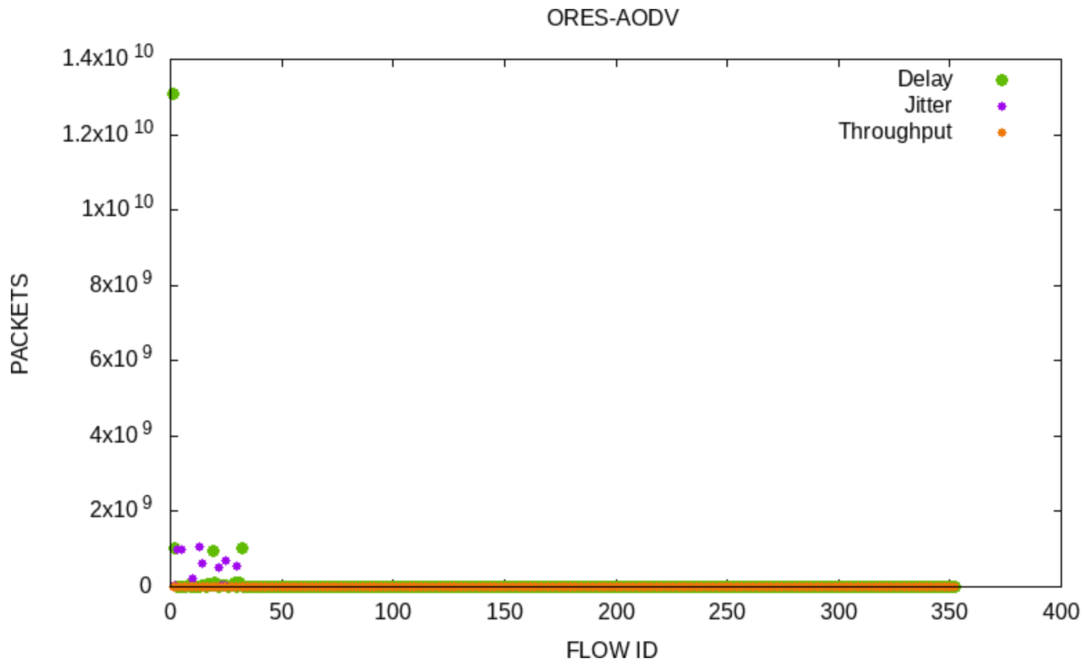

Fig. 5.35: Comparative Analysis of Delay, Jitter, and Throughput in ORES-AODV protocol. From the result as shown in Fig.5.35, we can analyze that the maximum number of packets is lost during thebeginning of the simulation.

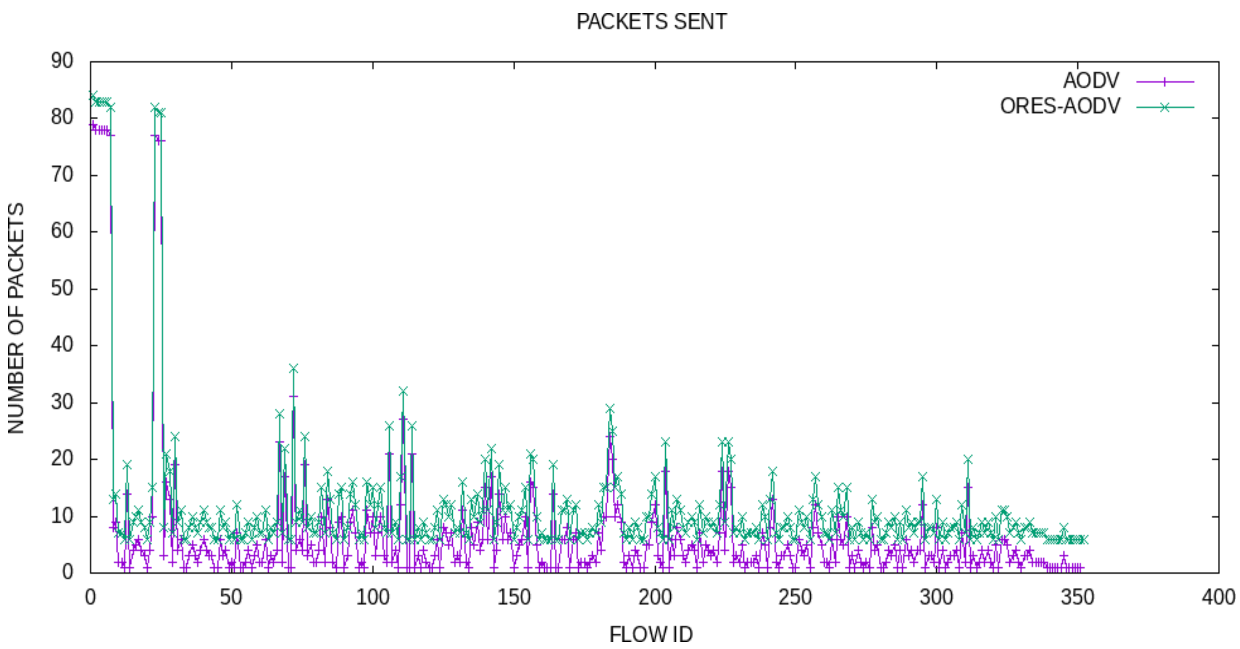

Fig. 5.36: Comparative Analysis of AODV and ORES-AODV protocols for sendingpackets.

From the result as shown in Fig.5.36, we can see that ORES-AODV has improved the network's efficiency by increasing the number of packets sent.

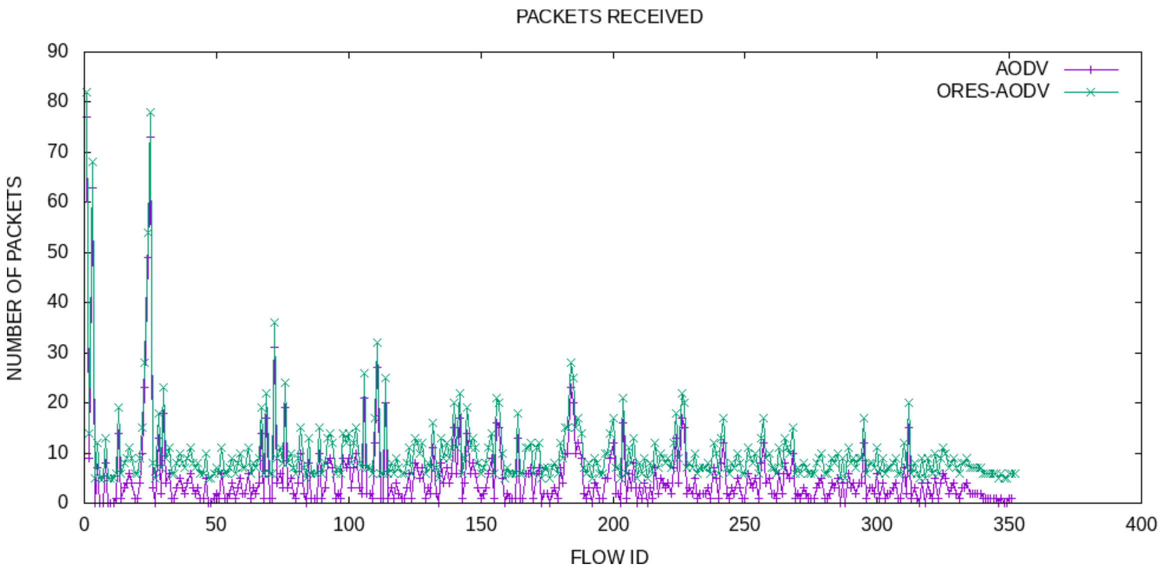

Fig. 5.37: Comparative Analysis of AODV and ORES-AODV protocols for receivedpackets. From the result as shown in Fig.5.37, we can analyze that ORES-AODV has improved network efficiencyby increasing the number of packets received.

5.7 Comparative Evaluation of AODV and ORES-AODV with simulation Metrics

The comparative analysis of AODV and ORES-AODV is evaluated using NS3, and theresults are plotted using graphs.

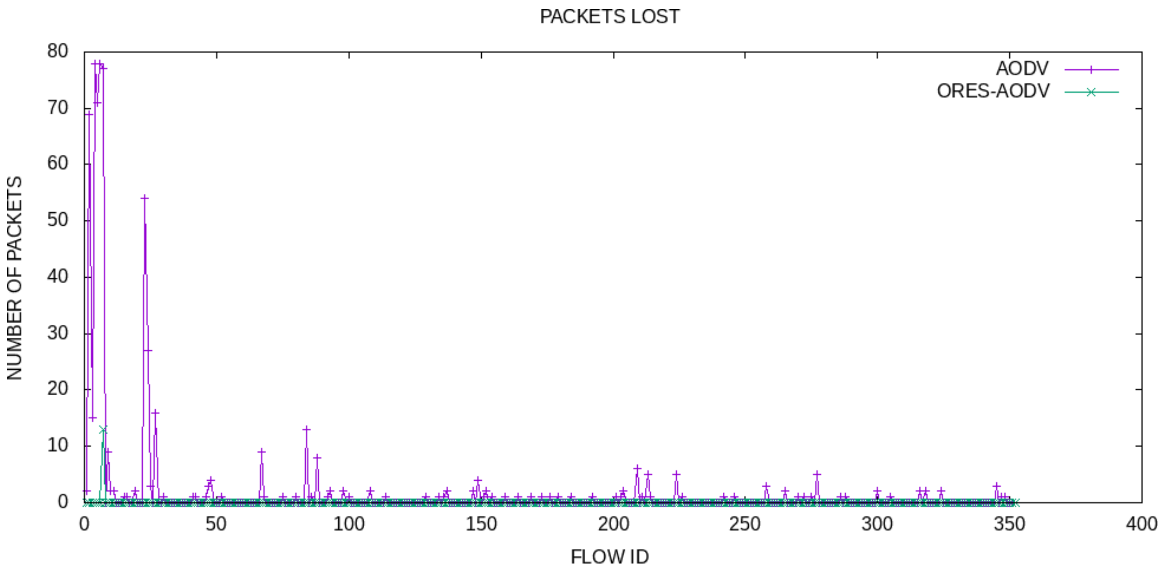

Fig. 5.38: Comparative Analysis of packets lost in AODV and ORES-AODV protocol.

From the result as shown in Fig.5.38, we can analyze that ORES-AODV has improved network efficiencyby decreasing the number of packages lost compared to the AODV protocol.

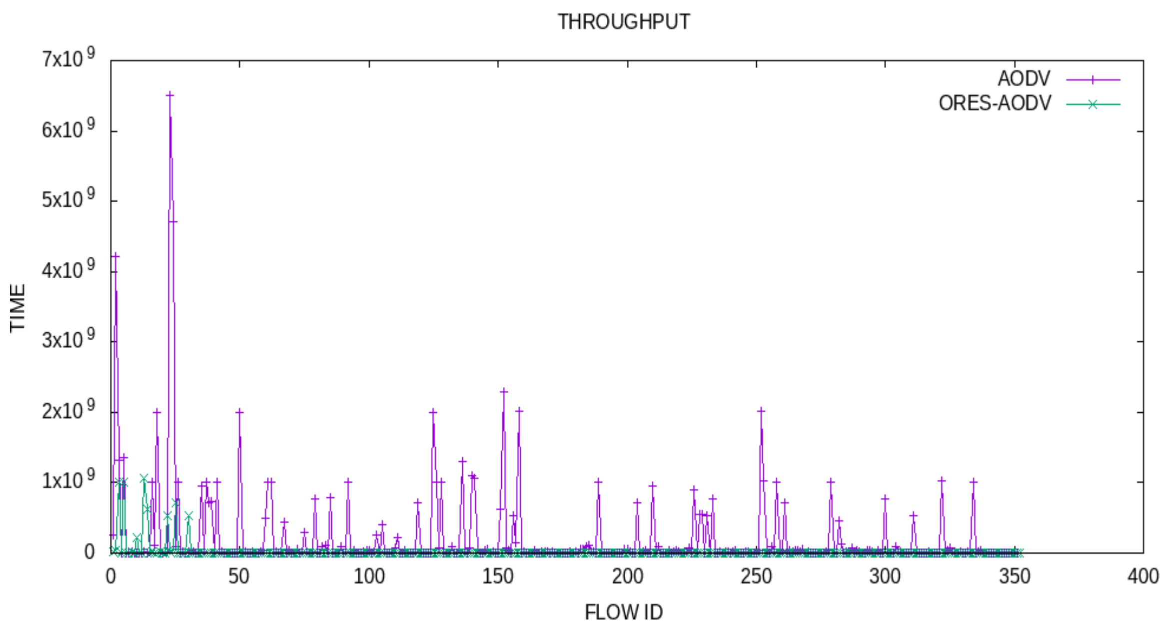

Fig. 5.39: Comparative Analysis of throughput in AODV and ORES-AODV protocols.

From the result as shown in Fig.5.39, we can analyze that ORES-AODV has improved the efficiency of the network by increasing the throughput compared to the AODV protocol.

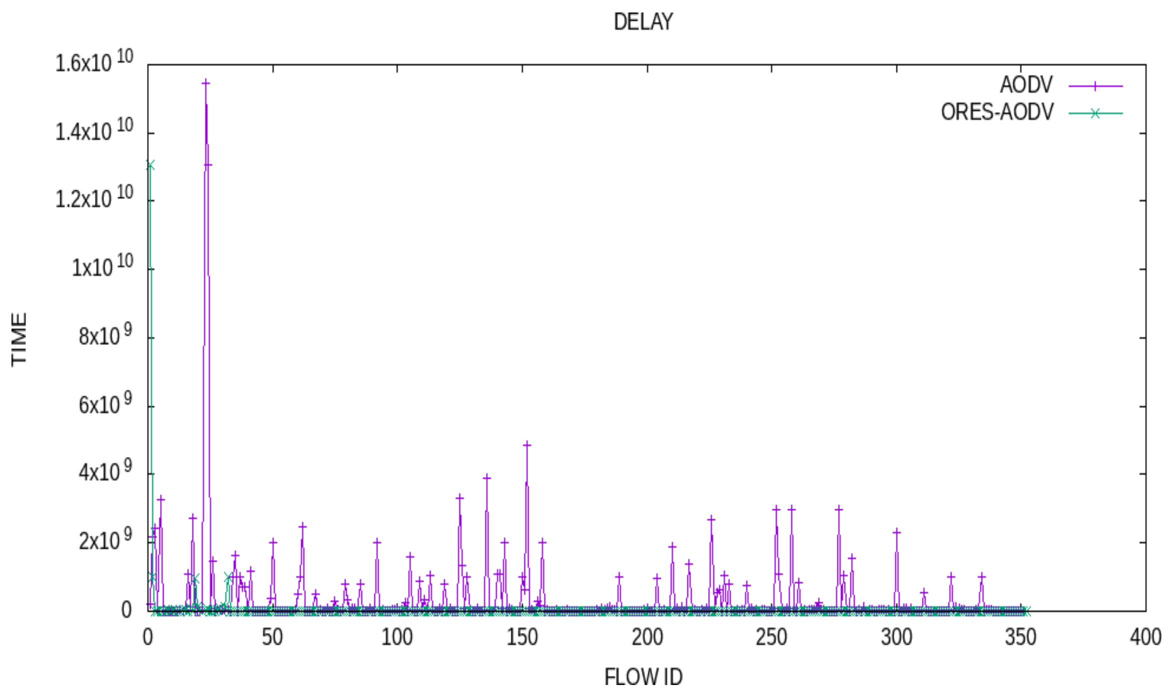

Fig. 5.40: Comparative Analysis of Delay in AODB and ORES-AODV protocol.

From the result as shown in Fig.5.40, we can analyze that ORES-AODV has improved the efficiency of the networkby decreasing the delay compared to the AODV protocol.

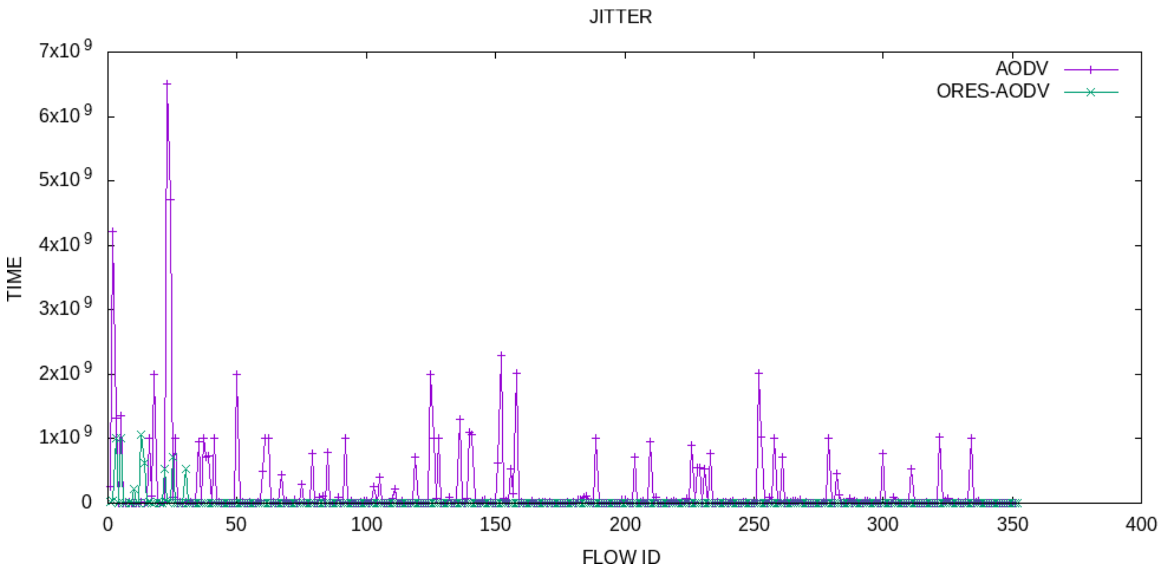

Fig. 5.41: Comparative Analysis of Jitter in ORES-AODV protocol.

From the result as shown in Fig.5.41, we can analyze that ORES-AODV has improved the efficiency of the networkby decreasing the jitter compared to the AODV protocol.

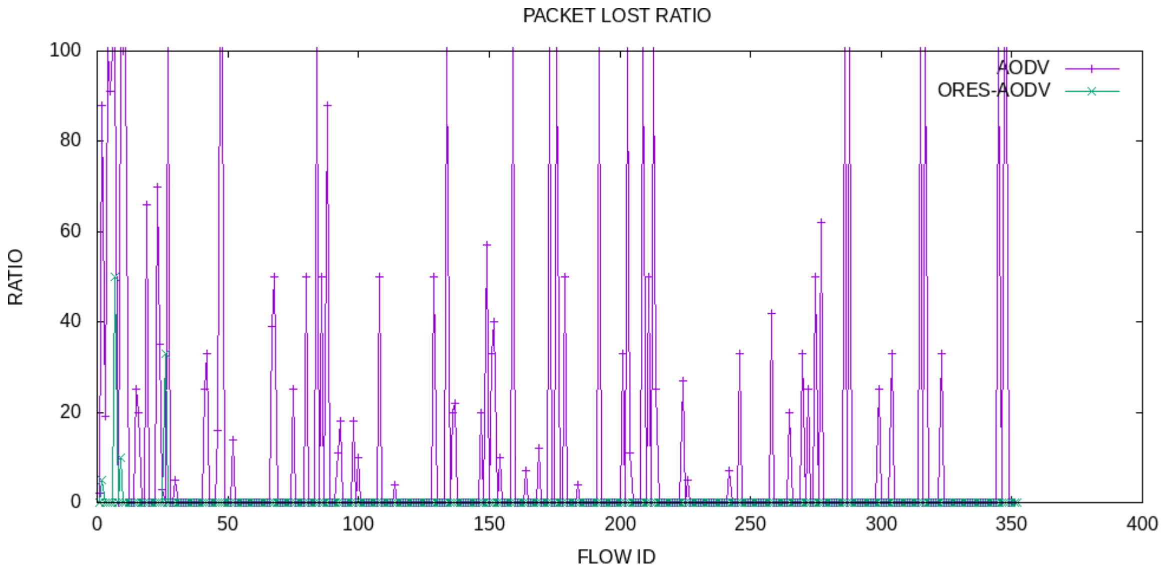

Fig. 5.42: Comparative Analysis of Packet Delivery Ratio in AODV and ORES-AODVprotocol.

From the result as shown in Fig.5.42, we can analyze, ORES-AODV has improved the efficiency of the networkby decreasing the Packet Lost Ratio compared to the AODV protocol.

5.8 Energy evaluation of AODV using Energy Evaluation Metrics

The current and remaining energy of the AODV protocol is evaluated using energymetrics, and obtained results are plotted using graphs.

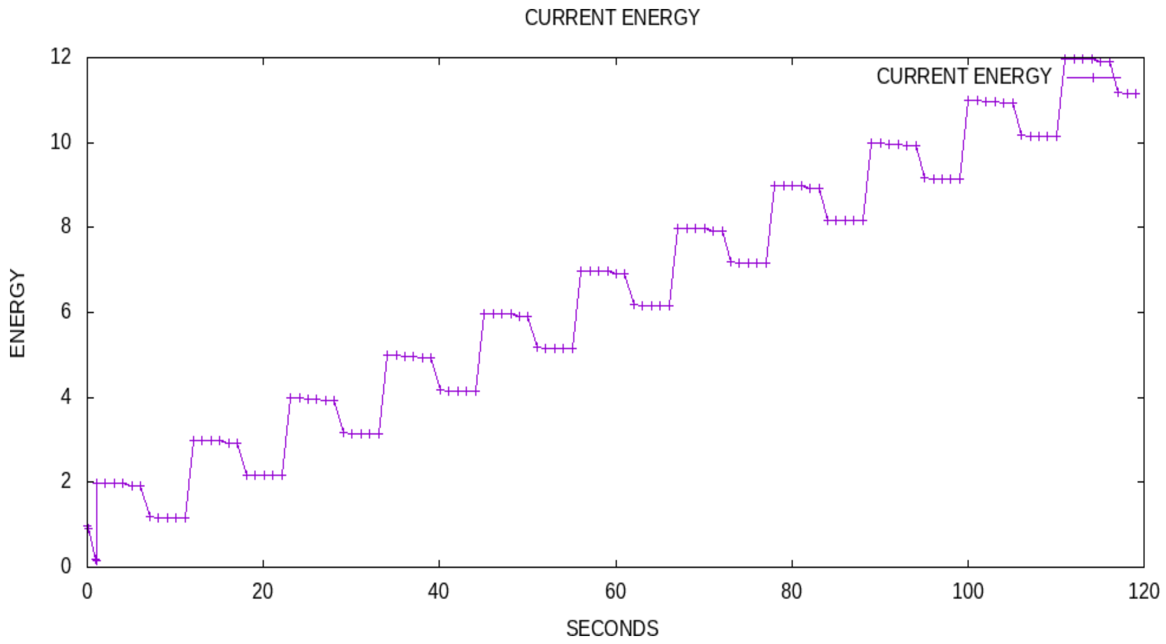

Fig. 5.43: Analysis of current energy in AODV.

From the result as shown in Fig.5.43, we can analyze that ORES-AODV has improved the efficiency of a network by decreasing the current energy usage as compared to the AODV protocol.

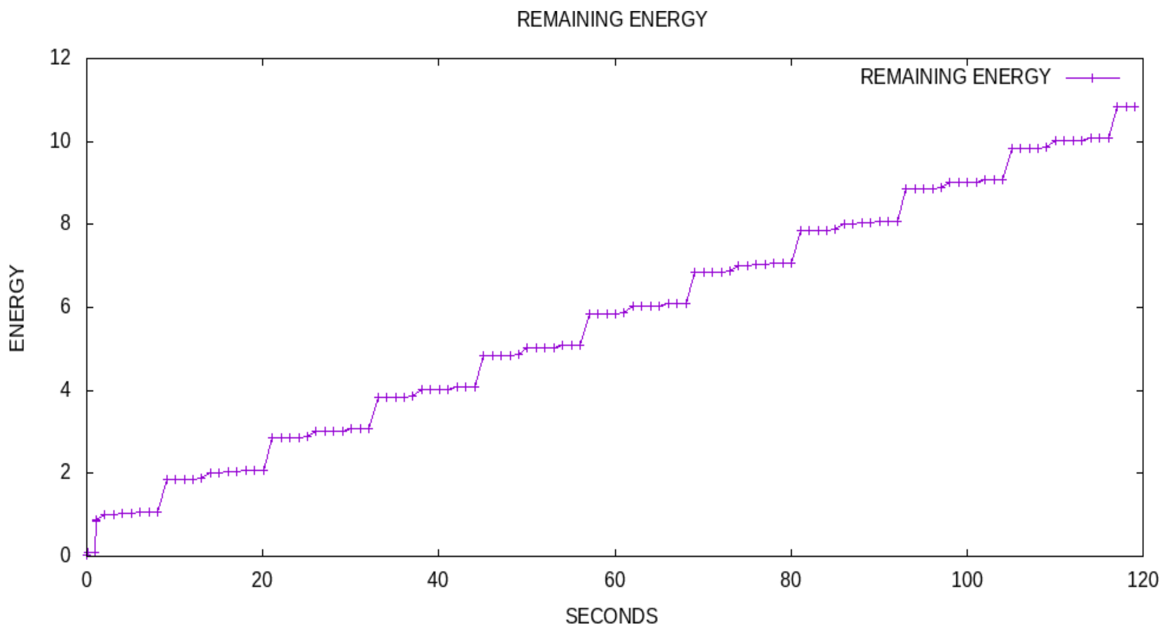

Fig. 5.44: Analysis of remaining energy in AODV.

From the result as shown in Fig.5.44, we can analyze that ORES-AODV has improved the efficiency of the networkby decreasing energy usage compared to the AODV protocol.

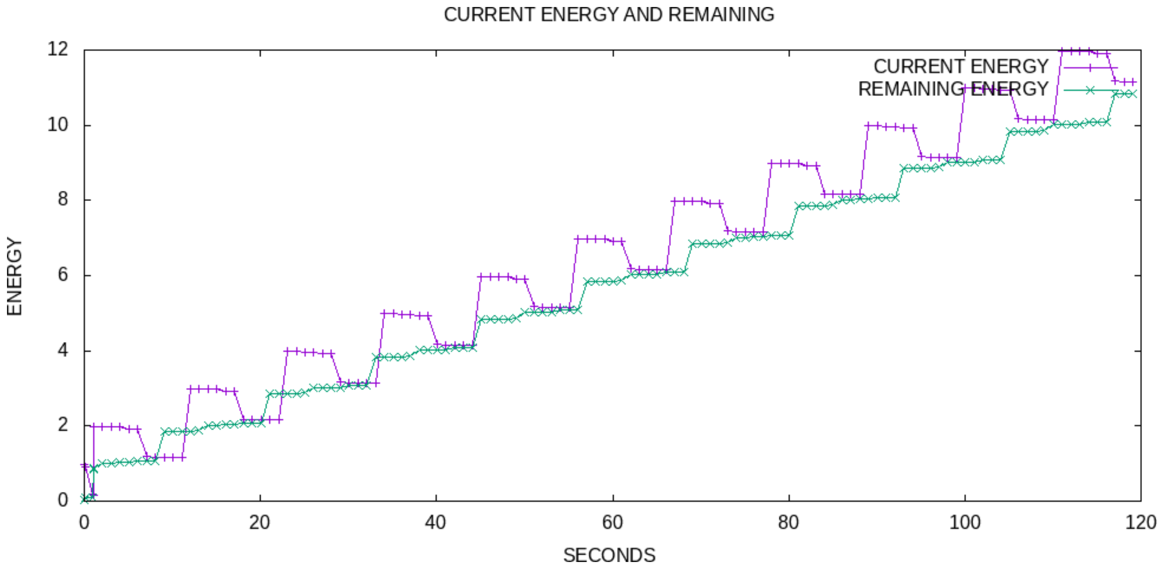

Fig. 5.45: Comparative Analysis of current and remaining energy in AODV.

From the result as shown in Fig.5.45, we can analyze that ORES-AODV has improved the efficiency of the networkby decreasing energy usage compared to the AODV protocol.

5.9 Energy analysis and comparison of AODV and ORES-AODV

The current energy and remaining energy of the AODV protocol is compared and analyzedwith the proposed protocol ORES-AODV using energy metrics, and obtained results are plotted using graphs.

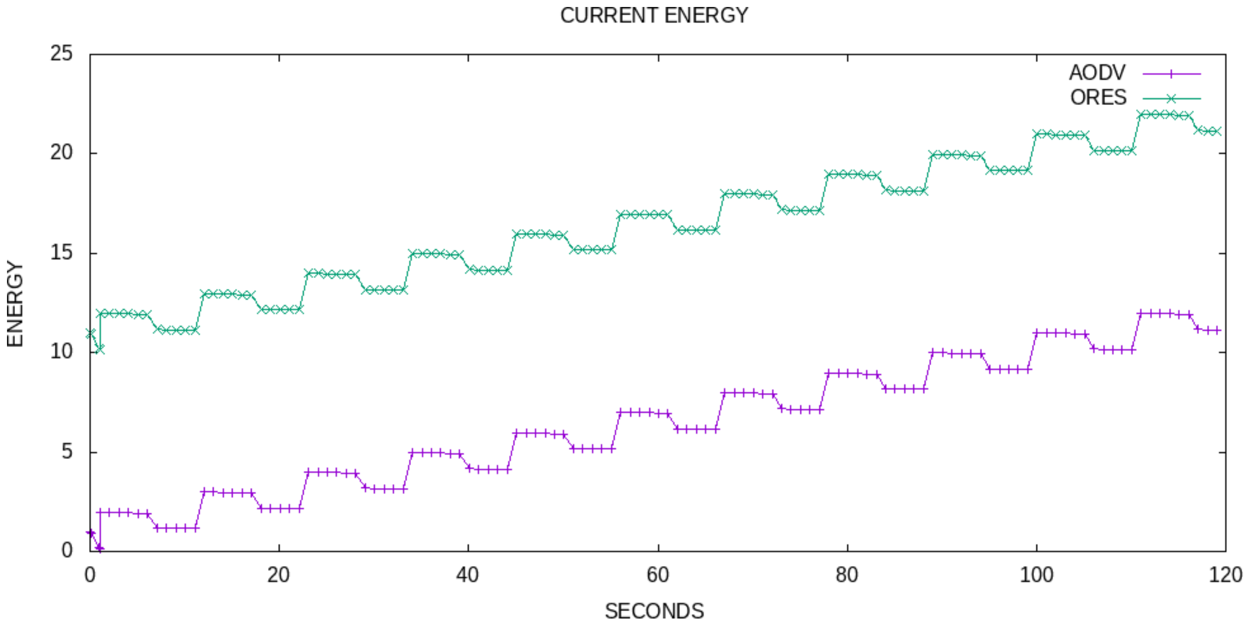

Fig. 5.46: Comparative Analysis of current energy in AODV and ORES-AODV.

From the result as shown in Fig.5.46, we can analyze that ORES-AODV has improved the efficiency of the networkby decreasing energy usage compared to the AODV protocol.

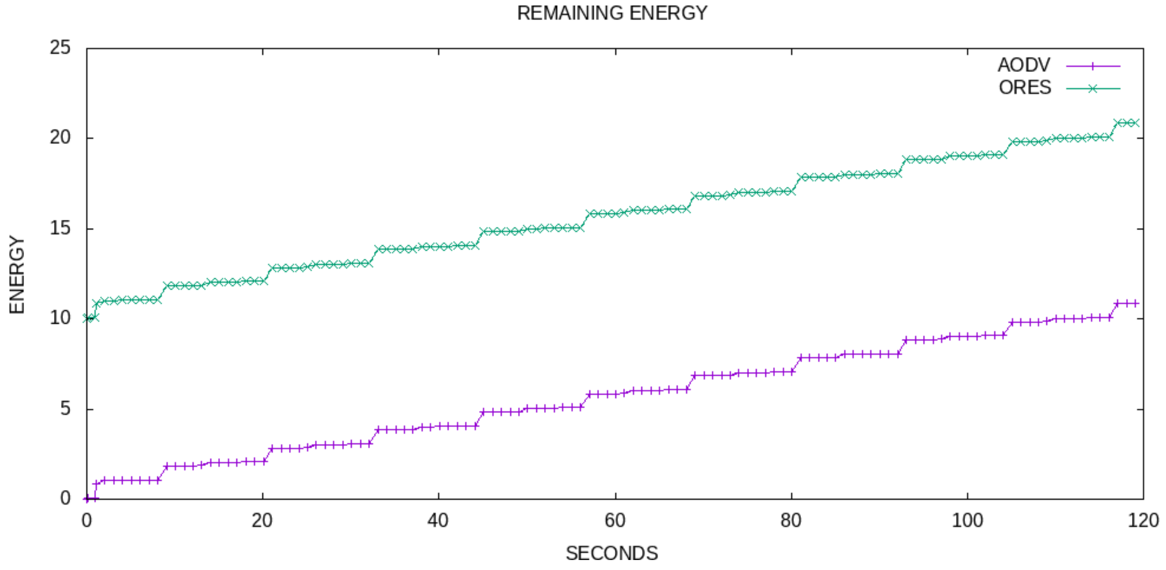

Fig. 5.47: Comparative Analysis of Remaining energy in AODV and ORES-AODV.

From the result as shown in Fig.5.47, we can analyze that ORES-AODV has more efficiency in remaining energycompared to the AODV protocol.

5.10 Comparative analysis of ORES-AODV and other leading AODV-based protocols

The proposed protocol of this research work is compared against three leading AODV-based protocols, and the efficiency of the protocol is analyzed and evaluated using different performancemetrics.

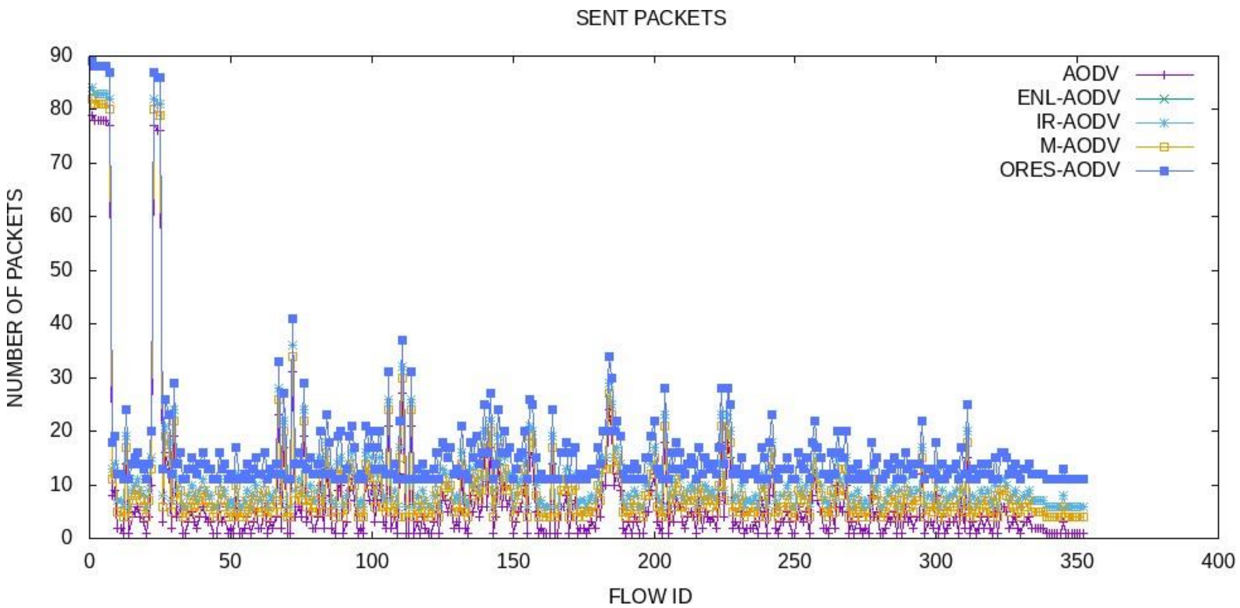

Fig. 5.48: Comparison of AODV and ORES protocol based on Sent Packets.

The proposed ORES-AODV protocol is evaluated and compared for sent packets withAODV-based protocols such as ENL-AODV, IR-AODV, M-AODV, and AODV using the NS3 simulator and the result are generated as shown in Fig.5.48.

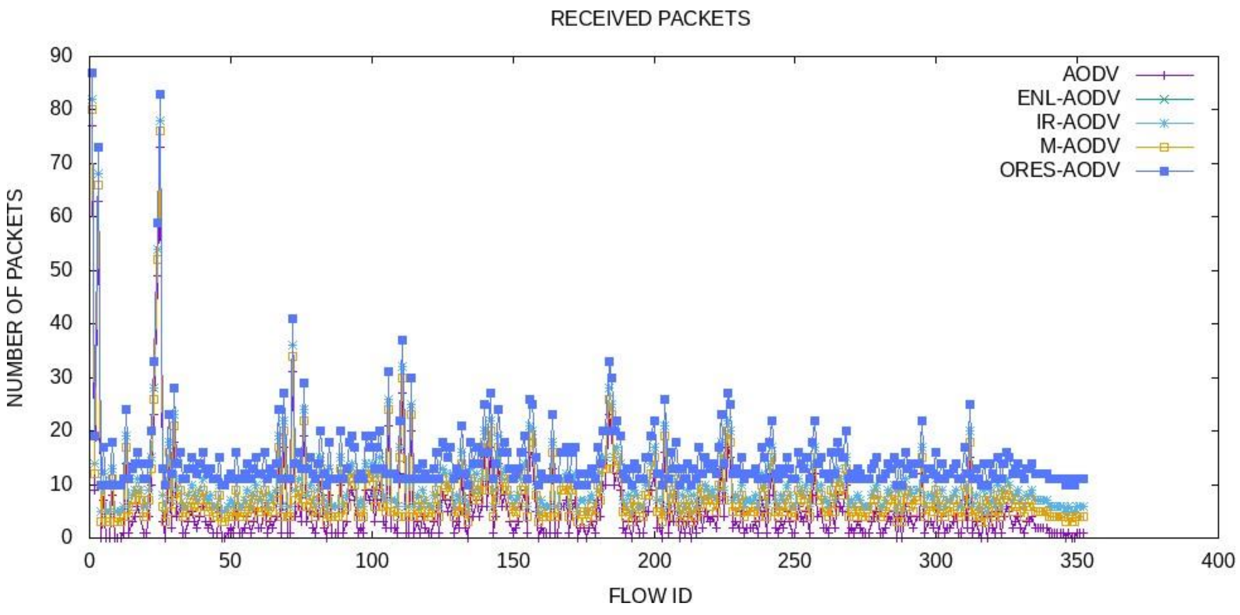

Fig. 5.49: Comparison of AODV-based and ORES protocols based on Received Packets.

The proposed ORES-AODV protocol is evaluated and compared for received packets withAODV-based protocols such as ENL-AODV, IR-AODV, M-AODV, and AODV usingNS3 network simulator. The result is generated as shown in Fig.5.49.

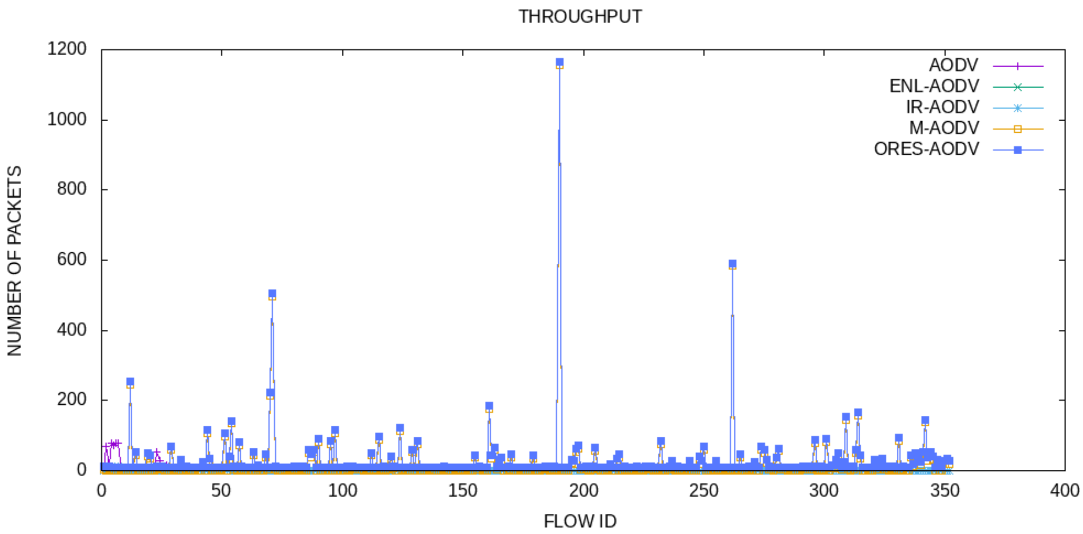

Fig. 5.50: Comparison of AODV-based and ORES protocols based on throughput.

The proposed ORES-AODV protocol is evaluated and compared for throughput evaluationwith AODV-based protocols such as ENL-AODV, IR-AODV, M-AODV, and AODVusing an NS3 network simulator. the result is generated as shown in Fig.5.50.

5.11 Energy analysis of ORES-AODV and other leading AODV-based protocols

The proposed protocol of this research work is evaluated against the energy efficiency of three top AODV-based protocols. The energy efficiency of the protocol is analyzed and evaluatedusing different energy evaluation metrics.

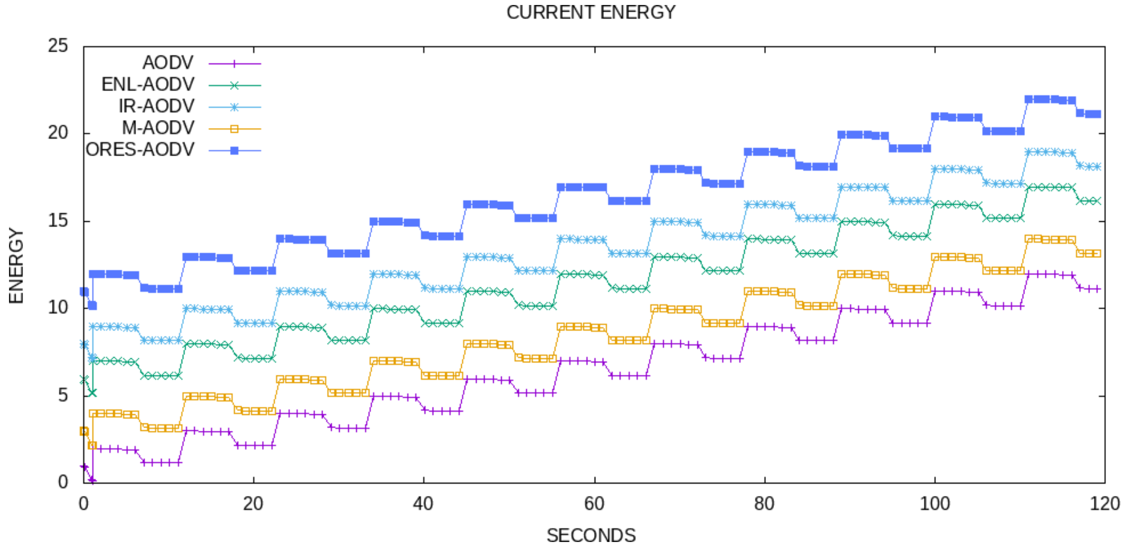

Fig. 5.51: Comparison of AODV-based and ORES protocols based on Current Energy.

The proposed ORES-AODV protocol is evaluated and compared for Current Energy withAODV-based protocols such as ENL-AODV, IR-AODV, M-AODV, and AODV using the NS3 network simulator. the result is generated as shown in Fig.5.51.

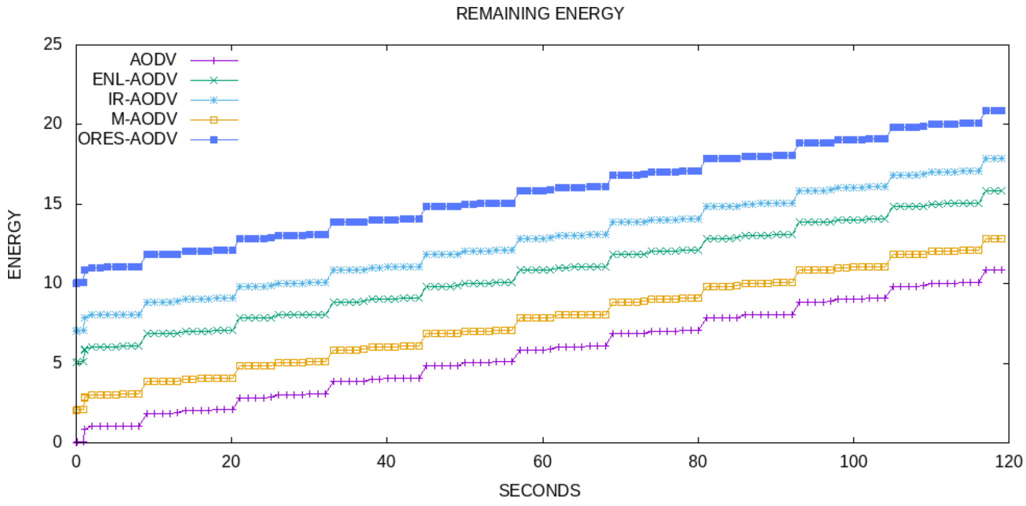

Fig. 5.52: Comparison of AODV and OLSR protocol based on Remaining Energy.

The proposed ORES-AODV protocol is evaluated and compared for Remaining Energy with AODV-based protocols such as ENL-AODV, IR-AODV, M-AODV, and AODV using the NS3 network simulator. the result is generated as shown in Fig.5.52.

5.12 Simulation for ORES-AODV to analyze the impact of Mobility on Energy Consumption

The following results were discovered when we tested the AODV routing protocol in a MANET using the mobility model with varied mobility, speed, and node density in the NS3 simulation platform:

Table 5.2: Simulation parameters for ORES-AODV

Parameters for the simulation	Value of experimentation
Time for simulation	300 s
Size of the terrain	700 x 700 m
Total nodes	50
Speeds of mobility	1–20 m/s
Connection count	10
Mobility models	Constant Position Mobility Model, Random waypoint, and Gauss–Markov mobility Model
Protocol for routing	ORES-AODV
Power sent out	One mW

The number of transmits in control packets increases as mobility increases because there are more frequent breaks in connections between nodes [145]. In Fig. 5.53 (a), For networks with 30 nodes, constant position mobility exhibits linear behavior in the domains of medium and sluggish mobility, but linearity declines for networks with 40 and 50 nodes.

For networks with 30 nodes, constant position mobility exhibits linear behavior in medium and sluggish mobility domains, but linearity declines for networks with 40 and 50 nodes. This decline is due to fewer connections breaking because each node can predict the trajectoriesof other nodes. s network density rises, the pace at which received control packets changes.

Figure 5.53 (b) shows how a Gauss Markov mobility model behaves when each node independently moves while traveling in a cluster. In the case of 50 nodes, random waypoint mobility displays linearly increasing zigzag behavior over the mobility zone as shown in Fig.5.53 (c).

The total number of transmitted control packets is less in the Markov model than in the random waypoint model [146].

The packet sent is less due to fewer connections breaking because each node can predict the trajectories of other nodes. s network density rises, the pace at whichreceived control packets changes.

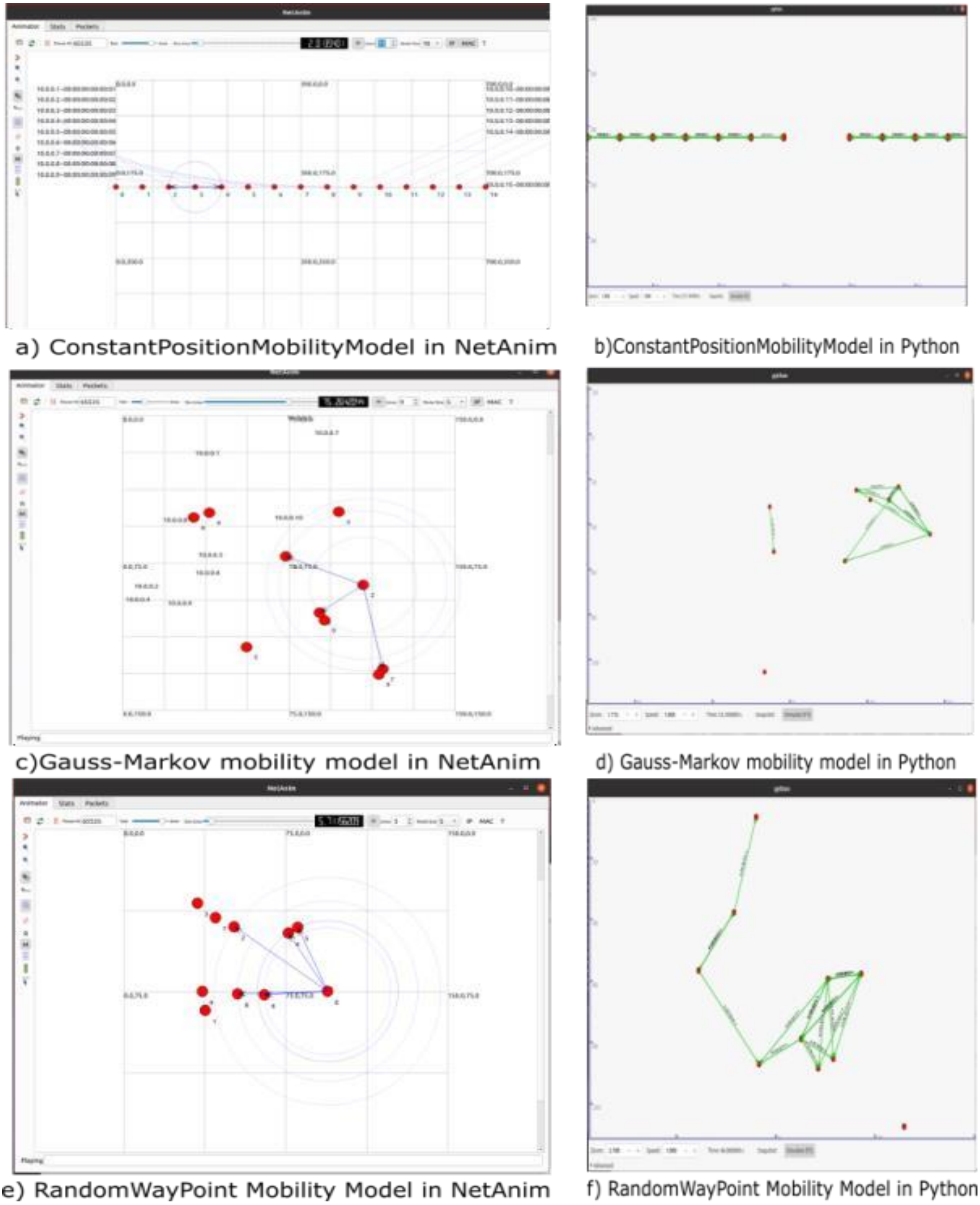

Fig. 5.53: Simulation results in NS3.

5.13 Simulation for WSN

Using NS3, we simulate several Low Energy Adaptive Clustering Hierarchy (LEACH) and its modification protocols MECA, as well as the proposed protocol of our research study Multi-MECA in WSNs [152]. The variables in table 5.3 are used for simulation and the Fig.54 shows the simulation of Multi-MECA in NS3. Energy and residual energy network evaluation all three protocols that have been examined as shown in Fig.5.55, Fig.5.56, Fig.5.57 and Fig.5.58.

Table 5.3: Simulation Parameters for Multi-MECA.

Parameter	**Value**
Area (m*m)	300 x 1500 m
Simulation Time(s)	500 Seconds
Speed (m/s)	20 m/s
MAC type	802.11 p MAC
Traffic type	Two-Ray Ground
Packet size	64-byte packets
Protocols	MULTI-MECA, MECA, LEACH
Mobility Model	Random Waypoint Mobility Model

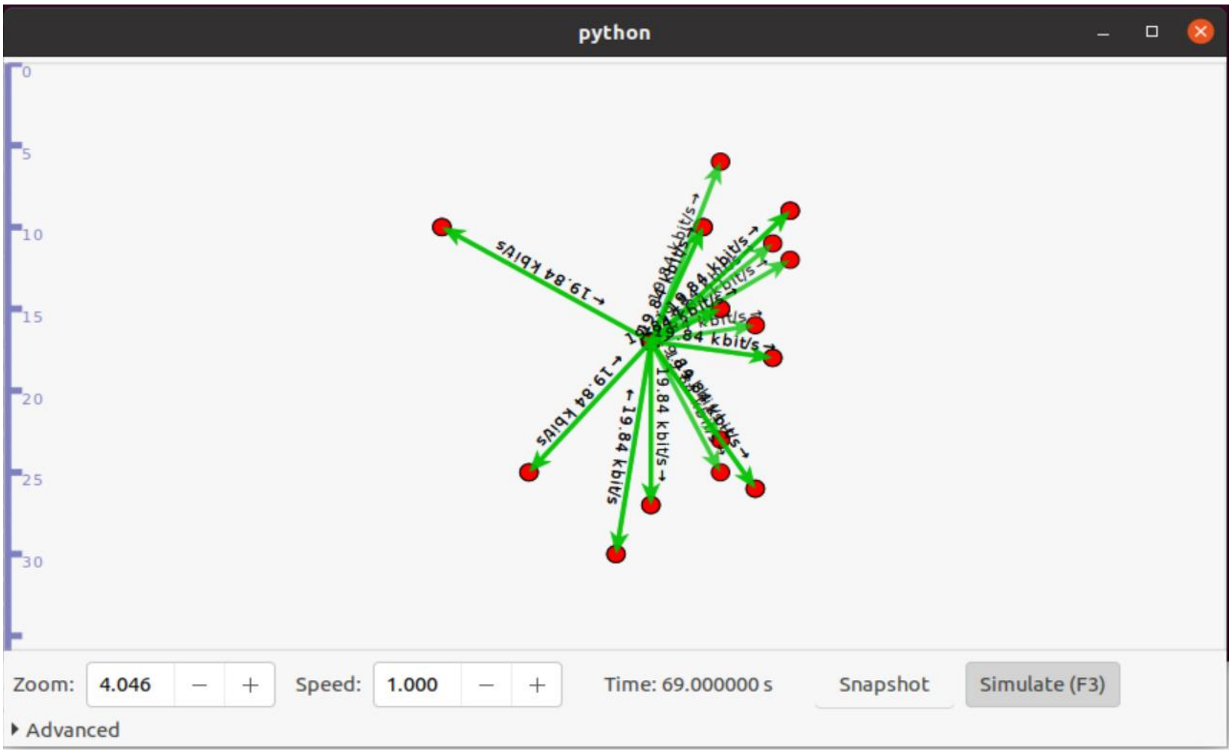

Fig.5.54: Simulation of Multi-MECA protocol in NS3

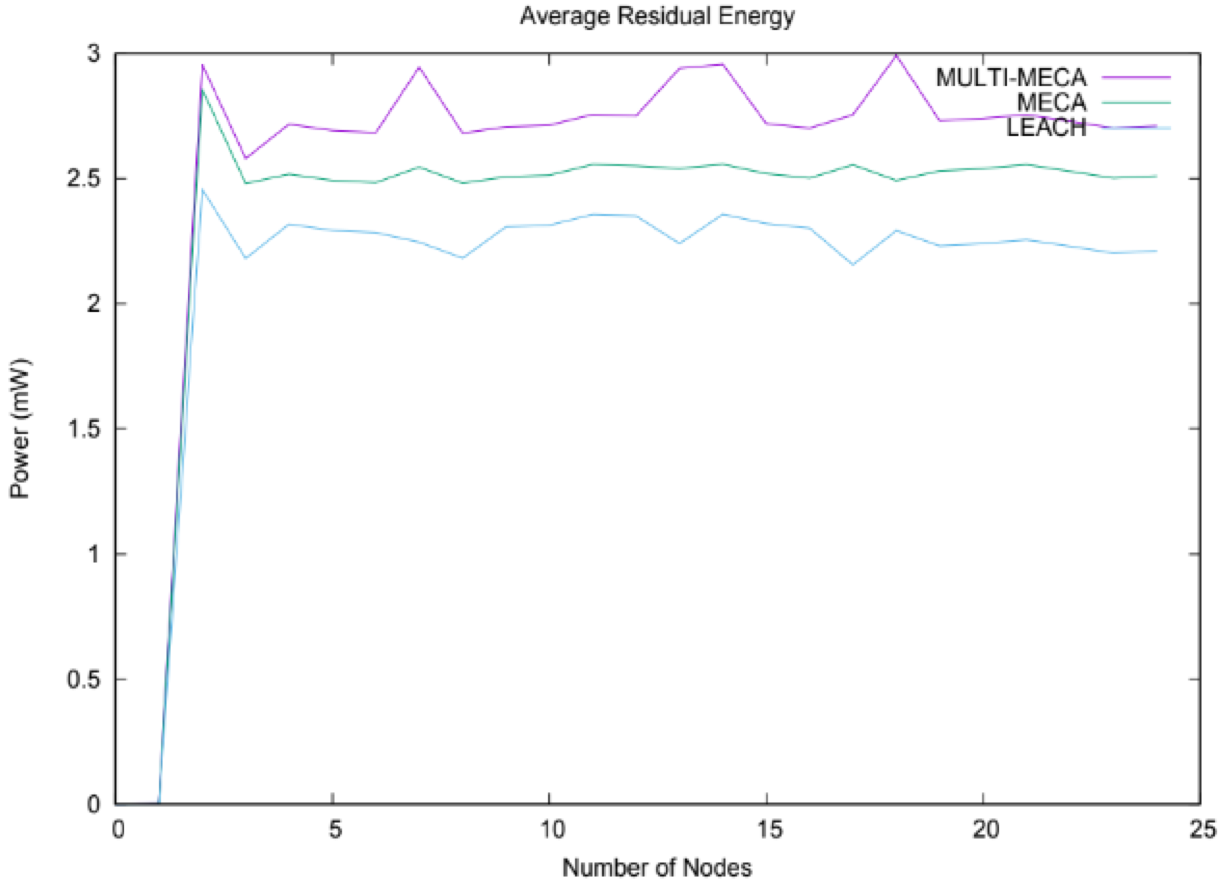

Fig.5.55: Average Residual Energy of LEACH, MECA and Multi-MECA for 25 nodes

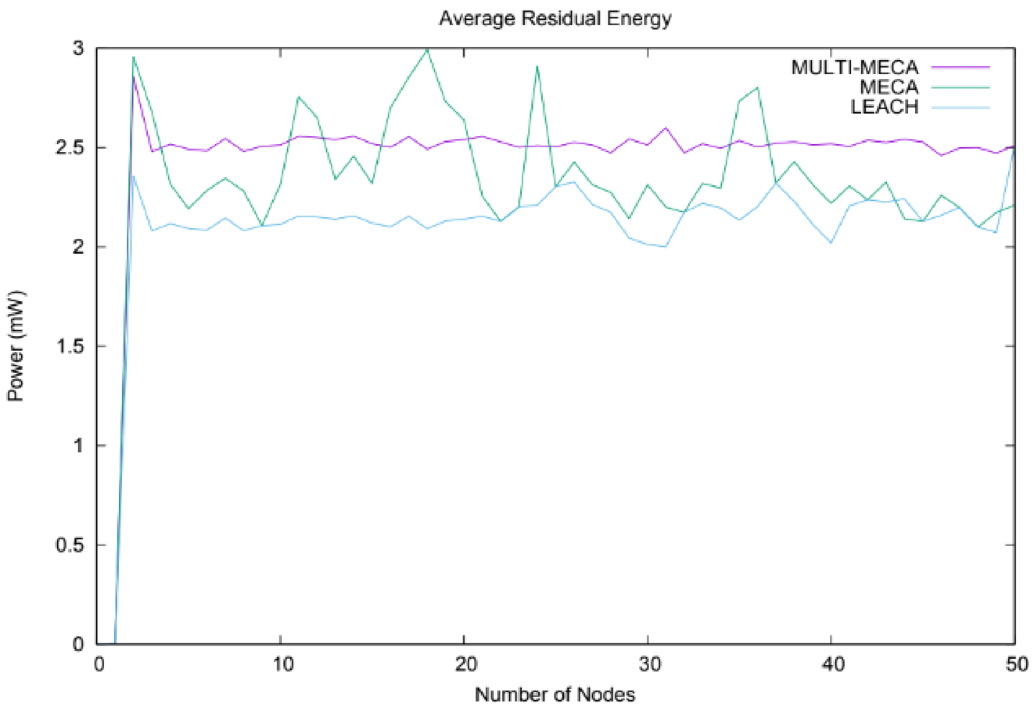

Fig.5.56: Average Residual Energy of LEACH, MECA and Multi-MECA for 50 nodes.

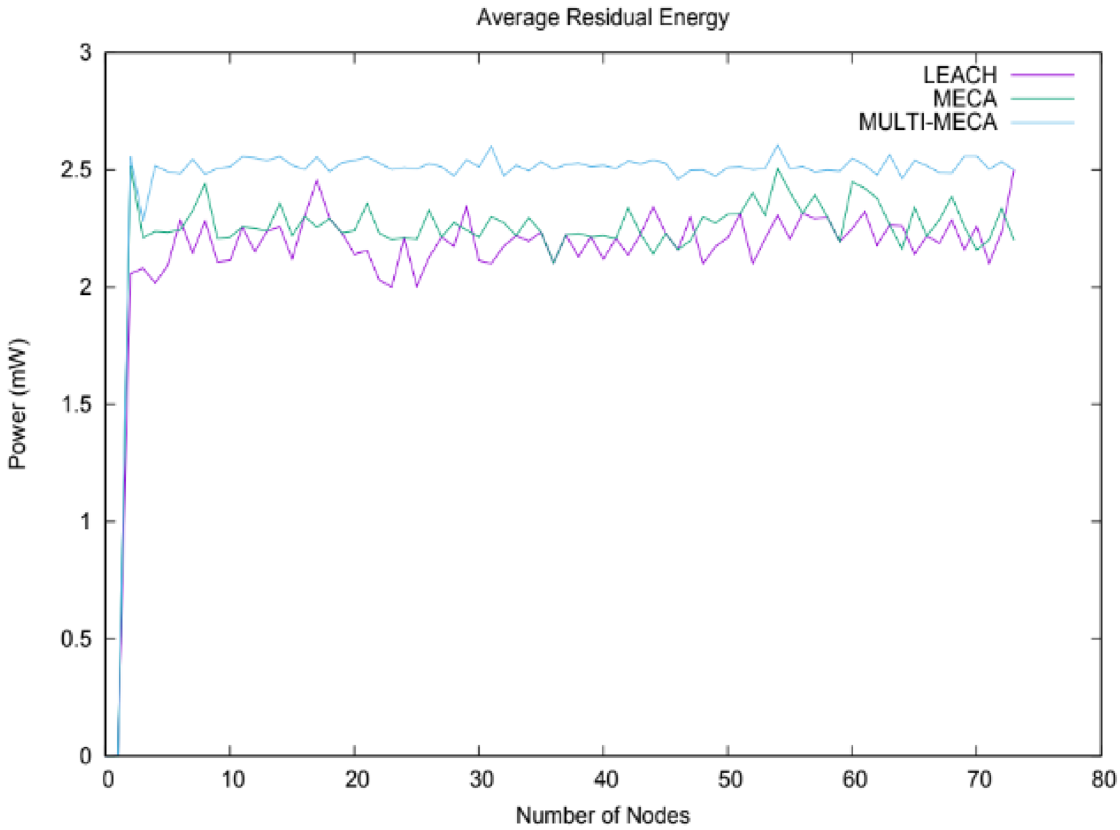

Fig.5.57: Average Residual Energy of LEACH, MECA and Multi-MECA for 75 nodes.

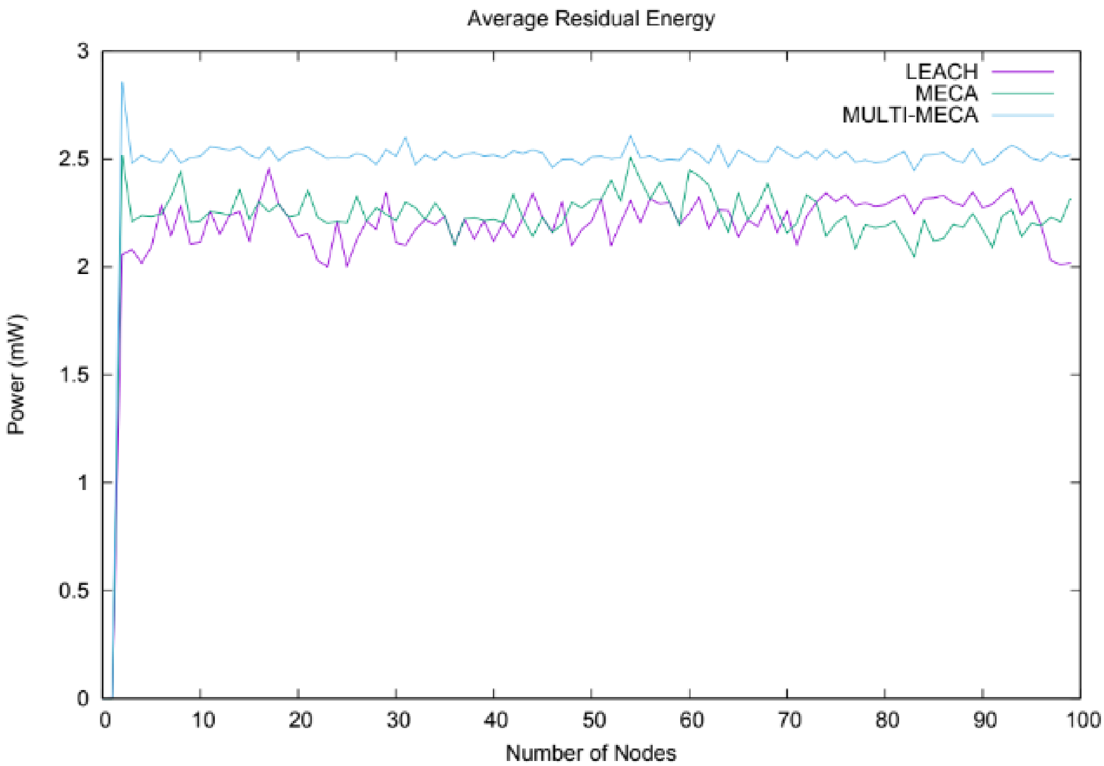

Fig.5.58: Average Residual Energy of LEACH, MECA and Multi-MECA for 100 nodes.

Using MATLAB R2021a, we simulate several Low Energy Adaptive Clustering Hierarchy (LEACH) and its modification protocols MECA, as well as the proposed protocol of our research study Multi-MECA in WSNs [147].

The variables in table 5.3 are used for simulation. Energy and residual energy network, the number of nodes alive between rounds, a number of data packets transferred to BS are the consequences of changing parameters used for evaluating clustering methods for heterogeneous WSNs that have been examined.

5.14 Simulation metrics

1- Dead nodes: Because they produce the fewest dead nodes, good performance is determinedby how many nodes have died since the previous round.

2- Alive nodes: The nodes that remained through the last round are the ones—with improvedperformance due to more active nodes.

3- Packets sent to the BS: specify how many packets the BS received for each round.

Table 5.4: Table of simulation inputs in MATLAB.

S. No.	Parameters	Values
1	Network Area	500*500
2	Number of nodes	500
3	Cluster head probability	0.1
4	Transmitter energy	50*0.000000001
5	Receiver energy	50*0.000000001
6	Number of rounds	2500
7	Hard threshold	100
8	Soft threshold	2
9	Initial Energy	0.5
10	Aggregation energy	5*0.000000001

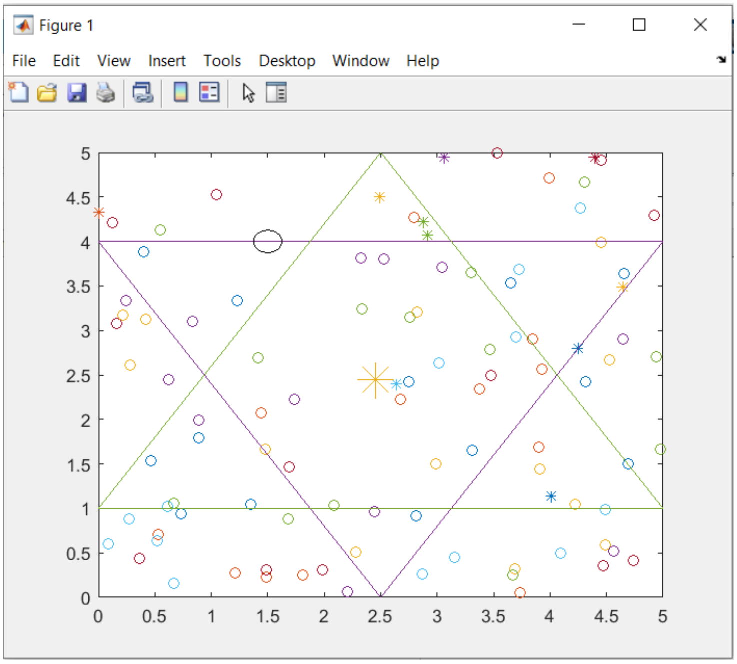

Fig.5.59: Movement of Sink Node 1 in Multi-MECA protocol.

Fig.5.59 shows the simulation of Multi-MECA protocol in MATLAB and the movement of Sink node 1. Fig.5.60 shows the simulation of Multi-MECA protocol in MATLAB and the movement of Sink node 2

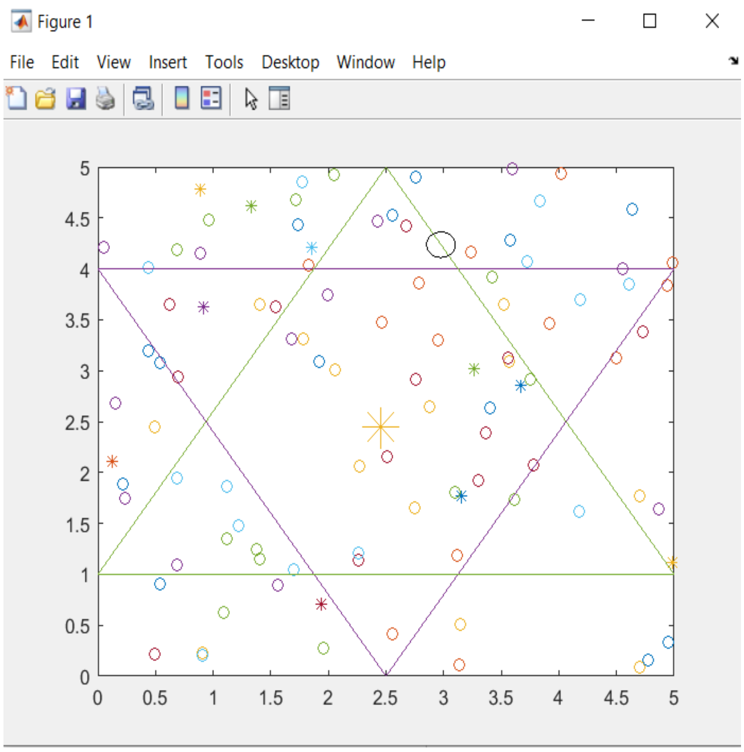

Fig.5.60: Movement of Sink Node 2 in Multi-MECA protocol.

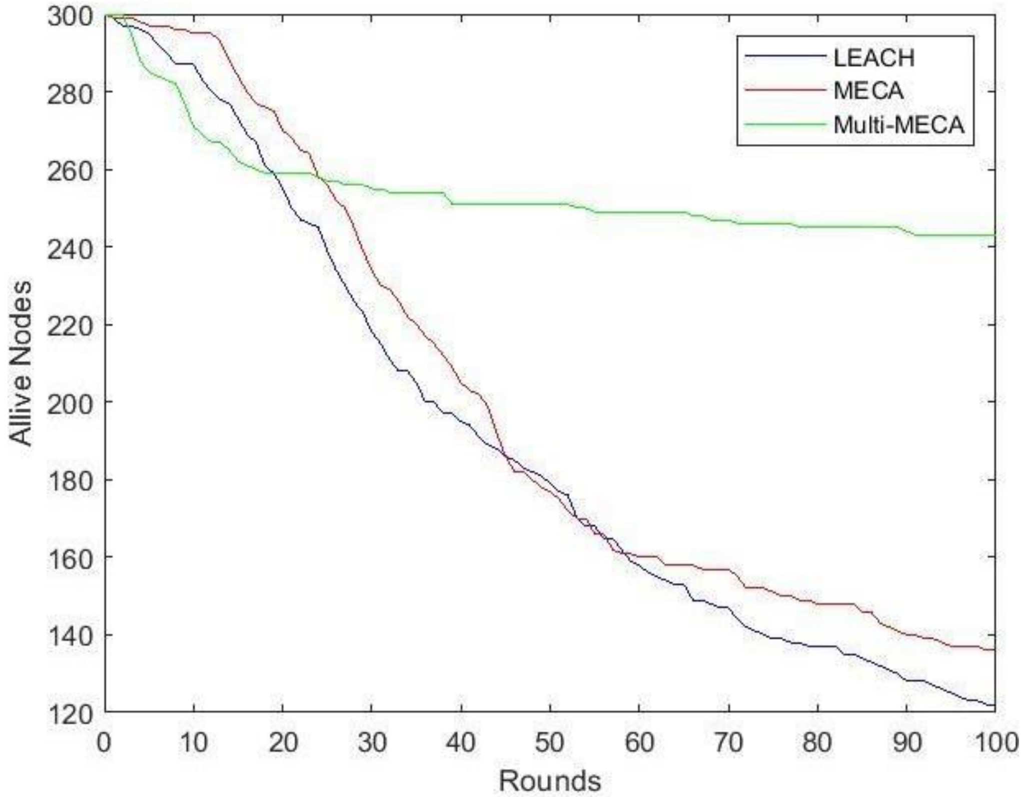

Fig.5.61: Alive Nodes

Fig.5.59 illustrates how fewer live nodes are present for all protocols as the number of rounds rises. Multi-MECA operates well but requires multiple hops for all rounds, which has increased the lifespan of the protocol network for our comparisons. Multi-MECA has proven to be the best lifetime protocol.

Fig.5.60 demonstrates that as the number of rounds rises, all dead nodes exceed. Compared to other protocols, Multi-MECA has fewer dead nodes.

The Multi-MECA protocol counts dead nodes up to the limit in 2500 rounds, which is the final round, while other protocols count dead nodes up to the limit in 2500 rounds more quickly and before Multi-MECA.

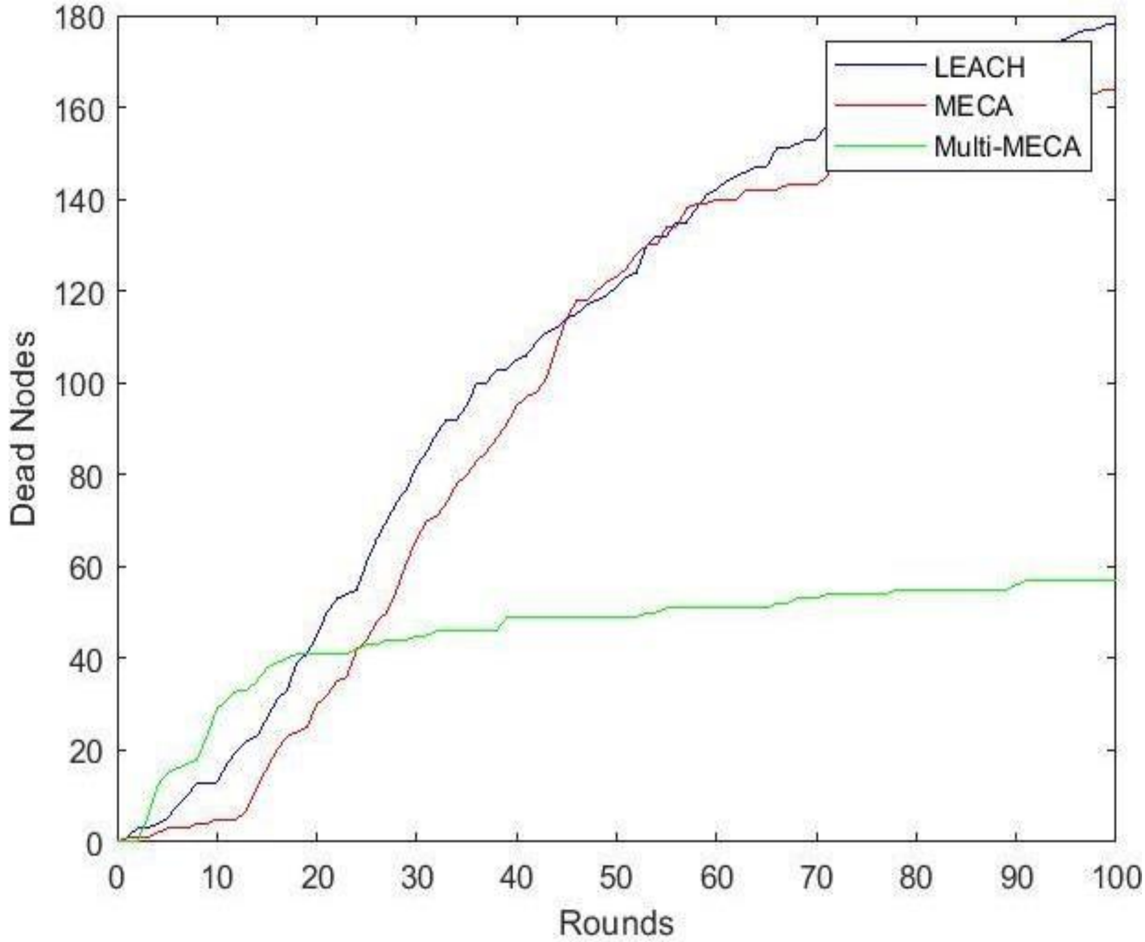

Fig.5.62: Dead Nodes

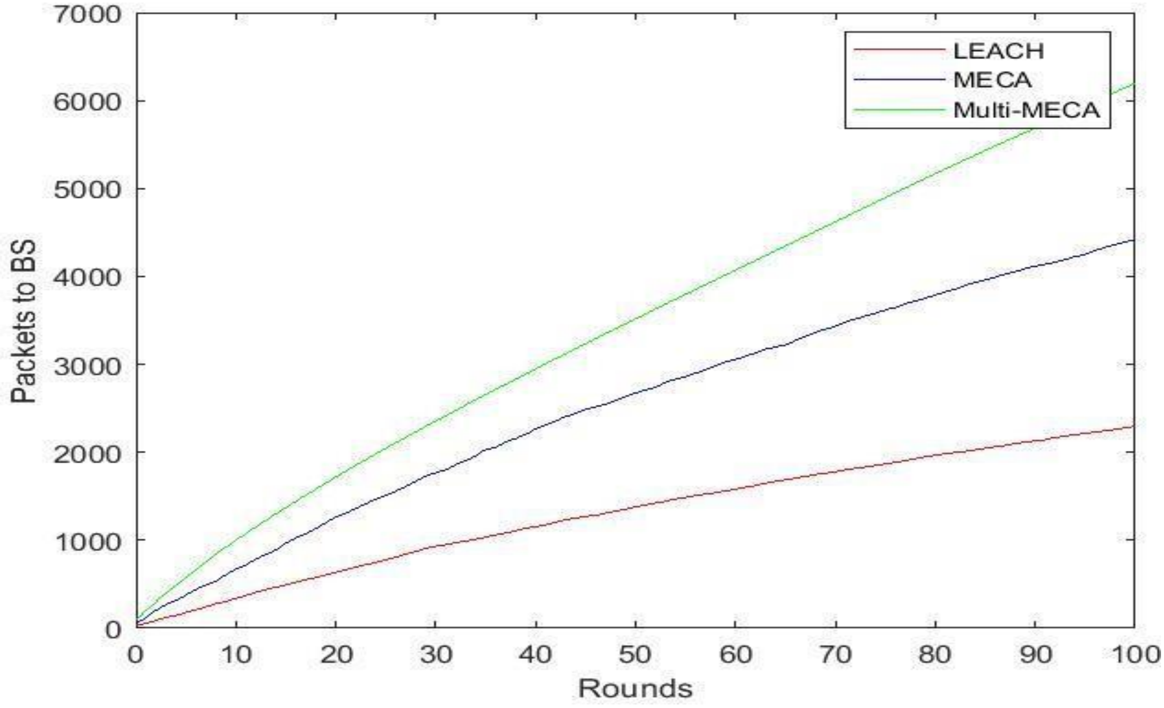

Fig.5.63: Packet sent to BS

Fig.5.61 demonstrates that the package arrives at the base station with outstanding performance protocol and reaches the maximum with more rounds than it does with LEACH, MECA, and Multi- MECA protocols [148]. However, Multi-MECA performance is outstanding compared to other protocols.

5.15 Chapter Summary

In this chapter, we have initially discussed the protocols selected for the simulation in MANET and those chosen for simulation in WSN. The following section discusses Performance Evaluation, AODV protocol, and Comparison of AODV with other MANET protocols. Further Performance Evaluation of AODV with simulation Metrics isconcerned. Also, the Performance Evaluation of ORES-AODV with simulation Metrics is discussed. In the next section, Comparative Evaluation of AODV and ORES-AODV with simulation Metrics is discussed to perform further analysis. Energy evaluation of AODV using Energy evaluation Metrics, Energy analysis and comparison of AODV and ORES-AODV, Comparative analysis of ORES-AODV and other leading AODV-based protocols, Energy analysis of ORES-AODV and other top AODV-based protocols, Simulation for ORES- AODV, Simulation for WSN, Simulation metrics are discussed in detail in this chapter.

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CHAPTER SIX

Analysis and Interpretation

Contents	Page. No

6.1 INTRODUCTION

This chapter does the advanced simulation analysis, the outcomes of the simulations carried out on the NS3 simulator on Mobile Ad Hoc networks, and the simulation performed for WSN in MATLABR2021a. This study includes multiple scenarios for the simulation chosen, and results are obtained. The Mobile Ad Hoc Network simulation performed on NS3 analyses the network's performance using different protocols, as well as with varying models of mobility, to see the influence on energy use by the network. The results of various simulations are analyzed using tables and graphs.

Table 6.1: Protocol Comparison in MANET

Protocol	Enhancement From Predecessor	Enhancement in ORES-AODV
M-AODV (Modified AODV)	Uses HELLO Packets for RREQ and two parameters, trust and Willingness, to establish the path.	Performs Route Discovery based on RREQ packets, Finds the residual energy difference between two nodes, saves it in Route Table, and finds the Average of Maximum Residual Energy. It also finds the threshold value of the node.
Intelligent Routing AODV (IR-AODV) protocol M. Anand Springer Nature 2018	Uses RSSI (Received Signal Strength Indication) to determine distance when exact positioning is not possible.	ORES-AODV focuses on preventing link breakage. If there is the possibility of link breakage, protocol discards the RREQ.
Energy and Load-Based Protocol (ENL-AODV) Nandanwar Chetan Damodar 2018	The remaining energy, traffic load, and delay areparameters takenin to consideration. And protocol compares the residual energy level with the threshold value if residual energy is fewer discards the RREQ.	The ORES- AODV Protocol refreshes the routing table to avoid stale routes by removing the path information during the link breakage.

In the Wireless Sensor Network, MATLABR2021a is used for simulation, the multi-sink model is used for the data capturing, and the data captured from every sensor node is transmitted tothe sink nodes, which are in mobility at a predefined path. The energy efficiency of the proposedmodel is analyzed in this chapter with the help of tables and graphs.

6.2 Node Mobility and its impact on Routing Protocols

This section assesses the effect of node mobility on MANET routing protocols' performance using the Random Waypoint mobility model [149]. AODV, IR-AODV, M-AODV, ENL-AODV, and in this study, ORES-AODV routing protocols were employed. Fifty randomly placed nodesin a 500x500 m2 landscape have been the subject of simulations, both with and without node mobility. Variable node speeds of 10 to 50 meters per second have been used for mobility. Performance measures such as Average Throughput and Average End to End Delay and the effectiveness of routing methods have been evaluated using average Jitter (s).

Average Throughput

Three routing methods' effectiveness has been examined according to Average Throughput inthe possibility of node mobility and absence. These protocols include AODV, IR- AODV, M-AODV, ENL-AODV, and ORES-AODV. According to the Average Throughput, the routing protocols' Average Throughput is directly impacted by node mobility. ORES- AODV routing protocol provides the highest average Throughput when there is node mobility, and the ENL-AODV routing protocol has the lowest Average Throughput (bits/s) of the three routing protocols. Table 6.1 and Fig 6.1 display the result.

Comparison between Average End-to-End Delay

The findings show that, in the absence of node mobility, all five routing protocols— AODV, IR-AODV, M- AODV, ENL-AODV, and ORES-AODV — exhibited improved Average performance Average End-to-End Delay (s). results show that End-to-End Delay in routing protocols is directly impacted by node mobility [150]. Previous investigations also support this. If nodes move, the AODV routing protocol has the highest End to End Delay, whereasthe ENL-AODV routing system has the lowest End to End Delay.

Table 6.2 Comparison of Throughput IR-AODV, AODV, M-AODV ENL-AODV, and ORES-AODV, including and excluding node mobility.

Routing Protocol	Average Throughput(bits/second)
AODV(NM)	2.57E-02
AODV(WM)	2.73E-02
IR-AODV(NM)	2.56E-02
IR-AODV(WM)	2.71E-02
M-AODV(NM)	1.89E-02
M-AODV(WM)	2.65E-02
ENL-AODV(NM)	1.89E-02
ENL-AODV(WM)	2.55E-02
ORES-AODV(NM)	2.78E-02
ORES-AODV(WM)	2.98E-02

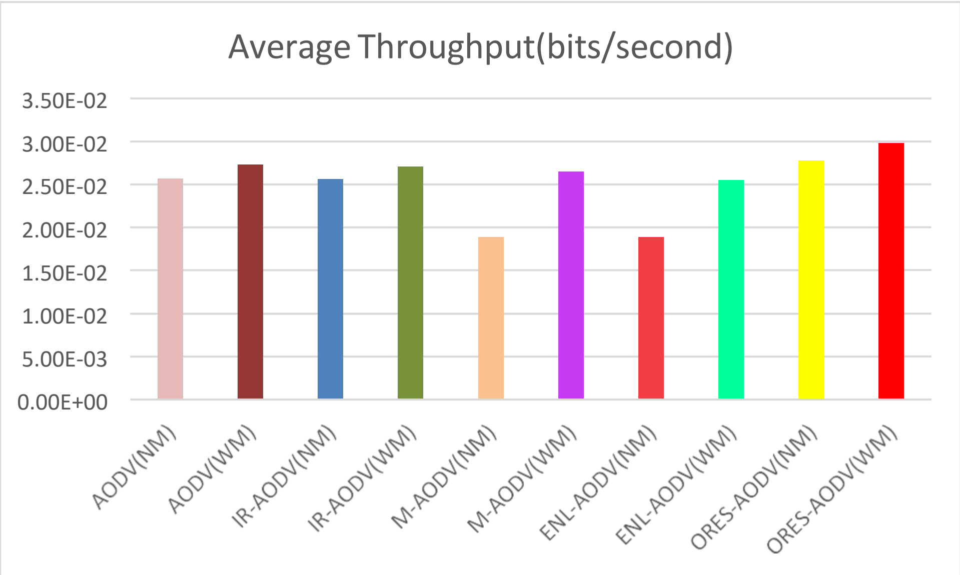

Fig 6.1: Average Throughput for AODV, IR-AODV, M-AODV, ENL-AODV, and ORES-AODV, including and excluding node mobility.

Without movement, routing outperformed AODV and M-AODV routing protocols with the smallest average end-to-end delays. As opposed to M-AODV, the AODV routing systemhas the most significant end-to-end delay. ORES-AODV has an average end-to-end delay. The outcomes are shown in Fig 6.2 and also in table 6.2.

Table 6.3 Comparing end-to-end delay for AODV, IR-AODV, M-AODV, ENL-AODV, andORES-AODV, including and excluding node mobility.

Routing Protocol	**Average End-to-End Delay (s)**
AODV(NM)	1.57E-02
AODV(WM)	1.75E-02
IR-AODV(NM)	1.25E-02
IR-AODV(WM)	1.49E-02
M-AODV(NM)	1.01E-02
M-AODV(WM)	1.44E-02
ENL-AODV(NM)	2.89E-02
ENL-AODV(WM)	2.55E-02
ORES-AODV(NM)	1.40E-02
ORES-AODV(WM)	1.23E-02

Average Jitter

The findings show that when node mobility wasn't present, all five routing protocols—AODV,IR-AODV, M-AODV, and ENL-AODV—performed better in terms of Average Jitter (s). the resul illustrates a clear relationship between the average Jitter and node mobility.

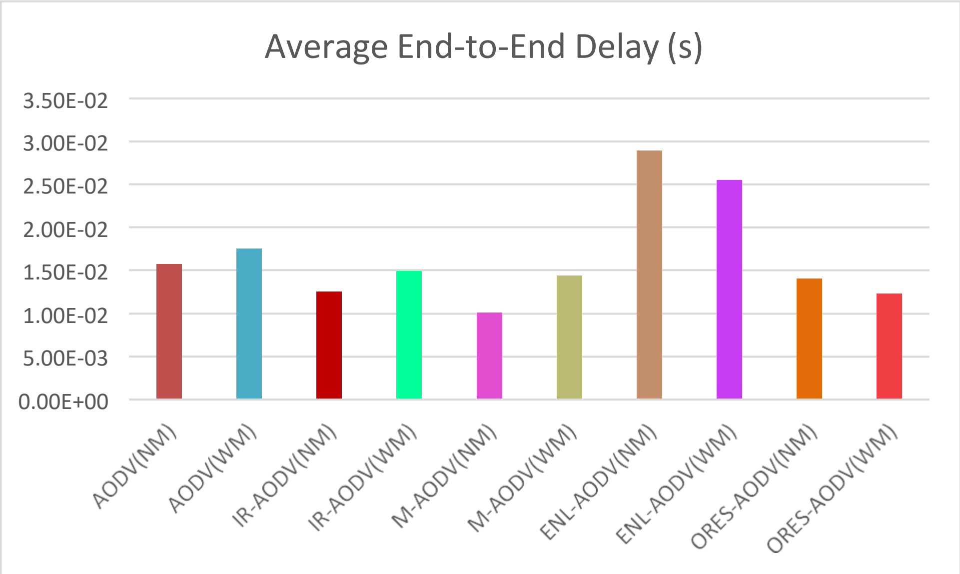

Fig. 6.2 Comparing End to End Delay for AODV, IR-AODV, M-AODV, ENL-AODV, andORES-AODV, including and excluding node mobility.

When there is node mobility, the AODV routing protocol contains the highest average Jitter, whereas the ORES-AODV routing protocol has the lowest average Jitter (s). When there is no mobility, IR-AODV routing performs better than AODV and M-AODV routing protocols withthe least Average Jitter. The ORES-AODV routing protocol, when compared to ENL-AODV and IR-AODV, has the lowest Average Jitter when there is no node mobility. The simulation

Results are depicted in Table 6.3 and Figure 6.3.

Table 6.4 Average Jitter for routing protocols including and excluding node mobility.

Routing Protocol	Average Jitter (s)
AODV(NM)	4.70E-02
AODV(WM)	3.70E-02
IR-AODV(NM)	3.98E-02
IR-AODV(WM)	2.98E-02
M-AODV(NM)	3.77E-02
M-AODV(WM)	3.77E-02
ENL-AODV(NM)	2.21E-02
ENL-AODV(WM)	2.21E-02
ORES-AODV(NM)	2.12E-02
ORES-AODV(WM)	2.01E-02

6.3 Movement of node affecting consumption of energy for various protocols

This section uses the Random Waypoint mobility model to analyze how the movement of nodes affects energy usage in routing protocols. AODV, IR-AODV, M-AODV, ENL-AODV, and ORES-AODV have been selected for this study. Fifty nodes were analyzed and subjected to simulations, including and excluding node mobility.

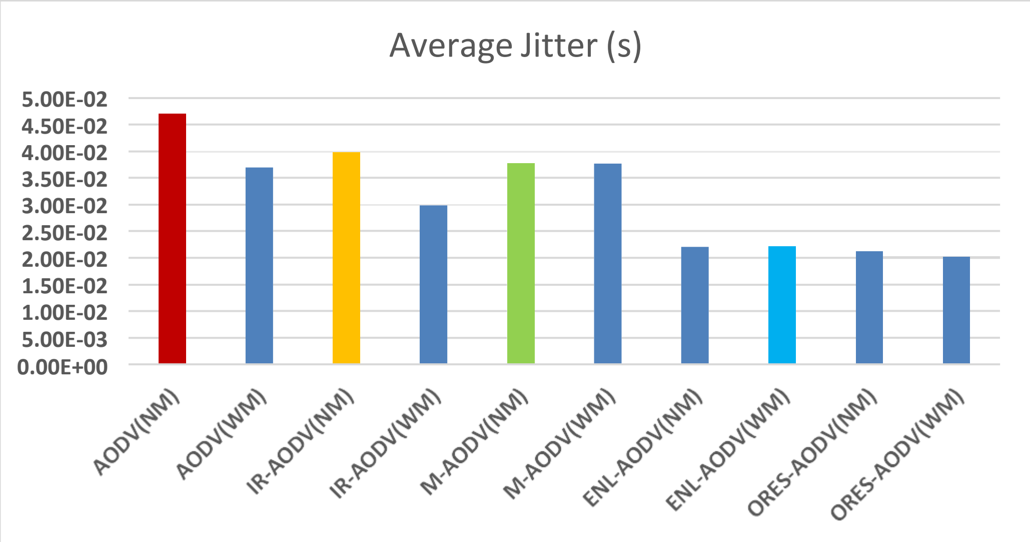

Figure 6.3 Average Jitter for routing protocols including and excluding node mobility.

A speed of 15 to 30 meters per second and a CBR traffic pattern is specified for mobility.The energy consumption modes are —Transmit, Receive, and Idle Mode is assessed, includingand excluding node mobility.

Energy usage of the node in the transmission

results found the AODV, IR-AODV, M-AODV, ENL-AODV, and ORES-AODV routing protocols use more energy when nodes are mobile than when they are not mobile. Because of this, research demonstrates that mobility negatively affects routing techniques' capacity to transfer data while consuming the smallest possible amount of energy. Previous investigations also support this. Compared to ORES-AODV and other routing protocols, The IR-AODV and ENL-AODV routing protocols use more energy in mobile and stationary conditions [150].Compared to IR-AODV and ENL-AODV routing protocols, the ORES-AODV routing protocol uses the least amount of energy when nodes are mobile and fixed. Table 6.4 also Fig. 6.4 illustrate the outcomes of the simulation.

Table 6.5 Energy Consumption in Transmit Mode for AODV, IR-AODV, M-AODV, ENL-AODV, and ORES-AODV, including and excluding node mobility.

Routing Protocol	**Transmit Mode (mJoule)**
AODV(NM)	**2.70E-02**
AODV(WM)	**2.70E-02**
IR-AODV(NM)	**3.20E-02**
IR-AODV(WM)	**3.20E-02**
M-AODV(NM)	**2.70E-02**
M-AODV(WM)	**2.70E-02**
ENL-AODV(NM)	**2.61E-02**
ENL-AODV(WM)	**2.61E-02**
ORES-AODV(NM)	**2.30E-02**
ORES-AODV(WM)	**2.10E-02**

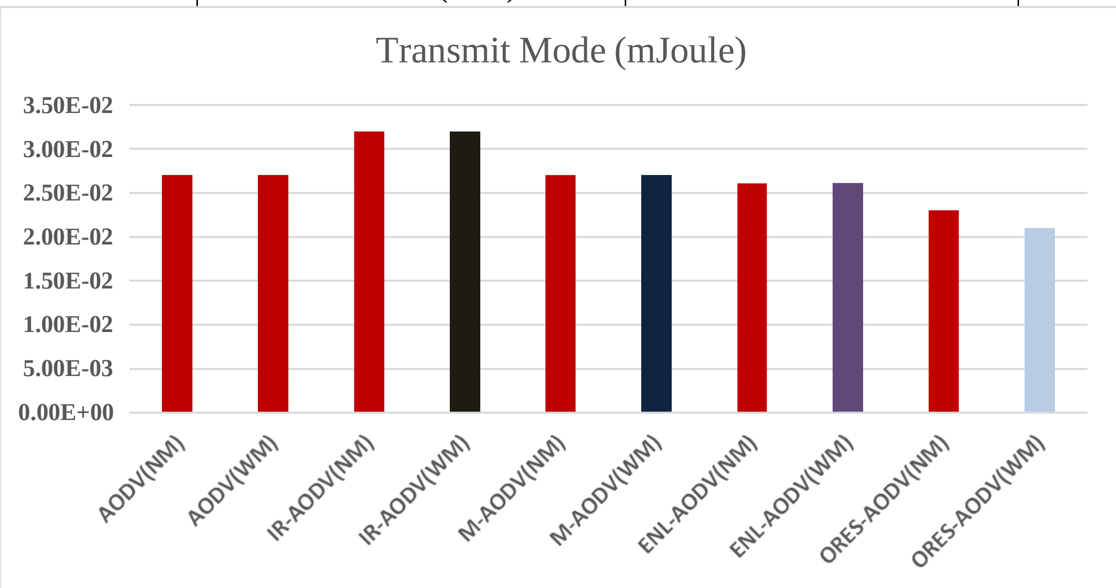

Fig 6.4 Energy use in transmission for AODV, IR-AODV, M-AODV, ENL-AODV, andORES-AODV routing protocols, including and excluding node mobility.

Energy use for Receival

In Receive Mode, results found that the AODV, IR-AODV, M- AODV, ENL-AODV, and ORES-AODV protocols used more energy when nodes were mobile than when they weren't mobile in Receival. In cases where nodes in Receival did not have a mobility effect, AODV, IR-AODV, M-

AODV, ENL-AODV, and ORES-AODV routing protocols were used, respectively 29%, 15%, 19%, 16%, and 32% less energy than nodes that did have a mobility effect. Results are further confirmed by the evidence showing that mobility negatively affects routing systems' energy use when transmitting information from one node to another. M-AODVrouting protocol has a higher energy usage than the other two routing protocols, whether or notit includes mobility. Compared to AODV, IR-AODV, and ENL-AODV routing protocols, the ORES-AODV routing protocol uses the least amount of energy when nodes are mobile and stationary. Additionally, the research backs it up. The results are shown in Table and Fig. 6.5.

Table 6.6 Energy use in Receival for AODV, IR-AODV, M-AODV, ENL-AODV, and ORES-AODV, including and excluding node mobility.

Routing Protocol	Receive Mode (mJoule)
AODV(NM)	1.31E-02
AODV(WM)	1.41E-02
IR-AODV(NM)	1.95E-02
IR-AODV(WM)	1.73E-02
M-AODV(NM)	2.30E-02
M-AODV(WM)	2.30E-02
ENL-AODV(NM)	1.20E-02
ENL-AODV(WM)	1.20E-02
ORES-AODV(NM)	1.50E-03
ORES-AODV(WM)	1.19E-02

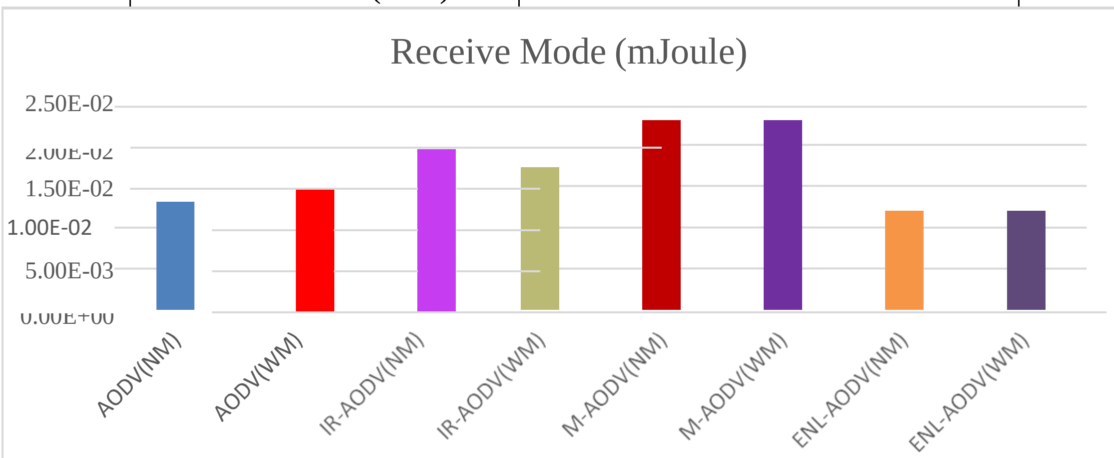

Fig 6.5 Energy use in receival for AODV, IR-AODV, M-AODV, ENL-AODV, and ORES-AODV routing protocols, including and excluding node mobility.

Energy use when a node is Idle

The results from the simulation showed that AODV, IR-AODV, M-AODV, ENL-AODV, and ORES-AODV protocols utilized slightly more energy when nodes were mobile than when nodes were immobile or in idle Mode.

Mobility and idle state further corroborate that when nodes are inactive and not actively transmitting or receiving information, mobility negatively influences energyusage in routing protocols. The investigation results are also confirmed by earlier studies that have been done [151]. In comparison to IR-AODV and ENL-AODV routing protocols, AODV routing methods use more energy, whether they are mobile. Although less energy-intensive than AODV routing protocols, M-AODV and ORES-AODV routing methods have approximately the same energy consumption with and without node mobility.The results of the simulation are displayed in Table 6.6 also Fig 6.6.

Table 6.7 Energy use when a node is idle for AODV, IR-AODV, M-AODV, ENL-AODV, and ORES-AODV routing protocols, including and excluding node mobility.

Routing Protocol	IDLE Mode (mJoule)
AODV(NM)	2.21E+00
AODV(WM)	2.15E+00
IR-AODV(NM)	2.75E+00
IR-AODV(WM)	2.64E+00
M-AODV(NM)	2.83E+00
M-AODV(WM)	2.95E+00
ENL-AODV(NM)	2.54E+00
ENL-AODV(WM)	2.68E+00
ORES-AODV(NM)	2.02E+00
ORES-AODV(WM)	2.01E+00

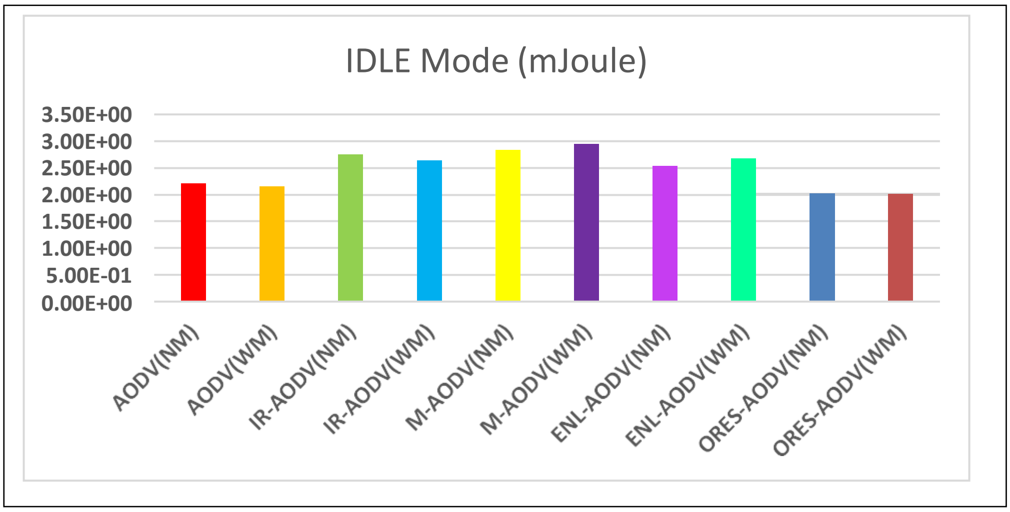

Fig 6.6 Energy use when a node is idle for AODV, IR-AODV, M-AODV, ENL-AODV, andORES-AODV, including and excluding node mobility.

6.4 Performance of MANET Routing Protocols with Varying Node Density

The protocol is evaluated with varying node densities under two distinct mobility concepts, Random Waypoint mobility model and the Gauss Markov mobility model.

Evaluation results for routing protocols with different node densities in the Random Waypoint and Gauss Markov mobility model are given in the Table:

6.4.1 Simulation results with varying numbers of node density

In this section, the Random Waypoint mobility model has been used to assess the four routing systems' effectiveness at various node densities. as many as nodes in a MANET with mobility speeds of 20 to 30 m/s and CBR traffic patterns in a terrain area of 500 by 500 m2 are used in the various network scenarios meant to test the effectiveness of routing algorithms. The efficacy of protocols is examined using performance metrics:

Average Throughput

The average Throughput (bits/s) of the AODV, IR-AODV, M-AODV, ENL-AODV, and ORES-AODV routing protocols have been compared using the Random Waypoint mobility model with different node densities. The routing techniques' resulting Average Throughput has been reported in scientific value format for easy analysis. Figure 6.7 and Table 6.7, respectively.

Table 6.8 Average Throughput for AODV, IR-AODV, M-AODV, ENL-AODV, and ORES-AODV routing procedures with different node densities under random waypoint mobility model.

Average Throughput (bits/s)					
	Number of Nodes				
Routing Protocols	**30**	**50**	**70**	**90**	**110**
ADV	4.11E+03	4.21E+03	4.51E+03	4.41E+03	4.31E+03
IR-ADV	3.24E+03	3.34E+03	3.14E+03	3.54E+03	3.34E+03
M-AODV	3.24E+03	3.44E+03	3.14E+03	3.64E+03	3.74E+03
ENL-AODV	3.74E+03	3.74E+03	3.74E+03	3.74E+03	3.74E+03
ORES-AODV	4.34E+03	4.54E+03	4.91E+03	4.84E+03	4.74E+03

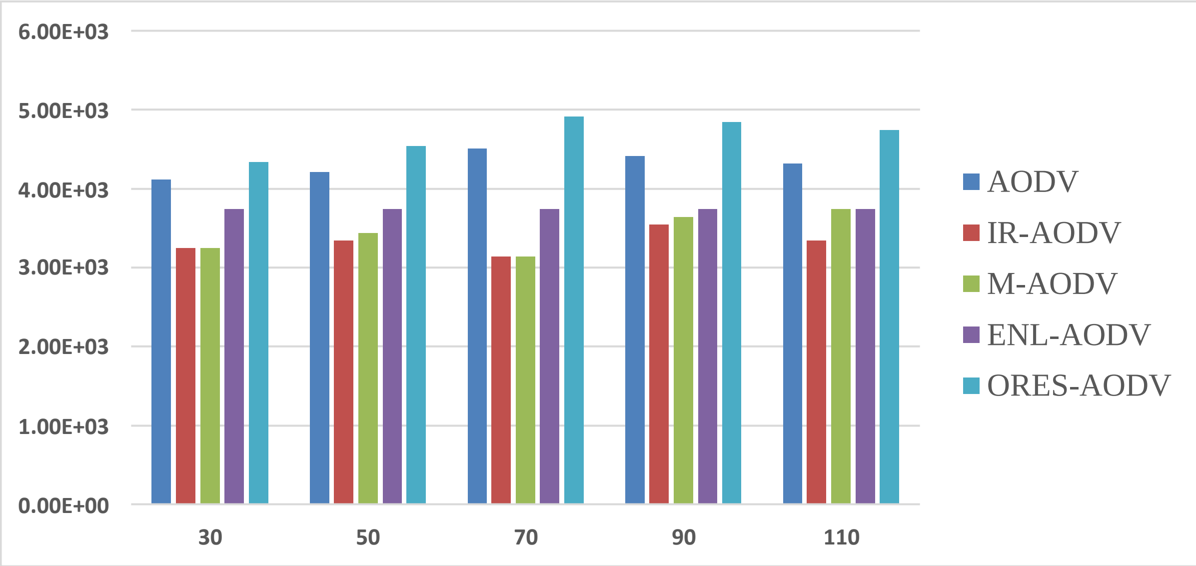

Fig 6.7 Average Throughput for AODV, IR-AODV, M-AODV, ENL-AODV, and ORES-AODV routing protocols using a random waypoint mobility model and changing node densities.

The ENL-AODV protocol, however, has worked admirably except for a significant setback at node densities of 50 nodes. The ENL-AODV performance has somewhat increaseddue to the more substantial amount of nodes.

End-to-End Delay

The model used is RWP with various node densities has been used to compare the Average Endto End Delay of AODV, IR-AODV, M- AODV, ENL-AODV, and ORES-AODV routing protocols. The resulting Average End-to-End Delay from the routing techniques has been displayed in exponent form to make it easier to grasp. The average end-to-end delay data are shown graphically in Fig 6.8 also Table 6.8.

Table 6.9: End to End Delay for AODV, IR-AODV, M-AODV, ENL-AODV, and ORES-AODV variable node density routing methods with an RWP model.

Average End-to-End Delay					
	Number of Nodes				
Protocols Used	**30**	**50**	**70**	**90**	**110**
ADV	4.11E+03	4.21E+03	4.51E+03	4.41E+03	4.31E+03
IR-ADV	3.24E+03	3.34E+03	3.14E+03	3.54E+03	3.34E+03
M-AODV	3.24E+03	3.44E+03	3.14E+03	3.64E+03	3.74E+03
ENL-AODV	3.74E+03	3.74E+03	3.74E+03	3.74E+03	3.74E+03
ORES-AODV	4.34E+03	4.54E+03	4.91E+03	4.84E+03	4.74E+03

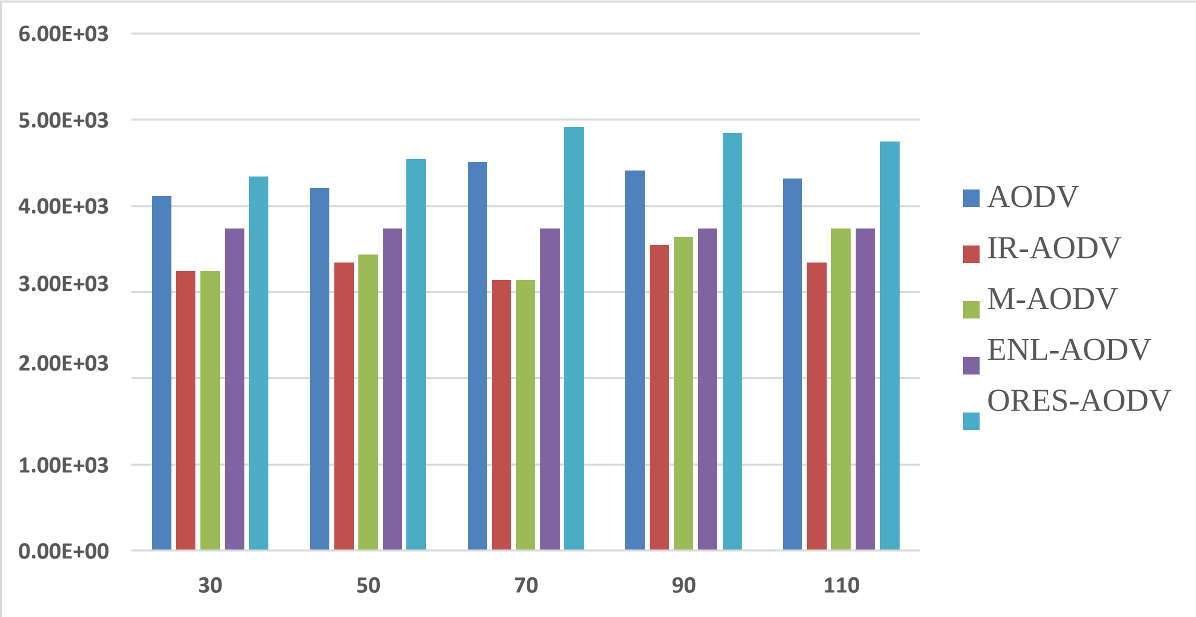

Fig 6.8: Average End to End Delay for AODV, IR-AODV, M-AODV, ENL-AODV, andORES-AODV variable node density routing methods with a random waypoint mobility model.

The graph shows that the ORES-AODV routing protocol does not outperform other routing protocols in End-to-End delay as node density increases. However, for a situation with 70 nodes dense, the ENL-AODV routing protocol has fluctuated toward a minimum End to End Delay.

The M-AODV also demonstrated subpar performance with growing node counts in many network contexts.

In contrast, IR-AODV routing methods have consistently outperformed all otherrouting protocols as node density has increased in various network circumstances. For the situations with higher node densities, AODV functioned satisfactorily and showed a slight increase in End to End delay [152].

Although it has performed averagely for networks with smaller and more significant numbers of nodes, AODV routing outperforms other routing algorithms in networks with 70 nodes.

For all of the network cases being investigated, ENL-AODV routing protocols also demonstrated average performance with slight variations in End-to-End Delay.

Average Jitter

The Random Waypoint mobility model with varied node densities has been used to compare the performance of AODV, IR-AODV, M-AODV, ENL-AODV, and ORES-AODV based on Jitter. For ease of comprehension, the result is in exponentiation notation. Jitter data are presented graphically in Figure 6.10 and Table 6.10, respectively.

Table 6.10: Average Jitter for AODV, IR-AODV, M-AODV, ENL-AODV, and ORES-AODV variable node density routing methods with an RWP model.

Average Jitter					
	Number of Nodes				
Routing Protocols	**30**	**50**	**70**	**90**	**110**
ADV	4.11E+03	4.21E+03	4.51E+03	4.41E+03	4.31E+03
IR-ADV	3.24E+03	3.34E+03	3.14E+03	3.54E+03	3.34E+03
M-AODV	3.24E+03	3.44E+03	3.14E+03	3.64E+03	3.74E+03
ENL-AODV	3.74E+03	3.74E+03	3.74E+03	3.74E+03	3.74E+03
ORES-AODV	4.34E+03	4.54E+03	4.91E+03	4.84E+03	4.74E+03

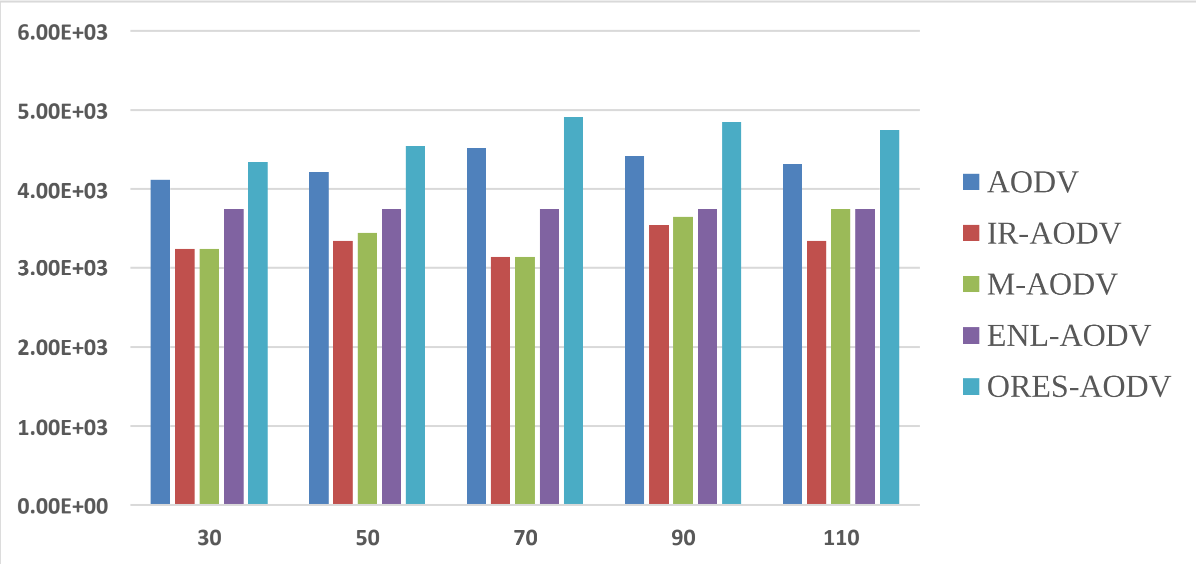

Fig 6.9: Average Jitter for AODV, IR-AODV, M-AODV, ENL-AODV, and ORES-AODV routing protocols with variable node density routing methods with an RWP model.

The graph shows that ORES-AODV routing methods have outperformed the rest of the protocols concerning Average Jitter as node density has increased in various network circumstances. In many network contexts, the M-AODV and ENL-AODV protocol has also demonstrated subpar performance with growing nodes. The IR-AODV routing system, however, has performed the worst as node density has increased [153]. However, the M-AODV has indicated a lower Average Jitter value for a scenario with 70 nodes. For situations with different node densities, the AODV routing protocols likewise performed well, but their performance suffered for the scenario with a node density of 110nodes. The AODV routing protocol is similarly suitable in performance in a 70-node situation. For scenarios with lower and larger node densities, its result value declined.

6.4.2 Simulation of selected protocols with different node densities under Gauss Markov Mobility Model

This section uses the Gauss Markov Mobility Model to evaluate the performance of fourrouting protocols with different node densities.

The performance of routing protocols has been examined using three performance metrics: average Throughput (bits/s), average end-to-end delay (s), and average Jitter (s). The following has been said about how outcomes should be interpreted:

Average Throughput

The Mobility Model Gauss Markov with varied node densities has been used to compare the performance of the routing protocols in terms of Average Throughput (bits/s). The average throughput figures are presented graphically in Fig. 6.10 also Table 6.10, respectively.

The graph shows that in network situations with node densities, ORES-AODV protocol performance in terms of Average Throughput (bits/s) is most excellent among all the routing protocolsunder examination.

For networks with 30 and 90 nodes, however, OLSR protocols have not fared well; in contrast, they have done well in other network settings.

In comparison, ENL-AODVhas excelled in low-density and high-density network scenarios, except in 50- and 70-node networks, where it has been displayed. Variance in Average Throughput that is on the lower side.

Table 6.11: Average Throughput for AODV, IR-AODV, M-AODV, ENL-AODV, and ORES-AODV routing procedures with different node densities under Gauss Markov Mobility Model.

Average Throughput					
	Number of Nodes				
Routing Protocols	**30**	**50**	**70**	**90**	**110**
ADV	4.11E+03	4.21E+03	4.51E+03	4.41E+03	4.31E+03
IR-ADV	3.24E+03	3.34E+03	3.14E+03	3.54E+03	3.34E+03
M-AODV	3.24E+03	3.44E+03	3.14E+03	3.64E+03	3.74E+03
ENL-AODV	3.74E+03	3.74E+03	3.74E+03	3.74E+03	3.74E+03
ORES-AODV	4.34E+03	4.54E+03	4.91E+03	4.84E+03	4.74E+03

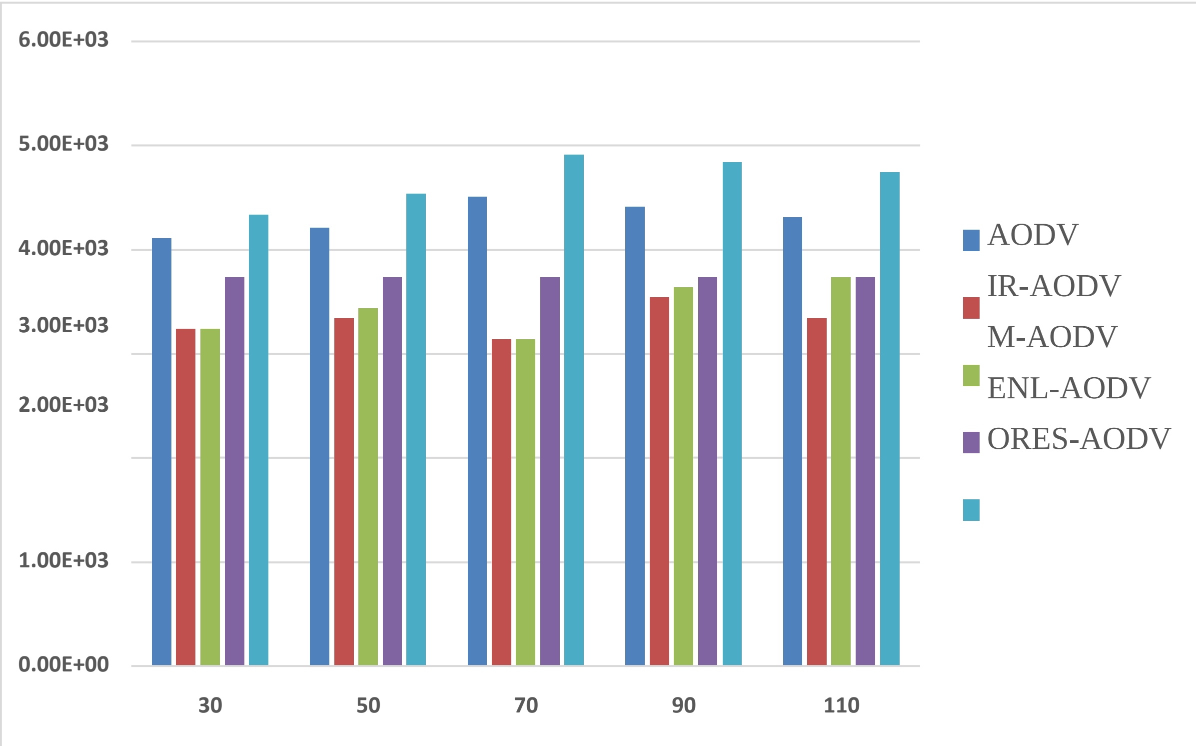

Fig 6.10: Average Throughput for AODV, IR-AODV, M-AODV, ENL-AODV, and ORES-AODV routing procedures with different node densities under Gauss Markov Mobility Model.

Average End-to-End Delay

A comparison in End-to-End Delay (s) for the Group Mobility Model's AODV, IR-AODV, M-AODV, ENL-AODV, and ORES-AODV routing protocols has been made. A scientific value format has been used to demonstrate the routing techniques' resulting Average End-to-End Delay for clarity—table 6.11 and Figure 6.11, respectively.

Table 6.12: Average End to End Delay for AODV, IR-AODV, M-AODV, ENL-AODV, and ORES-AODV with different densities in Gauss Markov Mobility Model

Average End-to-End Delay					
	Number of Nodes				
Routing Protocols	**30**	**50**	**70**	**90**	**110**
ADV	4.11E+03	4.21E+03	4.51E+03	4.41E+03	4.31E+03
IR-ADV	3.24E+03	3.34E+03	3.14E+03	3.54E+03	3.34E+03
M-AODV	3.24E+03	3.44E+03	3.14E+03	3.64E+03	3.74E+03
ENL-AODV	3.74E+03	3.74E+03	3.74E+03	3.74E+03	3.74E+03
ORES-AODV	4.34E+03	4.54E+03	4.91E+03	4.84E+03	4.74E+03

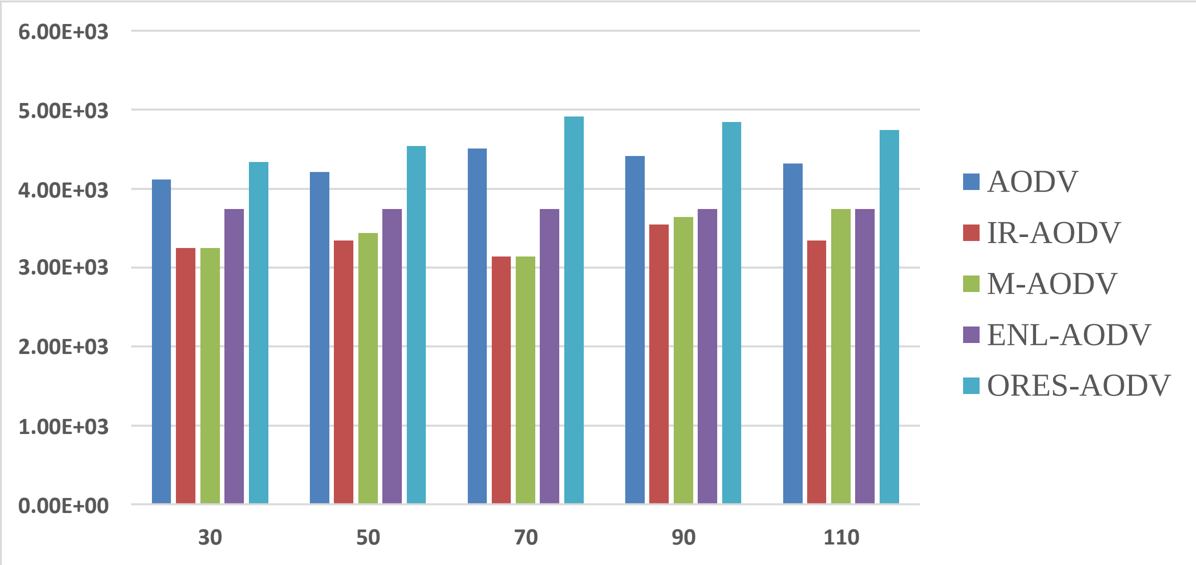

Fig 6.11: Average End to End Delay for AODV, IR-AODV, M-AODV, ENL-AODV, and ORES-AODV with different node densities under Gauss Markov Mobility Model.

In contrast to AODV, IR-AODV, M- AODV, ENL-AODV, and ORES-AODV routing protocols, IR-AODV routing protocols have demonstrated high performance with practically the same Average End to End (s) for varied network situations. As the node count increases, the AODV routing protocol's performance improves. Unlike the 90-node scenario,ENL-AODV protocols have likewise demonstrated a rise in Average End to End Delay for simulations with varied node densities from low to high.

Average Jitter (s)

This article compares Jitter (s) performance in Group Mobility Model under various node densities for the routing protocols AODV, IR-AODV, M-AODV, ENL-AODV, and ORES-AODV. To easily understand, the Jitter resulting routing protocols has been shown in exponent form. Average Jitter data are displayed graphically in Figure 6.12 and Table 6.12, respectively.

Table 6.13: Average Jitter for AODV, IR-AODV, M-AODV, ENL-AODV, and ORES-AODV routing procedures with different node densities in Gauss Markov Mobility Model.

Average Jitter					
	Number of Nodes				
Routing Protocols	**30**	**50**	**70**	**90**	**110**
ADV	4.11E+03	4.21E+03	4.51E+03	4.41E+03	4.31E+03
IR-ADV	3.24E+03	3.34E+03	3.14E+03	3.54E+03	3.34E+03
M-AODV	3.24E+03	3.44E+03	3.14E+03	3.64E+03	3.74E+03
ENL-AODV	3.74E+03	3.74E+03	3.74E+03	3.74E+03	3.74E+03
ORES-AODV	4.34E+03	4.54E+03	4.91E+03	4.84E+03	4.74E+03

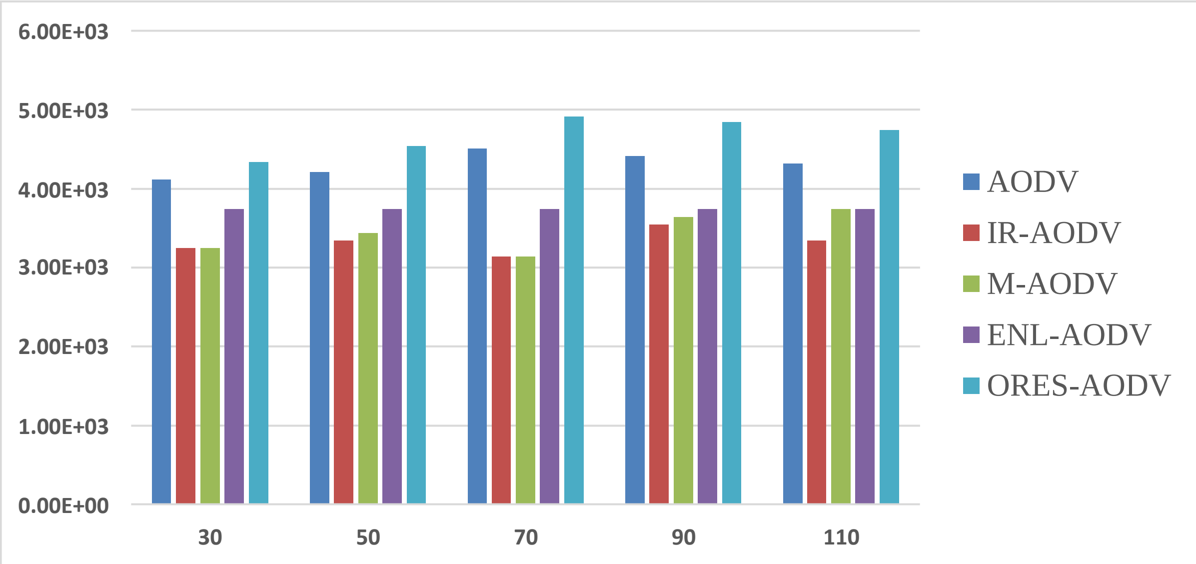

Fig 6.12: Average Jitter for AODV, IR-AODV, M-AODV, ENL-AODV, and ORES-AODV with different node densities under Gauss Markov Mobility Model.

The IR-AODV routing protocols have the worst results compared to other routing protocols. ENL-AODV has displayed poor and rising Jitter with more node density in many simulated network settings. The earlier research also supports it. In contrast, ORES-AODV has the best overall performance compared to its rivals [154]. Additionally, M-AODV routing methods have demonstrated that Average Jitter remains constant regardless of node density. In network scenarios, the number of nodes has expanded along with the performance of the AODV routing protocol. The AODV routing system has also worked admirably in settings with various node densities.

6.5 Mobility models' effects on energy usage in protocols using the basic energy model

This section looks at the energy usage in MANET routing protocols. This study used varied node densities and varying mobility speeds to evaluate energy usage in MANET routing protocols.

Energy usage in receival

The simulation findings for energy used in Receive Mode showed that the ENL-AODV routing protocol consumed a significant amount of energy in each simulation scenario and that energy consumption rose as the number of nodes in the MANET increased. Concerning mobility speed, there have been certain variations in energy usage. In Table 6.20 and Fig. 6.20, all simulation results are displayed. With the increase in node density following ENL-AODV.

Table 6.14: Energy Consumption in Manet Routing Protocols Using Basic Energy Model For AODV, IR-AODV, M-AODV, ENL-AODV, And ORES-AODV.

No. of Nodes	Mobility Speed (m/s)	AODV	IR-AODV	ENL-AODV	M-AODV	ORES-AODV
30	0-10	2.270E-02	3.460E-02	1.850E-02	8.07E-02	8.9400E-02
	10-20	1.590E-02	2.180E-02	1.760E-02	8.03E-02	8.0600E-02
	20-30	1.630E-02	3.210E-02	1.720E-02	7.89E-02	8.8100E-02
	30-40	2.040E-02	3.030E-02	1.710E-02	7.74E-02	7.8100E-02
	40-50	1.810E-02	3.400E-02	1.710E-02	8.52E-02	8.9900E-02
40	0-10	2.270E-02	3.460E-02	1.850E-02	8.07E-02	8.9900E-02
	10-20	1.590E-02	2.180E-02	1.760E-02	8.03E-02	8.9900E-02
	20-30	1.630E-02	3.210E-02	1.720E-02	7.89E-02	8.9900E-02
	30-40	2.040E-02	3.030E-02	1.710E-02	7.74E-02	8.9900E-02
	40-50	1.810E-02	3.400E-02	1.710E-02	8.52E-02	8.9900E-02
50	0-10	2.270E-02	3.460E-02	1.850E-02	8.07E-02	8.9900E-02
	10-20	1.590E-02	2.180E-02	1.760E-02	8.03E-02	8.9900E-02
	20-30	1.630E-02	3.210E-02	1.720E-02	7.89E-02	8.9900E-02
	30-40	2.040E-02	3.030E-02	1.710E-02	7.74E-02	8.9900E-02
	40-50	1.810E-02	3.400E-02	1.710E-02	8.52E-02	8.9900E-02
60	0-10	2.270E-02	3.460E-02	1.850E-02	8.07E-02	8.9900E-02
	10-20	1.590E-02	2.180E-02	1.760E-02	8.03E-02	8.9900E-02
	20-30	1.630E-02	3.210E-02	1.720E-02	7.89E-02	8.9900E-02
	30-40	2.040E-02	3.030E-02	1.710E-02	7.74E-02	8.9900E-02
	40-50	1.810E-02	3.400E-02	1.710E-02	8.52E-02	8.9900E-02
70	0-10	2.270E-02	3.460E-02	1.850E-02	8.07E-02	8.9900E-02
	10-20	1.590E-02	2.180E-02	1.760E-02	8.03E-02	8.9900E-02
	20-30	1.630E-02	3.210E-02	1.720E-02	7.89E-02	8.9900E-02
	30-40	2.040E-02	3.030E-02	1.710E-02	7.74E-02	8.9900E-02
	40-50	1.810E-02	3.400E-02	1.710E-02	8.52E-02	8.9900E-02

OLSR and Bellman-Ford have both consumed more energy. But compared to proactive routing protocols like OLSR and Bellman-Ford, reactive protocols like AODV, IR-AODV, and M-AODV used less power. Less energy is consumed when node density rises.

Regarding the least energy consumed in Receive Mode, ORES-AODV routing protocols have excelled over all others. Additionally, in instances with dense networks, it has used less power. Further, a scientific study backs it up.

However, the AODV routing protocol has also demonstrated an increase in energy consumption in Receive Mode for scenarios including 60,90, and 110 nodes.

Simulation of AODV, IR-AODV, M- AODV, ENL-AODV, and ORES-AODV Routing Protocols with Varying Node Density and Mobility Speed under Random Waypoint Mobility.

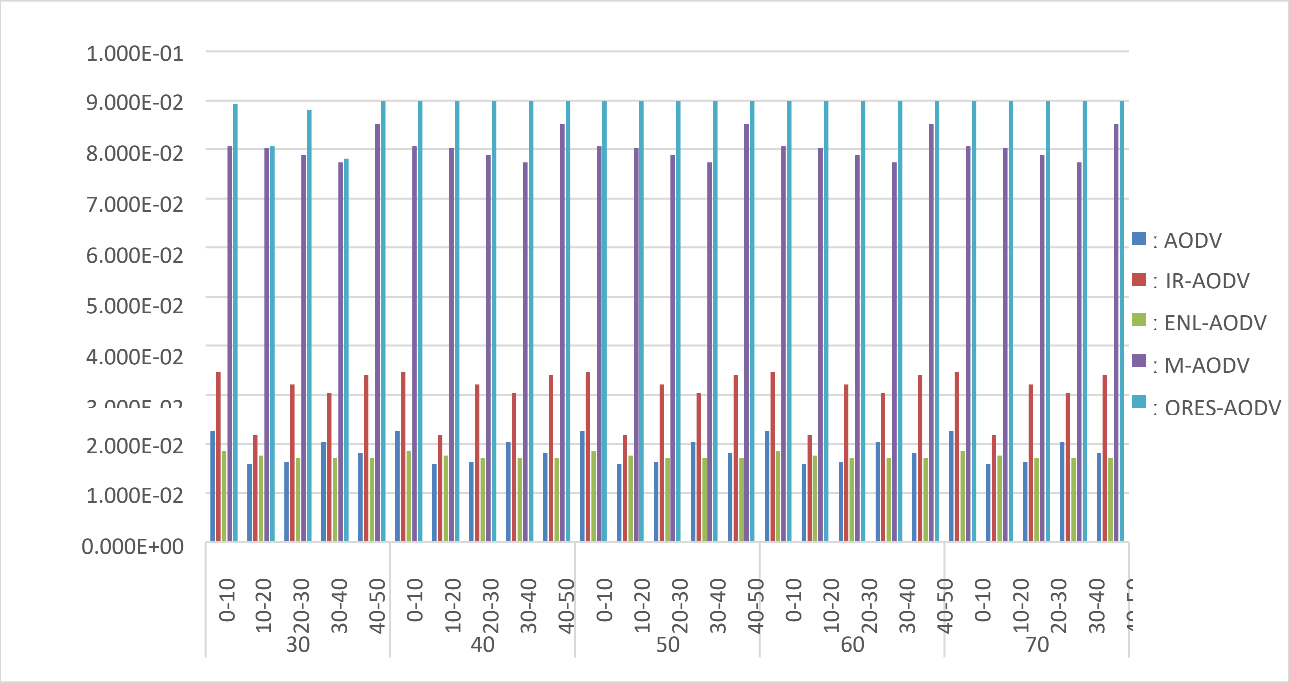

Fig 6.13: Energy Consumption In ManetRouting Protocols Using Basic Energy Model For AODV, IR-AODV, M-AODV, ENL-AODV, And ORES-AODV.

Energy usage in transmission in the simulation findings for energy used in transmission showed that the ENL-AODV routing protocol consumed a significant amount of energy in each simulation scenario and that energyconsumption rose as the number of nodes in the MANET increased.

Concerning mobility speed, there have been certain variations in energy usage. In Table 6.20 and Fig. 6.20, all simulation results are displayed.

With the increase in node density following ENL-AODV. All simulation results have been shown in Table 6.22 and Fig. 6.22.

AODV and IR-AODV have both consumed more energy., AODV, ENL-AODV, and M-AODV used less power. Less energy is consumed when node density rises.

Regarding the least energy consumed in Receive Mode, ORES-AODV routing protocols have excelled over all others. Additionally, in instances with dense networks, it has used less power. Further, a scientific study backs it up.

However, the AODV routing protocol has also demonstrated an increase in energy consumption in Receive Mode for scenarios including 60,90, and 110 nodes.

6.6 Analysis of WSN protocols using evaluation methods

The study WSN protocols chosen in this research work are LEACH and MECA, and the proposed protocol is Multi-MECA.

The three protocols are evaluated for the performance metrics number of aliveand dead nodes, the Packets sent to the Base station, and Energy Consumption.

Table 6.15: Energy Consumption In ManetRouting Protocols Using Basic Energy Model For AODV, IR-AODV, M-AODV, ENL-AODV, And ORES-AODV.

No. of Nodes	Mobility Speed (m/s)	AODV	IR-AODV	ENL-AODV	M-AODV	ORES-AODV
30	0-10	6.510E-04	6.510E-04	6.510E-04	6.510E-04	6.980E-04
	10-20	6.710E-04	1.350E-03	6.310E-04	2.920E-03	6.00E-03
	20-30	6.870E-04	9.960E-04	5.340E-04	2.870E-03	9.79E-03
	30-40	1.010E-03	1.430E-03	5.230E-04	3.190E-03	9.97E-03
	40-50	6.290E-04	1.890E-03	5.250E-04	3.870E-03	9.88E-03
40	0-10	3.150E-04	7.390E-04	5.050E-04	3.300E-03	5.99E-03
	10-20	3.160E-04	7.250E-04	6.280E-04	3.290E-03	9.36E-03
	20-30	3.830E-04	6.870E-04	4.550E-04	3.280E-03	9.36E-03
	30-40	3.690E-04	6.690E-04	4.900E-04	3.250E-03	9.38E-03
	40-50	3.690E-04	5.620E-04	3.890E-04	3.320E-03	9.39E-03
50	0-10	2.180E-04	5.140E-04	4.090E-04	3.940E-03	9.30E-03
	10-20	3.170E-04	6.650E-04	3.720E-04	3.920E-03	9.25E-03
	20-30	3.120E-04	8.830E-04	4.030E-04	3.860E-03	9.30E-03
	30-40	3.270E-04	8.410E-04	3.330E-04	3.880E-03	9.30E-03
	40-50	3.630E-04	8.700E-04	3.190E-04	3.870E-03	9.29E-03
60	0-10	2.510E-04	5.930E-04	4.410E-04	4.670E-03	9.04E-03
	10-20	1.720E-04	4.470E-04	4.280E-04	4.620E-03	9.00E-03
	20-30	2.050E-04	5.190E-04	4.090E-04	4.600E-03	9.11E-03
	30-40	2.110E-04	5.820E-04	3.180E-04	4.750E-03	9.01E-03
	40-50	2.130E-04	5.630E-04	2.580E-04	4.660E-03	9.12E-03
70	0-10	1.390E-04	3.510E-04	4.170E-04	5.760E-03	9.02E-03
	10-20	1.420E-04	3.190E-04	3.790E-04	6.100E-03	9.99E-03
	20-30	1.440E-04	3.120E-04	3.230E-04	5.740E-03	9.04E-03
	30-40	1.420E-04	3.840E-04	2.750E-04	5.890E-03	9.08E-03
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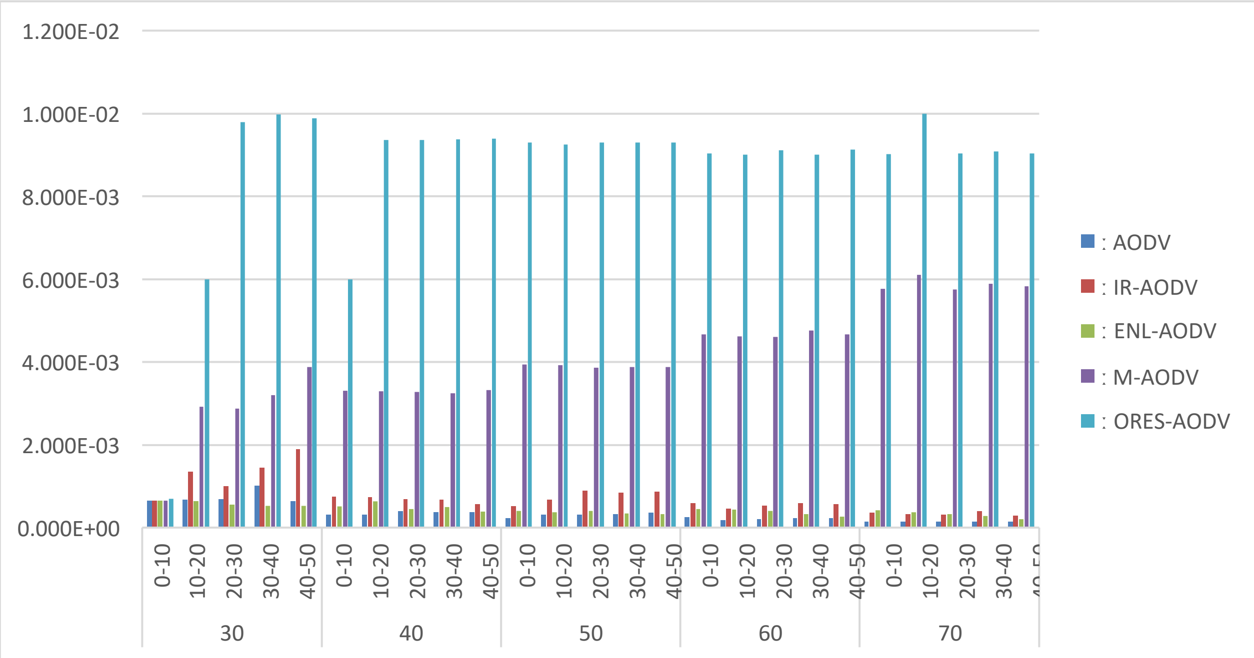

Fig 6.14: Energy Consumption In ManetRouting Protocols Using Basic Energy Model For AODV, IR-AODV, M-AODV, ENL-AODV, And ORES-AODV.

Table 6.16: Alive Nodes in WSN

Alive Nodes					
	Number of Nodes				
Routing Protocols	**100**	**150**	**250**	**350**	**500**
LEACH	74	121	221	256	423
MECA	86	135	237	321	452
Multi-MECA	95	142	245	345	489

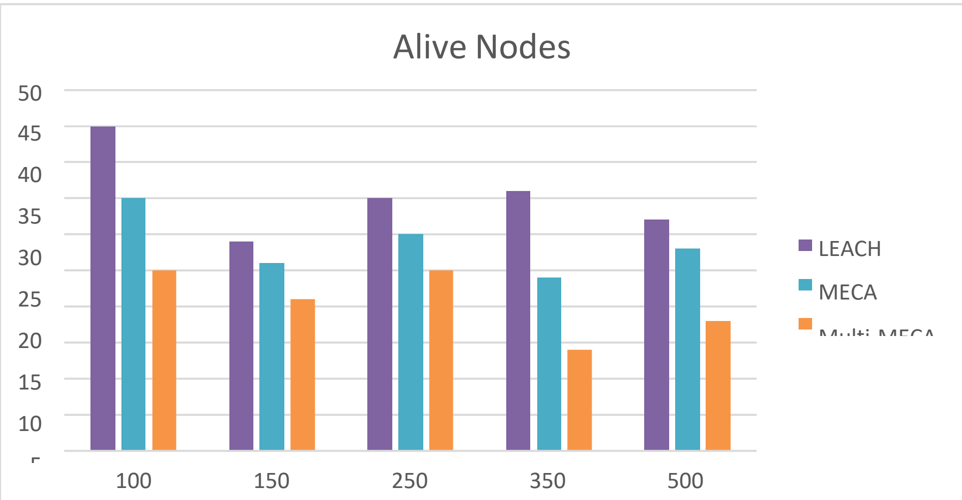

Fig 6.15: Alive nodes

The alive node count in LEACH is comparatively less, and in MECA [155], the number of alive nodesincreases after each round. The multi-MECA protocol has more active nodes compared to LEACH and MECA.

Table 6.17: Dead Nodes in WSN

Dead Nodes					
	Number of Nodes				
Routing Protocols	**100**	**150**	**250**	**350**	**500**
LEACH	26	29	29	94	77
MECA	14	15	13	24	48
Multi-MECA	5	8	5	5	11

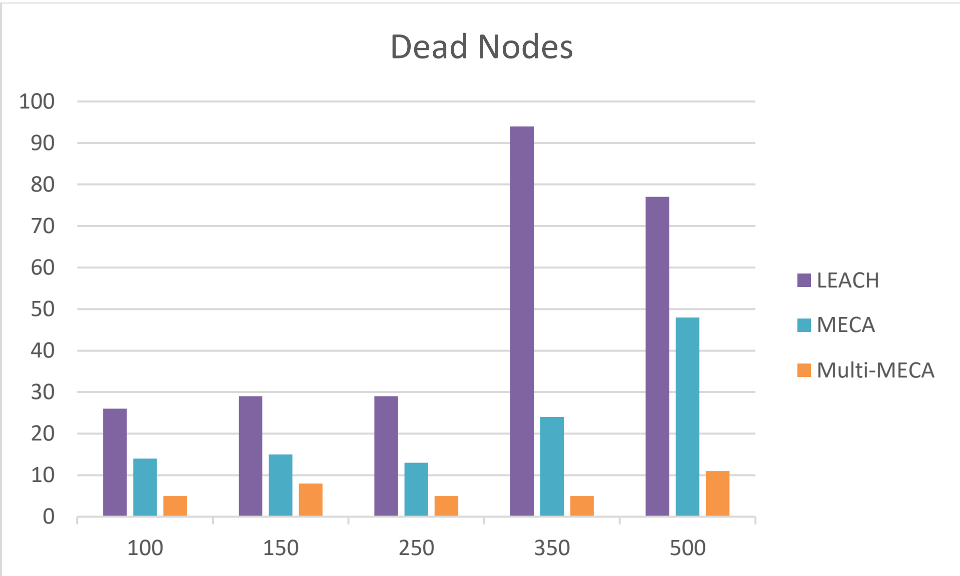

Fig 6.16: Dead nodes

Increases when the number of nodes increases after each round. The multi-MECA protocol has asmaller number of dead nodes compared to LEACH and MECA.

Table 6.18: Energy Consumption in WSN

Energy Consumption					
	Number of Nodes				
Routing Protocols	**100**	**150**	**250**	**350**	**500**
LEACH	45	29	35	36	32
MECA	35	26	30	24	28
Multi-MECA	25	21	25	14	18

The energy consumption evaluation of WSN is based on current and remaining energy parameters [156]. In LEACH, energy consumption is comparatively more; in MECA, when the number of nodes increases, energy consumed is more. The multi-MECA protocol consumes less power than LEACH and MECA due to the network architecture and efficiency of the algorithm.

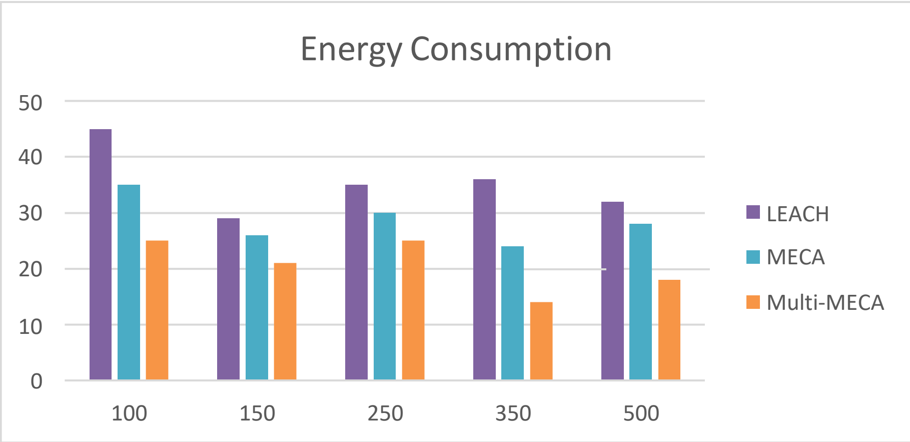

Fig 6.17: Energy Consumption

6.7 Chapter Summary

In this chapter, the Mobile Ad Hoc network protocols are analyzed against parameters such as node mobility, speed, and density of nodes in the network. Initially, the network is analyzed for its efficiency by evaluating the varying number of nodes and density. In the next section, mobility models and finally, energy models are considered with varying numbers of nodes. In WSN, the evaluation is performed to know the number of alive and dead nodes among three protocols LEACH, MECA, and Multi-MECA. Also, the energy consumption evaluation is performed among three protocols LEACH, MECA, and M-MECA, and Multi-MECA is evaluated as more efficient.

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CHAPTER SEVEN

SUMMARY, CONCLUSION, AND FUTURE SCOPE

Contents	Page No.

7.1 Summary

The summary of the suggested work and its potential for future enrichment are highlighted in this chapter. An intriguing study field that has expanded recently is energy-efficient routing in MANETs.

Ad Hoc networks have a lot of challenges because the environment, security, and lifespan of the network are constantly changing.

A routing protocol is used to choose the most appropriate route fortransferring data from a source node to the sink in this ever-changing environment.

Since power is scarce in mobile ad hoc networks, one of the main concerns is sending this data on a head node that uses less energy.

Therefore, to make our communication energy efficient, we must select a routing protocol that treatsenergy as a crucial parameter. Due to its potential usage in both the public and military spheres, ad hoc networks have seen significant growth in recent years.

Among the uses are tactical battlefield communications where the adversary, Because of the surrounding network, law enforcement operations, disaster recovery scenarios, major athletic events, or conferences, a protocol cannot employ a fixed backbone. Other instances include disaster recovery situations, police enforcement activities, and mobile computing in regions without access to other infrastructure.

A group of mobile nodes gets together to form an ad hoc network. These mobile nodes are all powered by finite energy batteries, and it is typically not practical to replenish or replace the batterieswhile the devices are in use. When the two mobile nodes are sufficiently close, the message can be transmitted in a single-hop transmission instead of being relayed through intermediary mobile nodes in a multi-hop transmission.

The network's performance is severely constrained by the limited battery lifetime because wireless communications use a substantial amount of battery power. Enhancing energy-efficient operations is crucial to extending network lifetime.

7.2 Conclusion

There have been numerous investigations and research on energy efficiency in wireless ad hocnetworks. This thesis proposes a novel routing method in MANET and cluster building for WSN.

Theproposed protocol is developed based on the remaining energy and threshold value of the node in the network to select the path in MANET. And a multi sink with mobility by considering the threshold value of the node for the selection of cluster head in WSN.

The simulation results show that compared to the present energy-efficient clustering methodologies, the proposed protocols use less energy. Because the suggested protocol approach has a lower delay value than the present energy-efficient strategy, the simulation results also demonstrate that it has a greater throughput and packet delivery ratio than the current energy-efficient strategy.

We've talked about the advantages and disadvantages of many types of ad hoc networks, including mesh networks, wireless sensor networks, and mobile ad hoc networks. The difficulties with Ad Hoc networks and the issue with exposed and hidden terminals were then covered.

Ad Hoc network vulnerabilities are also mentioned. The various vulnerabilities that Ad Hoc networks encounter are described. The description of several Ad Hoc Networks protocols follows the discussion. The characteristics of the Ad Hoc Network protocol are described. The fundamental ideas of ad hoc networking are covered in the section that follows. The next section discusses the use of ad hoc networks in military LAN, WAN, PAN, MANET, and WSN as well as the application areas for them.

Mobile Ad Hoc Network is a specific application area for ad hoc networks that is covered in depth. The issues with mobile ad hoc networks after MANET are thoroughly discussed. The vulnerabilities of mobile ad hoc networks and mobile ad hoc networking protocols are covered in the study that follows.

Proactive routing protocols are addressed using the MANET protocol DSDV as an illustration. Also mentioned as examples of reactive routing protocols are DSR and AODV. Also covered in detail is a hybrid routing protocol.

The features and difficulties of WSN, another application area of the Ad Hoc network, are covered in detail in this study. In order to comprehend the fundamental vulnerabilities encountered by Ad Hoc Network, vulnerabilities in the Ad Hoc network are explored in this work. The discussion of WSN protocols is covered in the following section. Additionally, the discussion includes performance indicators for evaluating energy efficiency as well as energy management in MANET and WSN.

Several fundamental theories about Ad Hoc Networks, their applications, MANET protocols, energy evaluation by various protocols, wireless sensor technologies, and WSN protocols were also covered. The chapter following this one, titled Review of Literature, covers the in-depth theories and research contributions made by other academics to the various phases stated in this research framework, such as Energy Efficient Routing protocols, energy-efficient routing protocols based on AODV protocols, energy efficient protocols for WSN, Cluster based WSN protocols, and mobile sink-based protocols.

We also talked about routing protocols for ad hoc networks that are energy efficient. First, there is an issue with Energy Efficient Protocol for Mobile Ad Hoc Network.

The AODV protocol is the foundation for the described protocols. The limitations of the AODV protocol are covered in the section that follows. Additionally, advanced AODV-based protocols including M-AODV, IR-AODV, ENL-AODV, and the proposed ORES-AODV protocol are explored. The discussion of WSN energy-efficient protocols, which are based on the LEACH protocol, is presented in the proposed study.

The MECA protocol, a variation of the LEACH protocol, and the recently suggested multi-MECA protocol are both covered in the study.

We have also talked about the protocols utilised for the MANET simulation and the WSN simulation. The Performance Evaluation, AODV protocol, and Comparison of AODV with Other MANET Protocols are covered in the work.

Additional AODV Performance Evaluation using Simulation Metrics is a concern. Discussion also includes ORES-performance AODV's evaluation using simulation metrics.

To conduct additional analysis, the comparative evaluation of AODV and ORES-AODV with simulation metrics is covered in the study.

Comparative analysis of ORES-AODV and other top AODV-based protocols, Energy evaluation of ORES-AODV and other leading AODV-based protocols, Simulation for ORES-AODV, Simulation for WSN, and Simulation metrics are all examined in detail.

Node mobility, network speed, and node density are some of the criteria used to evaluate the Mobile Ad Hoc network protocols. The network's efficiency is initially assessed by looking at its variable node density and number.

With varying numbers of nodes, mobility models and, lastly, energy models, are discussed in the study.

Three protocols—LEACH, MECA, and Multi-MECA—are evaluated in WSN to determine the proportion of live and dead nodes. Three protocols—LEACH, MECA, and M-MECA—are also tested for their energy usage, with Multi-MECA being found to be more effective.

By creating a better protocol, the suggested study focuses on minimizing energy-related problems. The AODV protocol is thoroughly examined in the proposed work because, following a thorough examination of the protocol, many researchers have come to see AODV as a popular energy-efficient protocol.

The AODV protocol has some flaws, which have been addressed in the proposed study along with corrective measures to address them.

The low-energy node identification technique is built into the proposed algorithm ORES-AODV. To propagate data packets, the suggested method selects the path with the most energy in its participating nodes. The hop count, which is discounted from source to destination, is the only factor considered when choosing a path.

The least number of hops are on the shortest path. However, if the parameter for path selection is merely the minimal hop count, the participating node may have low energy, which results in network link breaking.

As a result, the proposed protocol has created a cost metric to prevent further path connection breaking. There are two types of cost metrics used by the ORES-AODV protocol. The best path and the most energy-efficient path are determined using both cost measures. A path with residual energy that is always greater than the one with the least residual energy is discovered via the first cost metric.

A naturalistic movement method is used by the Multiple Mobile-Sinks-Based Energy-Efficient Clustering Algorithm (Multi-MECA). Triangle forms have a variety of uses in networks due to their benefits. The advantages of selecting two symmetrical triangles inside a circle are listed below.

Closely spaced symmetrical triangles contain fewer free spaces than other designs. Since it covers a larger area per perimeter, this method can cover more sensor nodes than earlier iterations.

The proposed system is composed of three stages: sink halting stations, energy-efficient hierarchical routing, and initial sink placement and movement strategy. Using a variety of accessible communication routes, sensing nodes can send data as cheaply as possible to the closest mobile sink.

In situations where the deployment of network topology formation doesn't require any planning, the ad hoc network is created.

Where the radio range of cellular network service providers is not available, we may rapidly establish a network in any hostile situation.

The topology of the network is built in real-time and is useful in a number of situations when nodes are moving about and need to connect with other nodes right away.

As a result, in addition to the battery issue, the unpredictable node movement from one site to another is another difficulty that the ad hoc protocol faces.

The behaviour of the nodes' mobility in an ad hoc network will depend on the mobility models that are employed. The Gauss Markov Mobility Model and the Random Way Point Mobility Model are the two separate mobility models employed in the network scenarios. The movement of the network nodes is arbitrary and unpredictable. In the Random Way Point Mobility Model and the Gauss Markov Mobility Model, the suggested protocol ORES-AODV is contrasted. The position, velocity, and acceleration of a node's movement within the network will all be described by the mobility model.

The mobility model is divided into two types: the first is an indoor mobility model, and the second is an outdoor mobility model. It does a random walk. In the Indoor Mobility Model, a scenario in which nodes move around indoors at random is selected. The three types of mobility identified by this approach are random walk, random waypoint, and random direction. Consider, for instance, two people walking and moving around a room while each is holding a cell phone.

In this case, participating node 1 may travel to participating node 2's location, and vice versa. The mobile node moves from its present site to its new one in the indoor mobility model by randomly choosing the direction and speed.

The Random Waypoint Mobility Model is the second division of the indoor mobility model. The Random Waypoint Mobility Model halts the transition between changes in speed and direction, which is how it differs from the Random Mobility Model. Before moving on, Mobile Node remains for a predetermined amount of time.

This protocol was proposed for modelling the movement of personal computers in the Gauss Markov mobility model for outdoor mobility. The Gauss Markov mobility model provides a number of advantages, including simple random mobility adaptation. The Gauss Markov mobility model assigns the nodes based on their current direction and speed. There is no starting point because the mobility is outdoor, and the simulation area is boundless. It moves in a random direction.

The Random Walk Mobility Model in Probabilistic Form is another technique used in the outdoor mobility model. In this mobility model, a probability matrix is utilised to determine a certain Mobile Node's position in the following phase. In the probabilistic matrix, states 0 and 1 represent the mobile node's current and past locations, respectively, while states 0 and 2 represent the node's upcoming position.

Another ad hoc network that collects data from sensor nodes spread over the network is the wireless sensor network. When speedy adaptation is required in a hostile environment, the wireless sensor network is also appropriate.

The suggested protocol emphasizes the advantages of having numerous sink nodes for data collection to get around problems like sinkholes and the techniques for constructing cluster heads to stay away from hot areas close to the base station.

The suggested protocol establishes a fictitious star cell where two mobile sinks move to lessen the communication overhead and energy hotspot close to the sink inside a circle made of two symmetrical equilateral triangles.

The Wireless Sensor Network routes data from one sensor device to another using an energy-efficient routing algorithm.

The protocols used to create the network must apply strategies to avoid energy dissipation because the network has nodes with limited battery power that are equipped with batteries.
LEACH is one of the most reliable protocols, and in this study, its variations are compared for energy efficiency to a modified procedure called Multi-MECA. A suggested protocol called Multi-MECA has been examined for effectiveness using the LEACH and MECA routing protocols.

The proposed research will be based on the LEACH protocol, which is a hierarchical cross-layer protocol and has a number of flaws.

The key issue with the standard LEACH strategy and the incorrect selection procedure is that it selects Custer Head without taking the position of the base station and the available energy into account.

The cluster head is chosen for the desired study using residual energy and a threshold value. The movement of a node is watched when its mobility is active. Route discovery and maintenance are initiated since every node in the network is aware of the movements of its neighbors.

Once the route has been created using the route discovery method, which determines the shortest path between the source and the destination, the packets are transmitted. When the source node transmits packets without knowing its route, the process for learning routes is utilized to finish the job.

With the use of a movable sink node at the detecting location, the MECA employs an energy balancing mechanism. The MECA assigns a sink node with a predetermined nature and a defined movement track.

The network is divided into equal portions, and cluster heads are chosen for each one. Cluster heads compile data and eventually transmit it to a moving sink node. Cluster heads send information to the mobile sink node when it gets to the rendezvous location.

The MECA algorithm provides a number of benefits, including the ability of the protocol to handle heavy traffic loads thanks to its data aggregation function.

The LEACH protocol randomly chooses cluster heads, whereas the MECA protocol can appoint cluster heads more consistently.

Another benefit of the MECA protocol is that the sink node handles communication instead of the sensor nodes when using it. The ability of sink nodes to communicate will allow the network lifetime to be increased.

The sensor nodes within a cluster may communicate data directly with the cluster head thanks to a number of clustering algorithms, including LEACH. Some sensor nodes may use a lot of energy during long-distance transmission due of the location's inflection. We created a multi-hop intra-cluster routing protocol as a result.

The MECA protocol, which has been modified from the LEACH protocol, is the foundation of the Modified Mobile-Sink-based Energy-efficient Clustering Algorithm (Multi-MECA). This study effort suggests the Modified MECA protocol multi-MECA, which distributes the network's energy load among a number of sink nodes.

The Multi-MECA protocol uses multi-sink nodes that travel along a predetermined path in the opposite direction of one another. Other sensor nodes in the network can forecast the movement of sinks.

The two symmetrical triangles are what the Multi-MECA regards as its network region, which contains sensors. If the sensors outside the boundary are close to neighbours of the clusters inside the triangles, the sink node can also communicate with those sensors.

The first triangle's corner is where sink node 1 is situated, while the second triangle's corner is where sink node 2.

The central cluster head, designated by the Multi-MECA protocol, is placed in the centre of the two symmetric triangles. It is in charge of communicating control messages to the network's other clusters. The message is sent by the central cluster head. This comes from both sink nodes, sink node 1 and sink node 2, respectively.

The message provides the major cluster head threshold value, the central cluster head residual energy, and the beginning location of the sink node.

The main cluster head motivates the other cluster heads to take over as the cluster head as well. The node with the most excess energy is chosen as the cluster head after its residual energy and threshold are evaluated.

The node is excluded from comparison for a given period of time if its threshold value falls below a predetermined cutoff.

Other sensor nodes are prompted to become cluster heads by the core cluster head. Data propagation from a network sensor to sink nodes one and two is the responsibility of the chosen cluster heads.

When cluster heads arrive at rendezvous sites, they can send data to any sink node. The distance formula and the sink nodes' initial locations can be used to determine where they are.

The research employs simulation tools, such as NS3 simulator for mobile ad hoc networks and MATLABR2021a for wireless sensor networks, to get the results from the suggested methodologies. The network simulators assist in comparing and analysing the various network protocols.

To examine the outcome, the study makes use of many performance measures and graphs. The base and modified procedures are the initial subjects of the simulation analysis. In-depth comparisons are made between the energy-efficient procedures.

The AODV protocol, which is well renowned for being energy-efficient, is utilized in the Mobile Ad Hoc network. With the aid of a simulation tool, research is being done to comprehend the behaviour of the AODV protocol. The AODV protocol is compared with various numbers of nodes using the simulation programme NS3 in the analysis.

Performance indicators are initially examined for fewer nodes and for a simulation with progressively more nodes. Following the evaluation of the AODV protocol, the protocol is examined using protocols that have been updated and shown to be more effective than the

AODV protocol by researchers. ENL-AODV, M-AODV, and other protocols are those that are compared to the AODV protocol.

The outcomes of analysing the NS3 protocols are plotted on graphs and then examined to have a thorough understanding of the NS3 procedures. The second step involves developing and accessing a modified procedure for the proposed work.

The suggested protocol ORES-AODV is then compared to the AODV protocol using the NS3 simulator, and it is found to be more effective. ORES-AODV is compared to AODV, as well as other modified protocols like ENL-AODV and M-AODV. Additionally, the ORES-AODV is assessed in various mobility models to examine its energy efficiency in these scenarios, including the Constant Mobility Model, the Gauss Markov Mobility Model, and the Random Way Point Mobility Model.

When it comes to wireless sensor networks, NS3 and MATLAB is used to assess the protocols that are thought to be the most energy-efficient, such LEACH. In this study, a modified M-MECA procedure is suggested, and the efficacy of MECA and M-MECA are contrasted.

The protocol chosen for the proposed research project is a reactive protocol. It is then demonstrated that the AODV protocol is effective by comparison to other well-known protocols as OLSR, DSDV, and DSR. The AODV protocol is then altered to become the ORES-AODV protocol, and it is evaluated in NS3 with regard to a number of factors, including energy consumption, end-to-end delay, throughput, and packet loss ratio, which are all calculated using an NS3 simulator.

ENL-AODV and M-AODV are the protocols that were compared to AODV and ORES-AODV. To address the issue of energy evaluation, the ORES-AODV uses certain additional factors, including residual energy and threshold.

The NS3 and MATLAB simulation tool is used to evaluate the energy-efficient LEACH methodology. The LEACH version MECA is tested for energy efficiency using the MATLAB simulator. To address the problem of energy depletion, a modified protocol dubbed Multi-MECA is suggested.

For the simulation used in this study, various situations are included, and conclusions are drawn. The Mobile Ad Hoc Network simulation run on NS3 examines the network's performance under various protocols and with various mobility models to determine the impact on the network's energy consumption. Tables and graphs are used for the analysis of the outcomes of various simulations.

The results demonstrate that all five routing protocols—AODV, IR-AODV, M-AODV, ENL-AODV, and ORES-AODV—exhibited better Average performance Average End-to-End Delay in the absence of node mobility. Results indicate that node mobility has a direct impact on the End-to-End Delay in routing methods. Additionally, earlier studies have found this.

The ENL-AODV routing system has the lowest End to End Delay, but the AODV routing protocol has the worst End to End Delay if nodes migrate.

The Random Waypoint mobility model is designed to examine how node movement impacts routing protocol energy consumption. For this investigation, AODV, IR-AODV, M-AODV, ENL-AODV, and ORES-AODV have been chosen. Fifty nodes were examined and put through simulations with and without node mobility.

Additionally, earlier studies have found this. The IR-AODV and ENL-AODV routing protocols consume more energy in mobile and stationary settings as compared to ORES-AODV and other routing protocols. When nodes are mobile and stationary, the ORES-AODV routing protocol consumes the least energy when compared to IR-AODV and ENL-AODV.

7.3 FUTURE SCOPE

Network Simulator 3 is used to simulate the planned MANET ORES-AODV protocol. This protocolyields superior outcomes when considering higher quality factors like reduced delay, a higher packetdelivery ratio, less energy consumption, a longer network lifespan, a higher throughput, and a more stable link. However, the outcomes may differ in real-time application due to environmental and physical limitations. Future studies may therefore go in this approach. MATLAB is used to simulatethe proposed Multi-MECA for WSN protocol. This protocol yields superior outcomes in terms of higher quality, including fewer dead nodes, more alive nodes, less energy consumption, an extended network ifespan, enhanced Throughput, and more packets sent to the cluster head and base station. However, real-time execution may produce different outcomes due to environmental and physical restrictions. Therefore, more studies might go in this direction. The ORES-AODV protocol can be further improved to create clusters. The additional features can be added to ORES-AODV to choose optimal path from source to destination by choosing a appropriate cluster head for the created clusters in a network. Multi-MECA protocol can further improved by adding features such as, adding more advanced synchronization techniques to the Mobile Sink.

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Annexure 1: Sample Source code of Implementation in MATLAB 2021a

Source code for Multi-MECA

```
figure;axis square;
xm=5;
ym=5;
n=100;

%Optimal Election Probability of a node
%to become cluster head
p=0.1;

%Energy Model (all values in Joules)
%Initial Energy
Eo=0.5;
%Eelec=Etx=Erx
ETX=50*0.000000001;
ERX=50*0.000000001;
%Transmit Amplifier types
Efs=10*0.000000000001;
Emp=0.0013*0.000000000001;
%Data Aggregation Energy
EDA=5*0.000000001;
t=1:0.5:10;
%Values for Hetereogeneity
%Percentage of nodes than are advanced
m=0.1;
%\alpha
a=1;
 %maximum number of rounds
rmax=100

%%%% END OF PARAMETERS %%%%%%%%%%%%%%%%%%%%%%%%%%%%

%Computation of do
do=sqrt(Efs/Emp);

 for i=1:1:n
    S(i).xd=rand(1,1)*xm;
    XR(i)=S(i).xd;
    S(i).yd=rand(1,1)*ym;
    YR(i)=S(i).yd;
    S(i).G=0;
    %initially there are no cluster heads only nodes
    S(i).type='N';

    temp_rnd0=i;
    %Random Election of Normal Nodes
```

```
    if (temp_rnd0>=m*n+1)
        S(i).E=Eo;
        S(i).ENERGY=0;
        plot(S(i).xd,S(i).yd,'o');

        hold on;
    end
    %x and y Coordinates of the Center Cluster Head
    cnt1=2.45;
    cnt2=2.45;
     plot(cnt1,cnt2,'*','MarkerSize',20);

    %Random Election of Advanced Nodes
    if (temp_rnd0<m*n+1)
        S(i).E=Eo*(1+a)
        S(i).ENERGY=1;

        plot(S(i).xd,S(i).yd,'*');
        %axis([-25 25 -25 25]);
        hold on;
        end
end

 set(gca,'XLim',[0,5],'YLim',[0,5]);
  x1=[0 5 2.5 0];
y1=[4 4 0 4];
plot(x1,y1);
hold on;
x3=[0 2.5 5 0];
y3=[1 5 1 1];
plot(x3,y3);

for ii=1:5
SinkNode1=rectangle('Parent',gca,'Position',[5,5,1,1],'Curvature',[1,1]);
 startPos=[2.5,0];
endPos=[0,4];
 vel=0.3;

x_dis=endPos(1)-startPos(1);
y_dis=endPos(2)-startPos(2);
Dis=sqrt(x_dis^2+y_dis^2);

Ttime=Dis/vel;
x_v=vel*x_dis/Dis;
y_v=vel*y_dis/Dis;

t=1:0.5:Ttime;
X=startPos(1)+x_v*t;
Y=startPos(2)+y_v*t;
```

```
trajectory=[X;Y];

startPos1=[0,4];
endPos1=[5,4];

vel1=0.3;

x_dis1=endPos1(1)-startPos1(1);
y_dis1=endPos1(2)-startPos1(2);
Dis1=sqrt(x_dis1^2+y_dis1^2);

Ttime1=Dis1/vel1;
x_vl=vel1*x_dis1/Dis1;
y_vl=vel1*y_dis1/Dis1;

t1=1:0.5:Ttime1;
X1=startPos1(1)+x_vl*t1;
Y1=startPos1(2)+y_vl*t1;

trajectory1=[X1;Y1];


startPos2=[5,4];
endPos2=[2.5,0];

vel2=0.3;

x_dis2=endPos2(1)-startPos2(1);
y_dis2=endPos2(2)-startPos2(2);
Dis2=sqrt(x_dis2^2+y_dis2^2);

Ttime2=Dis2/vel2;
x_v2=vel2*x_dis2/Dis2;
y_v2=vel2*y_dis2/Dis2;

t2=1:0.5:Ttime2;
X2=startPos2(1)+x_v2*t2;
Y2=startPos2(2)+y_v2*t2;

trajectory2=[X2;Y2];

 for frameNo=1:length(t)
    set(SinkNode1,'Position',[trajectory(1,frameNo)-0.125,trajectory(2,frameNo)-
0.125,0.25,0.25]);
    frames(frameNo)=getframe;
end

hold off;
for frameNo=1:length(t1)
```

```
    set(SinkNode1,'Position',[trajectory1(1,frameNo)-0.125,trajectory1(2,frameNo)-
0.125,0.25,0.25]);
    frames(frameNo)=getframe;
end
for frameNo=1:length(t2)
    set(SinkNode1,'Position',[trajectory2(1,frameNo)-0.125,trajectory2(2,frameNo)-
0.125,0.25,0.25]);
    frames(frameNo)=getframe;
end
delete(SinkNode1);


SinkNode2=rectangle('Parent',gca,'Position',[5,5,1,1],'Curvature',[1,1]);

strtPos=[0,1];
edPos=[2.5,5];

vl=0.3;

x_ds=edPos(1)-strtPos(1);
y_ds=edPos(2)-strtPos(2);
Ds=sqrt(x_ds^2+y_ds^2);

Ttme=Ds/vl;
x_v=vl*x_ds/Ds;
y_v=vl*y_ds/Ds;

t1=1:0.5:Ttme;
Xi=strtPos(1)+x_v*t1;
Yi=strtPos(2)+y_v*t1;

trjectory=[Xi;Yi];


strtPos1=[2.5,5];
edPos1=[5,1];

vl=0.3;

x_ds1=edPos1(1)-strtPos1(1);
y_ds1=edPos1(2)-strtPos1(2);
Ds1=sqrt(x_ds1^2+y_ds1^2);

Ttme1=Ds1/vl;
x_vl=vl*x_ds1/Ds1;
y_vl=vl*y_ds1/Ds1;
```

```
t1=1:0.5:Ttme1;
Xi1=strtPos1(1)+x_vl*t1;
Yi1=strtPos1(2)+y_vl*t1;

trjectory1=[Xi1;Yi1];

 strtPos2=[5,1];
edPos2=[0,1];

v2=0.3;

x_ds2=edPos2(1)-strtPos2(1);
y_ds2=edPos2(2)-strtPos2(2);
Ds2=sqrt(x_ds2^2+y_ds2^2);

Ttme2=Ds2/v2;
x_v2=v2*x_ds2/Ds2;
y_v2=v2*y_ds2/Ds2;

t2=1:0.5:Ttme2;
Xi2=strtPos2(1)+x_v2*t2;
Yi2=strtPos2(2)+y_v2*t2;

trjectory2=[Xi2;Yi2];

for frameNo=1:length(t)
   set(SinkNode2,'Position',[trjectory(1,frameNo)-0.125,trjectory(2,frameNo)-
0.125,0.25,0.25]);
   frames(frameNo)=getframe;
end
for frameNo=1:length(t1)
   set(SinkNode2,'Position',[trjectory1(1,frameNo)-0.125,trjectory1(2,frameNo)-
0.125,0.25,0.25]);
   frames(frameNo)=getframe;
end
for frameNo=1:length(t2)
   set(SinkNode2,'Position',[trjectory2(1,frameNo)-0.125,trjectory2(2,frameNo)-
0.125,0.25,0.25]);
   frames(frameNo)=getframe;
end
delete(SinkNode2);
end
```

LIST OF PUBLICATIONS

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Mrs Soumya S. is belonging to Mangalore, India born on 18/02/1984. She received his MCA (3 years) degree in Computer Science from IGNOU University in 2011, M. Phil Degree in Computer Science from Bharathiar Universityin 2014. Presently she is doing her part time Ph.D. in the field of Ad Hoc Networking in Srinivas University, Mangalore, India. Since June 2011, she is working as a Lecturer in Computer Science. She is having 9 years of teaching experience in different computer science subjects for BCA and BSC courses.

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Mrs. Soumya S. has published 7 research papers in referred international journals and She has also presented 5 papers in conferences, out of which 2 were international conferences and remaining were national conferences.