An update based Energy Efficient Multipath Routing Protocol with Optimized Packet Forwarding for MANETs

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Abstract: The ad hoc mobile network (MANET) is a collection of wireless mobile nodes that dynamically form a temporary network without depending on any infrastructure or central administration. Energy consumption is considered one of the main limitations of MANET, as mobile nodes do not have a permanent power supply and must depend on batteries, which reduces the useful life of the network, since the batteries discharge very quickly while the nodes move and quickly change position in MANET. This research work highlights the energy consumption in MANET by applying the Optimized Packet Forwarding (OPF) technique to optimize the energy consumption in ad hoc on demand multipath distance vector (AOMDV) routing protocol. The OPF function is used to find the optimal path from source node to destination node to reduce the energy consumption in multipath routing during the transmission of packets. The proposed method adjust it transmission range when its energy get exhausted to its one third and pursue for another path for packet forwarding. It is shown that use of variable range transmission approach achieves lower transmission power levels compared to using common-range transmission approach. Thus, the new schemes based on variable-range transmission increase the traffic carrying capacity of wireless ad hoc network, and at the same time, reduce the overall transmission power consumption in the network. The performance of the proposed OPF_AOMDV protocol has been evaluated by using network simulator version 2, where the performance was compared with FF-AOMDV and AOMDV protocols, the two most popular protocols proposed in this area. The comparison was evaluated based on energy consumption, throughput, packet delivery ratio, end-to-end delay, network lifetime and network routing load performance metrics, varying the node speed, packet size, and simulation time. The results clearly demonstrate that the proposed OPF_AOMDV outperformed FF-AOMDV and AOMDV under majority of the network performance metrics and parameters. The simulative results according to Packet size shows that proposed OPF_AODV performed well and has 0.493 % of improvement in terms of energy consumption, 2.069 % of improvement in terms of throughput, 1.99 % of improvement in terms of packet delivery ratio, 9.41 % of improvement in terms of end to end delay and 2.727% of improvement in terms of network routing load compared to existing FF-AOMDV protocol.

Index Terms **- Wireless Networks, MANET, AOMDV, Energy efficient, Multipath routing protocols.**

I. INTRODUCTION

Wireless communication networks have become a very popular and rapidly growing part of the telecommunications industry. Today this is part of every organization and individual life. It's an easy and fast implementation and the dependencies of the fixed infrastructure are not the main reasons. In general, a Mobile Ad-hoc network is a group of wireless nodes in motion; establish dynamic connectivity between them without a pre-existing network or centralized administration using IEEE 802.11 technology. More logically, the less wireless network infrastructure is a technological solution for establishing communications in areas where infrastructure is not available or not accessible. A simple Wireless Ad-hoc network is shown in Figure 1.

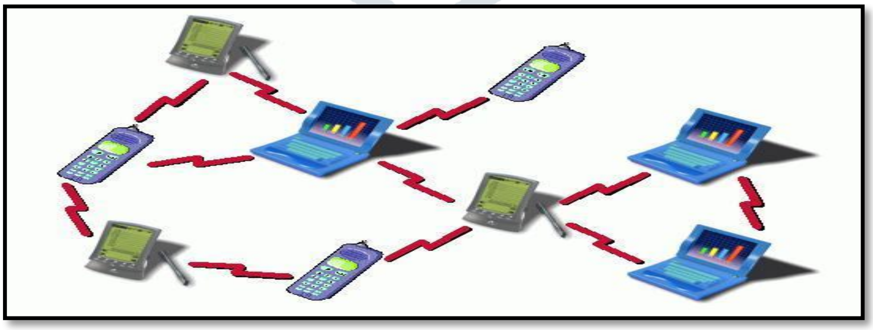


Figure 1: Wireless Ad Hoc Network [eexploria]

The involved nodes have the collaboration between them and can function as hosts and routers; they work together only in common agreement, without any knowledge of the network topology that surrounds them. Therefore, the network topology can be unpredictable and dynamic. Routing protocols, used in wired networks, cannot be used directly in the ad hoc mobile network. There are many reasons, such as bandwidth consumption, more than one route between two nodes, unidirectional connections between nodes and power supply are affected by the periodic updating of routing information and the slow convergence of routing protocol with respect to topology has changed dynamically. Therefore, efficient routing protocols are key components of successful communication in the mobile infrastructure minus the network.

A. Motivation

The multipath routing protocols invade a routing request to learn more than one route to the destination to forward packets through them. It is not necessary for the source to always find the optimal or shortest path available. Since the power supply to the mobile nodes is limited, the energy consumption of these nodes must be controlled to increase the useful life of the network. Multipath routing protocols have several problems. One of these is finding an optimal route from sources to destinations. The problem is complicated by a large number of mobile nodes connected to each other to transfer data. In this case, most of the energy will be consumed when examining the shortest routes. Later, more energy is wasted in data transfer.

So, this research paper presents an energy efficient multipath routing protocol called Optimized packet forwarding (OPF) ad hoc on demand multipath distance vector protocol. In this OPF method, two parameters is taken into consideration in order to select the optimum route; one of them is energy level of the route and the another one is the route distance in order to transfer the data to the destination more efficiently by consuming less energy and prolonging the network lifetime.

B. Research Problem

Among the various research challenges this research paper focuses on the aspects of energy limitation of MANET. Energy is a scarce resource in MANET, as the devices are portable and depend on limited energy resources, such as batteries, which may not be renewable. Therefore, energy awareness is essential for MANET. The main objective of the research paper is to design and study the performance of routing protocols for MANET networks in terms of energy savings.

The energy efficiency of a node is defined as the ratio between the amount of data provided by the node and the total energy spent. The node can transmit a greater number of packets with a certain amount of energy reserve which implies greater energy efficiency. The main reasons for energy management in MANET are:

(i). Limited Energy Reserve: MANETs have been developed to provide a communication infrastructure in environments where it is impossible to configure a fixed infrastructure. MANET has very limited energy resources. Advances in battery technologies have been negligible compared to advances in mobile communications. This growing gap between energy availability and energy consumption requirements increases the importance of energy management.

(ii). Difficulties in replacing batteries: Replacing or recharging the batteries becomes difficult sometimes, in situations like battlefields. Therefore, energy conservation becomes essential.

(iii). Lack of central coordination: Due to the lack of a central coordinator, some intermediate nodes act as relay nodes. If the retransmission traffic is high, it can lead to a faster exhaustion of power for the forwarding node. On the other hand, if the retransmission traffic is not allowed through the nodes, the network is divided. Therefore, unlike other networks, the retransmission traffic plays a very important role in MANET.

(iv). Constraints on battery source: Batteries tend to increase the size and weight of a mobile node. Reducing the size of a battery means less capacity, which decreases the duration of the node; therefore, in addition to reducing the battery size, energy management schemes are needed to use the battery capacity in the best possible way.

(v). Selection of best optimal transmission power: The selected transmission power determines the capacity of the nodes. The charge consumption of the battery increases with an increase in transmission power.

(vi). Channel utilization: A reduction in transmission power increases the reuse of the channel, which leads to better reuse of the channel. Power control becomes essential to maintain the required signal-to-interference ratio in the receiver and increase channel reuse.

C. Research Objective

This research paper presents a solution for energy efficient routing in MANETs considering the view points of the network and nodes. This solution improves the existing well known routing protocols of MANETs. The main contributions of this research work are as follow:

(i). To study and analyze existing energy efficient multipath routing protocols for mobile ad-hoc networks (MANETS) such as AOMDV and FF-AOMDV.

(ii). A new routing protocol have been developed i.e. Optimized Packet Forwarding (OPF) AOMDV protocol based on variable-range transmission control. It is shown that use of variable range transmission approach achieves lower transmission power levels compared to using common-range transmission approach. Thus, the new schemes based on variable-range transmission increase the traffic carrying capacity of wireless ad hoc network, and at the same time, reduce the overall transmission power consumption in the network.

(iii). To presents comparative study between proposed OPF_AOMDV with existing techniques FF_AOMDV and AOMDV.

(iv). Implementation and simulation study of the proposed energy efficient routing protocol is done in NS-2 and considerable improvements in energy consumption and network lifetime over the original standard multipath routing protocols is obtained.

(v). Simulation results show that proposed scheme has a higher node energy efficiency, lower average delay and control overhead than those protocols.

II. LITERATURE SURVEY

In 2013, Won-Suk Kim; Sang-Hwa Chung ***[1],*** proposed the OM-AODV (Optimized MIMC AODV) which includes the PREQ multi-objective mechanism, the predictive PREQ algorithm and the sender assignment algorithm PREQ. Furthermore, different performance parameters of the proposed routing protocol have been analyzed when applied to MIMC-WMN. Furthermore, the routing protocol performance have evaluated through several experiments on an external test bench with real mesh routers that have been implemented. The proposed routing protocol has been reduced by up to 72% of the number of administration frames and also increased by 37% in route quality.

In 2013, Jung-Jae Kim ; Min-Woo Ryu et.al. ***[2],*** Content-Centric Network (CCN), It is a content-based method of communication to use voluminous information on the Internet and next-generation Internet technology is providing a new paradigm. CCN communicates via interest package and data package. The package of interest is the content requested by the user and the data package is a response to the content information. CCN uses the communication based interest packet that retransmits the route of the packet of interest. In CCN, unidirectional routing has low load balancing only if data traffic is increasing. Therefore, this problem has increased the response time, which is the moment of transmission of the content to the user. To solve this problem, in this document they proposed a cluster-based multipath routing protocol to support load balancing.

In 2014, P. Selvigrija ; J. Premkumar ***[3],*** The theme of this document is to provide message delivery without problems in a MANET despite threats using random delivery and existing mechanisms, such as two-step recognition or origin recognition, are not maintained when using a Network topology changes frequently or when a node is compromised. These problems must be resolved by ensuring the secure connection edges between the origin and the destination. The source collision, exposure to vulnerability is also minimized through this mechanism. They proposed an optimized solution for the previous problem using BSA techniques that overcome the loss of listeners based on the recognition of intermediates only.

In 2014, C R Yamuna Devi; B Shivaraj et.al. ***[4],*** Taking into account the importance of communication between source-destination pairs in a wireless sensor network, this document proposes an opportunistic routing protocol based on the optimal position of multiple jumps. The algorithm chooses the path with the minimum distance and the number of jumps between the source and the destination for data transmission in the network. The simulation experiments illustrate that the proposed protocol has a good effect on the end-to-end delay and on the duration of the network. Furthermore, it is observed that the average end-to-end delay is lower for the different simulation times compared to the existing EEOR protocol.

In 2015, Yiming Lin; Weitian Huang et.al. ***[5],*** presented a multi-path routing protocol based on maps for VANET - MBMPR, which uses GPS, digital maps and sensors in the vehicle. With global route information, MBMPR finds an optimal forward path and an alternative route using the Dijkstra algorithm, which improves the reliability of data transmission. Taking into account the problem of load balancing in the joints, a congestion detection mechanism is proposed. Indicating the problem of packet loss due to the mobility of the target vehicle, MBMPR adopts a recovery strategy that uses services based on location and the forecast of the mobility of the target vehicle.

In 2015, Sheng-Lung Peng ; Yan-Hao Chen et.al. ***[6],*** proposed a multiple-energy (ERMP) sensitive routing protocol to improve the AODV protocol. They proposed four parts of communication to increase the performance of MANET, namely "Avoid the use of low battery nodes", "Routing with multiple paths", "Detect the quality of connections" and "Distribute energy consumption". Based on the experimental results, the ERMP has a better performance in the useful life of the network, the standard deviation of the residual power and the average end-to-end delay compared to AODV.

In 2015, Gan-Gun Lee ; Hyung-Kun Park ***[7],*** In an ad-hoc mobile network, establishing a stable routing path is one of the important technical problems for transmitting data from the source to the destination by transmitting multiple hops. The ad-hoc mobile network has time-varying channels and traffic congestion or unstable connection conditions can be serious problems. To solve these problems, multipath routing protocols have been proposed. However, conventional multipath routing requires many more nodes and energy consumption. In this article, the author proposed partial routing of multiple paths with interference prevention. The proposed routing does not establish another complete routing path, but establishes a partial multiple path to integrate some defective links and the routing routes are sufficiently spaced to reduce route interference.

In 2016, Alexandros Ladas; Nikolaos Pavlatos et.al. ***[8],*** This document presents Multipath-ChaMeLeon (MCML) as an update to the existing ChaMeLeon routing protocol (CML). CML is a hybrid and adaptive protocol designed for mobile Ad-Hoc networks (MANET), which supports emergency communications. M-CML adopts the attributes of the Proactive Optimized Link State Protocol (OLSR) and extends it to implement a multipath routing approach based on the expected transmission count (ETX). The document confirms the effectiveness of the protocol through a simulation scenario within a MANET using the NS-3 simulator. The results obtained indicate that the M-CML routing approach combined with an intelligent connection metric like ETX reduces the effects of link instabilities and improves network performance in terms of strength and scalability.

In 2016, Bhagyashri R Hanji ; Rajashree Shettar ***[9],*** The proposed method finds efficient and stable paths considering two parameters, the geographical position and the energy of the nodes. Reduce the number of flood routing request packets to establish routes with multiple routes. The destination node receives many routing request messages and responds with route responses. The source selects multiple paths. The data transfer starts with a path and then passes to other paths. This method shows better performance in terms of performance, routing load and network lifetime. The results showed an increase in performance between 25% and 30%, the routing load is reduced between 10% and 15% and the useful life of the network increases between 10% and 12%.

In 2016, Nagaraj M. Lutimath ; L Suresh et.al. ***[10],*** proposed an Efficient Power Aware Multipath Protocol based on AODV (EPAM-AODV) utilizing receiving power, transmission distance and hop count when request packets are received during route discovery. The simulation results showed that EPAM-AODV has higher average packet delivery ratio and average throughput than traditional AODV. It also showed that average packet loss ratio of proposed protocol is less than AODV.

In 2017, Mahmoud M. Shawara ; Amany M. Sarhan et.al. ***[11],*** proposal (EA-AOMDV) which is a modified energy-based routing protocol based on the ad-hoc multi-path distance vector on demand (AOMDV) for ad-hoc mobile networks. In the proposed protocol, the paths are chosen based on their energy metrics instead of the hop metric to minimize the average energy consumed and maximize the network operating time. The discovery of routes in the EA-AOMDV protocol avoids routes with low energy nodes in addition to total energy of the route. The simulation results showed that EA-AOMDV can offer better performance in terms of network lifetime, average power consumed, end-to-end delay, standardized routing load, package delivery report and packages delivered compared to AOMDV.

In 2017, M.M. Goswami ***[12],*** presented an adaptive hybrid distributed multipath routing solution based on AODV (ADHM). In a phase of configuration of reactive path, between origin and the destination of a data session, more paths are created. The data is distributed stochastically by different roads, based on their estimated quality. During course of the session, the paths are continuously monitored and improved proactively. Link failures are treated locally. The extensive use of periodic update packages is used to sample complete routes between source and destination nodes in a Monte Carlo form. The simulation results showed that the proposed solution produces a significant improvement in performance.

In 2017, Haijun Geng ; Xingang Shi et.al. ***[13],*** proposed a metric routing algebra for QoS routing of multiple paths in link state networks, in which a key property of routing metrics called isotonicity, which plays an important role. To allow routers to find more successive jumps efficiently and correctly for each destination developed two routing QoS algorithms. The algorithms are executed locally and independently, without the exchange of messages other than the basic connection states. They are specifically designed for algebras with rigorous or non-rigorous isotonicity and their correction has been formally demonstrated.

In 2017, Abhay K. Meshram ; D.C. Mehetre ***[14],*** Applications required a high integrity routing mechanism to regulate a large amount of traffic to be injected into the network to ensure reliable packet delivery and avoid packets in the Wireless Sensor Network (WSN). Mainly, two basic requirements considered in the WSN are high data integrity and low delay. In the proposed system to improve the performance of the network delay and energy consumption, they have implemented the grouping and programming algorithm with IDDR. If the access point is generated on the sensor node during data transmission, create a group and find the group head (CH) with the value of high energy and minimum depth. The data in the queue within the active zone will be redirected through different paths using CH. This will reduce the percentage of packets dropped and the delay in the network.

III. PROBLEM IDENTIFICATION

The energy depletion of the nodes was one of the main problems of MANET connectivity. Since MANET mobile nodes have limited battery power, it is necessary that the energy of each node in MANET is used efficiently. MANET is a multiple jump, in which the node can move freely in any direction and has a limited battery charge. A reliable routing protocol for mobile ad hoc networks (MANET) keeps energy consumption as low as possible. If a particular node is near the exhaustion condition of the battery, the route selection mechanism must exclude these nodes to increase the duration of the node, as well as the overall duration of the network and reduce the loss of packets caused by spent nodes. Therefore, an efficient routing protocol must be aware of the power of the node battery so that the low-energy nodes are not selected in the routing path.

Some problems are identified in the existing system, which can be listed below:

i. Simulation results showed that the Existing FF-AOMDV algorithm has performed much better than both AOMR-LM and AOMDV in throughput, packet delivery ratio and end-to-end delay.

ii. As a future work, there are several scenarios that could be implemented with this study to enhance the energy consumption and network lifetime.

iii. Another possibility is to test the fitness function with another multipath routing protocol that has a different mechanism than AOMDV and compare the results with the proposed FF-AOMDV.

IV. RESEARCH METHODOLOGY

In this research, the focus is on energy reduction at the network layer. The enhancements are implemented mainly in the routing protocols, and it is believed that it can help in reducing energy consumption in nodes, in a mobile ad hoc network. The enhancements proposed are based on adaptive power transmission (variable transmission power). By using the appropriate transmission power, at a level just enough to allow the transmitted packet to be received by the destination or intermediate node, the overall power expenditure can be reduced in the ad hoc network and, in addition, reduce the interference between nodes. The proposed routing algorithm uses remaining battery energy to balance the routing or forwarding of packets among nodes by choosing appropriate nodes to forward the packet.

Effective transmission power control is a critical design issue and it improves performance of mobile ad hoc networks. The overall network performance can be improved by using variable-range transmission control over common-range transmission control. A number of performance metrics of the network such as network connectivity, traffic carrying capacity, and power conserving properties of MANETs are affected while comparing routing protocols based on common-range transmission control and variable-range transmission control. The performance of the network layer may improve by transmitting at higher power and indirectly reducing the number of forwarding.

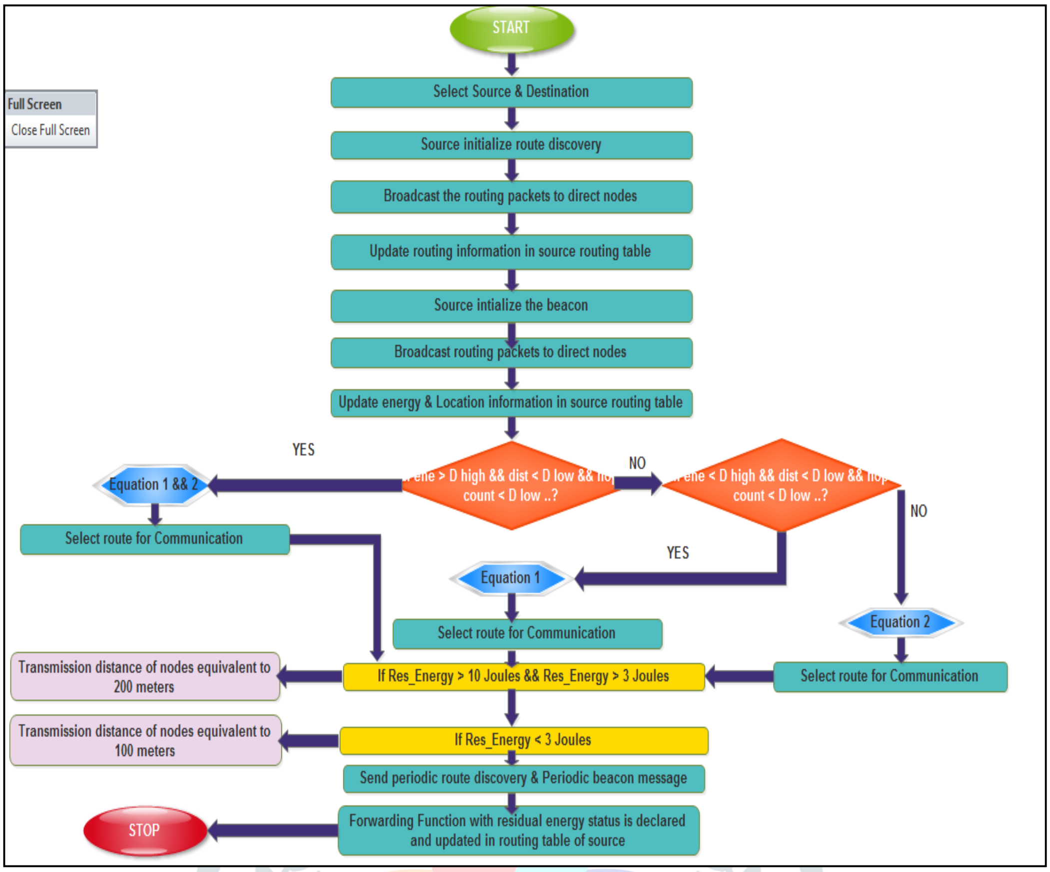


Figure 2: OPF Flowchart

In this research work, a new mechanism of energy saving in multipath routing protocol is proposed namely; Optimized Packet Forwarding (OPF). The scheme is based on variable-range transmission control. The specific contribution of this research here is that the use of variable range transmission power approach achieves lower transmission power levels compared with the power levels obtained using common range transmission approaches. This is an important result because it suggests that variable-range transmission based routing protocols can increase the traffic carrying capacity of wireless ad hoc network, and at the same time, reduce the overall transmission power consumption in the network and increase the lifetime of the network.

$$\text{Optimum route } 1=\sum_{k=0}^{n}\left(\left(V(n) \in rene\,(v(n))\right) \mid \left(V \in V\ ene\,(v)\right)\right) \ldots\ldots\ldots\ldots(1)$$

$$\text{Optimum route } 2=\sum_{k=0}^{n}\left(\left(E(n) \in rdist\,(e(n))\right) \mid \left(e \in E\right)\right) \ldots\ldots\ldots\ldots(2)$$

Figure 2 shows the research methodology flowchart for OPF method. Source and destination nodes are selected randomly; then the source node initializes the route discovery process and broadcast the routing packets to all the nodes in a network. During this process source node update the routing table about location and energy status of the nodes. If the nodes energy is higher and distance is lower within the minimum hop count; then the source node follows the equation 1 and equation 2.

Else the energy of the node is higher and the distance is also higher then it would search for another path which has lower distance. If the lower distance is found then the OPF algorithm follows the equation 1 else the equation 2 and finalized the route for the communication. Furthermore, if the nodes energy level depleted between 10 joules to 3 joules then the transmission range of nodes are adjusted to 200 meters. Also if the nodes energy level depleted below to 3 joules then the transmission power is adjusted to 100 meters only. Then the algorithm follows periodic route discovery process and beaconing of messages and the forwarding function keeps the updated energy of nodes and is kept updated.

A. Transmitter power detail

The transmit power of the node needs to be modified, to vary the transmission range. In the proposed algorithm, free space propagation has been chosen for simulation. Friis transmission equation is used to calculate the transmit power of nodes, given as:

$$Pr=\sum_{1}^{n} \left[Pt.Gr.Gt \left(\frac{\lambda}{4\Pi r}\right)^2 \right] \cdots\cdots\cdots\cdots..(3)$$

where, Pr and Pt are received and transmit powers respectively, Gt and Gr are the transmitter and receiver antenna gain, R is taken as the distance between the nodes and λ is the wavelength.

The main aim of the proposed algorithm is to make the network energy aware. Energy efficient design of the protocol is generated by varying the transmission range of the nodes. Variable transmission range means controlling the power level for each packet in a distributed manner at each node, thus affecting energy consumption of the network. By choosing a higher transmission range, the number of nodes needed to reach the destination reduces, but it also creates large interference, whereas by reducing the transmission range more number of forwarding nodes are needed leading to less utilization of energy. Each node communicates with the neighboring nodes during Route Discovery phase. Once the route is known, each individual node then controls the transmission range as per the distance between source and destination node, so that optimum energy is utilized for packet transmission. For establishing route using the proposed algorithm, the phases are explained below

B. Route Discovery Phase

When a node wishes to send a packet to some destination, it initiates a route discovery process if no valid route is available in its routing table. For route discovery, the node creates a Route Request (RREQ) packet and broadcasts it to its neighbors. A common transmission range Rmax is considered to maintain connectivity between nodes. The node then sets a timer to wait for reply. The timer is set to T_wait time. The node then collects all the Route Reply (RREP) received till this timer expires.

C. Forward Route Setup

When a node determines that it has a route current enough to respond to the RREQ, it creates a Route Reply (RREP). The RREP sent in response to RREQ contains the IP address of both source and destination. Besides these, in the OPF scheme two more parameters are added in the RREP packet. These parameters are used to specify the exact x-y location of the node that sends the route reply. These parameters are named as loc_X (x-axis location) and loc_Y (y-axis location). In on demand routing protocols, the first route reply received is forwarded and path is established. But in OPF, "each node waits for a time (T_wait) till it receives all" the RREP messages destined for the node. The node then calculates the distances between the nodes from where the RREP message is received and itself. This is done using own location and the locations of the intermediates nodes. Let location of a node is (nX,nY) and location received in RREP is (loc_X , loc_Y), Then distance d between the two nodes is calculated as:

$$n\_hop\_X = abs\,[nX - loc\_X] \ldots\ldots\ldots\ldots\ldots(4)$$

$$n\_hop\_y = abs[nY - loc\_Y] \ldots\ldots\ldots\ldots\ldots(5)$$

Therefore,

$$\text{Distance, } D = \sqrt{}\,(2\&n\_hopY^2 + n\_hopX^2) \cdots\cdots\cdots\cdots.(6)$$

So, for all the RREP received, distance is calculated as given in equation 6. The node having minimum distance is then selected as the next hop and its location is also updated in the routing table as two entries n_hopX and n_hopY.

Select node with d_(〖Min〗^) and add n_hopX, n_hopY in routing table.

The minimum distance (dmin) is the distance between the current node and the next hop node in the algorithm. The received power threshold of all the nodes is kept constant throughout the route discovery phase. This route between source and destination is maintained for data transfer.

D. Route Maintenance

Once a route has been discovered for a source/destination pair as explained above, it is maintained as long as needed by the source node. Movement of nodes within the network affects only the routes containing those nodes; such a path is called an active path. Route discovery is reinitiated if the source node moves during an active session to establish new route. A Route Error (RERR) message is generated if the destination or any intermediate node moves out. In OPF, RERR message is handled as in other on demand routing protocols. Following figure 3 shows the pseudo code for OPF method.

Step1: *Select the Source and Destination.*
Step 2: *Source Initialize the route Discovery.*
Step 3: *Broadcast the Routing Packet to direct nodes.*
Step 4: *Update the routing information in the Source Routing Table.*
Step 5: *Source Initialize the Beacon.*
Step 6: *Broadcast the Routing Packet to direct nodes.*
Step 7: *Update the Energy and location information in the Source Energy Table for all the nodes in the entire network.*
Step 8: *check*
If(ene >D High &&dist <D Low &&hop Count <D Low). . . (Eq. 1 & 2)
Select that route for Communication.
Else if (ene >D High &&dist >D high &&hop Count <D Low) . . . (Eq. 1)
Select that route for Communication.
Else if (ene <D Low&&dist <D Low &&hop Count <D Low t) . . . (Eq. 2)
Select that route for Communication
{ ***If Res_Energy < 10 Joules && Res_Energy > 3 Joules***
Then the transmission distance of nodes would be equivalent to ***200 meters****.*
If Res_Energy < 3 Joules
Then the transmission distance of nodes would be equivalent to ***100 meters*** }
Step 9: *Send the periodic route discovery.*
Step10: *Send the periodic beacon message.*
{ ***forwarding function with Residual Energy Status*** *is declared &* ***would be updated in the routing table*** *of Sender node.* }

Figure 3: OPF method pseudo code

In this research work, ***an Optimized Packet Forwarding (OPF)*** method is proposed which ***enhances the existing FF-AOMDV protocol***. The Proposed method utilizes the energy consumption of nodes. ***The transmitted energy of the nodes is adjusted*** according to residual energy of the nodes.

If Res_Energy < 10 Joules && Res_Energy > 3 Joules

Then the transmission distance of nodes would be equivalent to ***200 meters***. And;

If Res_Energy < 3 Joules

Then the transmission distance of nodes would be equivalent to ***100 meters***

Also the ***forwarding function with Residual Energy Status*** is declared so that in ***every beconing of messages from nodes would be updated in the routing table*** of Sender node.

V. RESULTS AND DISCUSSION

For simulation and result analysis, it must require setting of simulation parameters and mobility models. The summarized simulation parameter is depicted in table 1.

Table 1: Simulation Parameters

parameter	value
Simulator	NS-2 (ns-all-in-one-2.35)
Routing protocol	FF-AOMDV, OPF-AOMDV and AOMDV
Total Simulation time	100 seconds
Number of nodes	50
Traffic model	Constant Bit Rate (CBR)
Packet size	64, 128, 256, 512, 1024 Bytes
Nodes velocities	0 m/s, 2.5 m/s, 5 m/s, 7.5 m/s, 10 m/s
Simulation Area	1000 * 1000 meter square
Mobility model	Random Way Point
Mac layer protocol	IEEE 802.11

In this research Random Waypoint Model is used, where mobile node is allowed to move at random in any direction .Constant Bit Rate (CBR) traffic with a transmission rate of 4 packets per second is used. Nodes in experimental scenario select any arbitrary destination in the 1000 X 1000 M2area and moves with the speed of 0 m/s, 2.5 m/s, 5 m/s, 7.5 m/s and 10 m/s. Total 50 nodes are used in scenarios with change in pause times and 1 number of Blackhole node with simulation times of 100 seconds to compare the performance of the protocols for low as well as high density environment and for low mobility of the nodes to high mobility.

A. Results according to Packet Size

Following figure 4 shows the packet delivery ratio graph for all routing protocols considered in the experiment. The graphs shows the higher PDR ratio for small size packet viz. 128 bytes while the PDR ratio decreases as the packet size increases for all routing protocols since the network topology is arbitrary as per MANET structure. The graph clearly shows that proposed OPF-AOMDV protocol showed better performance with improvement of 0.493 % compared to FF-AOMDV protocol.

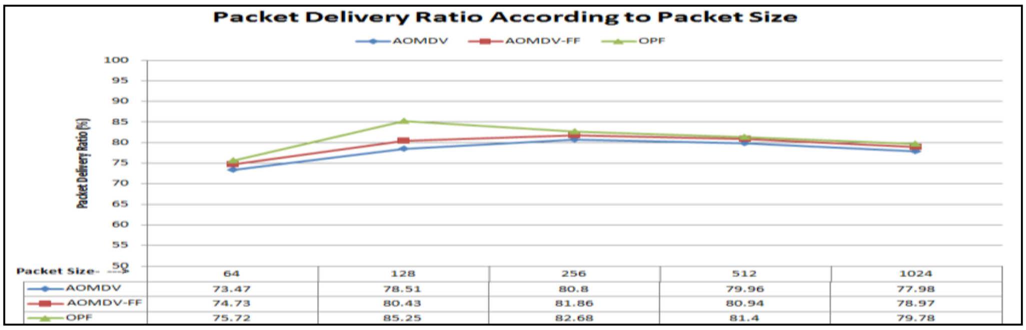


Figure 4: Packet Delivery Ratio

Figure 5 shows the graph obtained for average end to end delay for all routing protocols considered in the experiment. The graph shows that end to end delay is increasing for all routing protocols since the packet sizes are increasing for the experiment. The delay is higher for AOMDV protocol, moderate for FF-AOMDV and smaller for OPF-AOMDV protocol. Since the nodes are placed and moving in arbitrary direction of MANET scenario, the different sender and receivers increases the delay time with increasing the packet size while sending the data packets. This graph also shows that proposed OPF-AOMDV protocol performance is better than FF-AOMDV with an improvement of about 9.41 %.

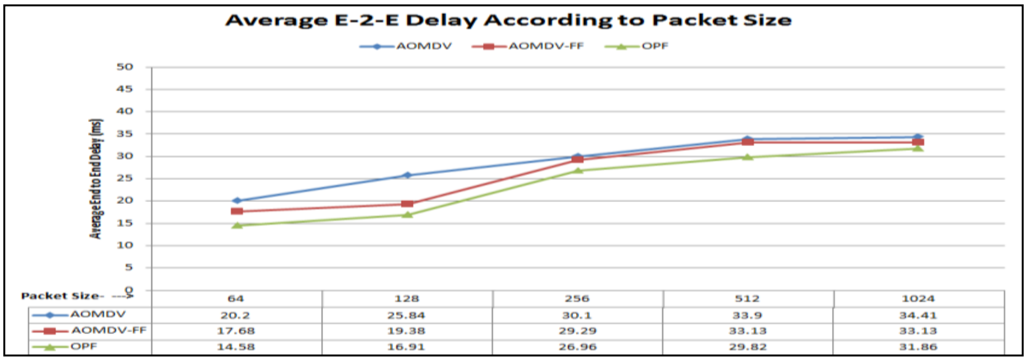


Figure 5: End to End Delay

Figure 6 shows the graph obtained for throughput for all routing protocols considered in the experiment. The graph shows that throughput is decreasing for all routing protocols since the packet sizes are increasing for the experiment. The throughput is higher for OPF-AOMDV protocol, moderate for FF-AOMDV and smaller for AOMDV protocol. This graph also shows that proposed OPF-AOMDV protocol performance is better than FF-AOMDV with an improvement of about 2.069 %.

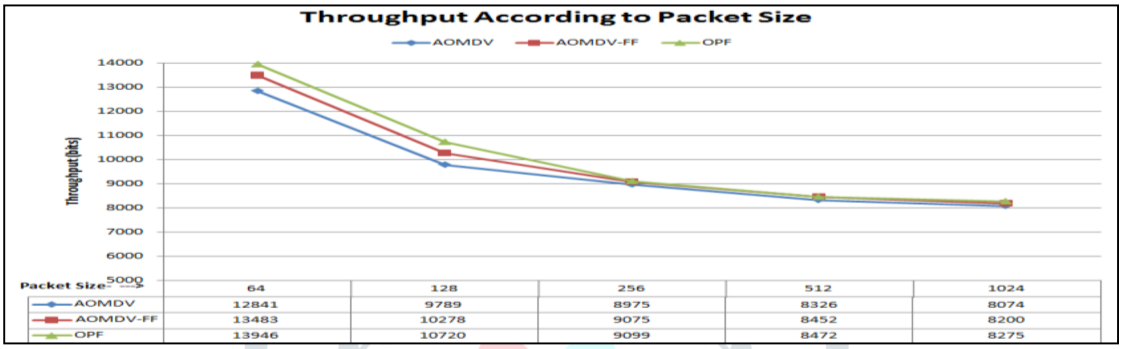


Figure 6: Throughput

Figure 7 shows the graph obtained for network lifetime for all routing protocols considered in the experiment. The graph shows that network lifetime is decreasing for all routing protocols since the packet sizes are increasing for the experiment. The network lifetime is higher for OPF-AOMDV protocol, moderate for FF-AOMDV and smaller for AOMDV protocol. This graph also shows that proposed OPF-AOMDV protocol performance is better than FF-AOMDV with an improvement of about 10.46 %.

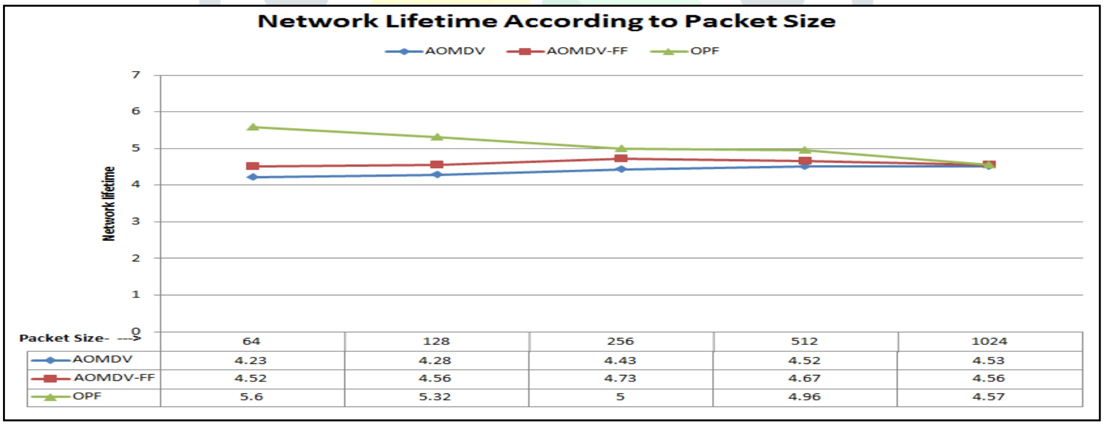


Figure 6.49: Network Lifetime graph

Figure 8 shows the graph obtained for routing overhead for all routing protocols considered in the experiment. The graph shows that routing overhead is increasing for all routing protocols since the packet sizes are increasing for the experiment. The routing overhead is higher for AOMDV protocol, moderate for FF-AOMDV and smaller for OPF-AOMDV protocol. For the better performance of routing protocol the routing overhead parameter should be les, since this decreases the efficiency of protocol and also increases the erroneous data of packets. This graph also shows that proposed OPF-AOMDV protocol performance is better than FF-AOMDV with an improvement of about 2.727 %.

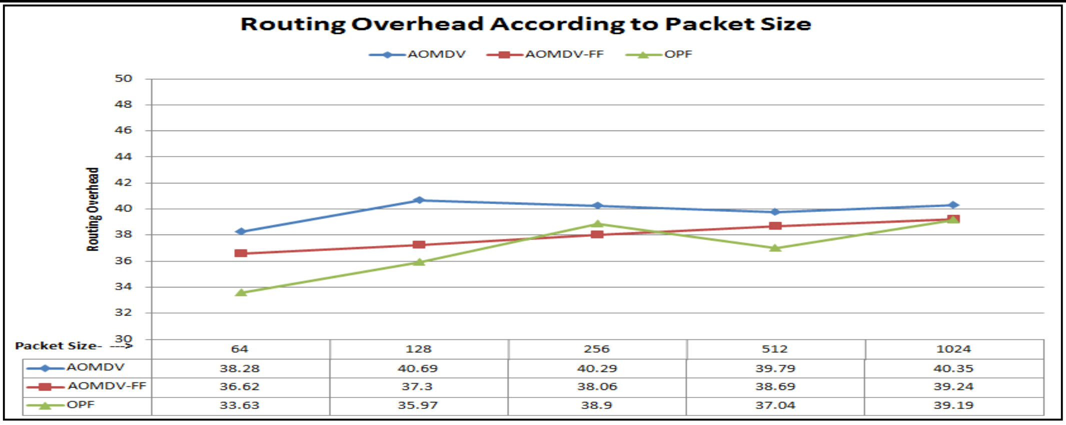


Figure 8: Routing Overhead

Figure 9 shows the graph obtained for average energy consumption for all routing protocols considered in the experiment. The graph shows that average energy consumption is increasing for all routing protocols since the packet sizes are increasing for the experiment. The routing overhead is higher for AOMDV protocol and about equivalent for FF-AOMDV and OPF-AOMDV protocol. This graph also shows that proposed OPF-AOMDV protocol performance is slightly better than FF-AOMDV with an improvement of about 0.493 %.

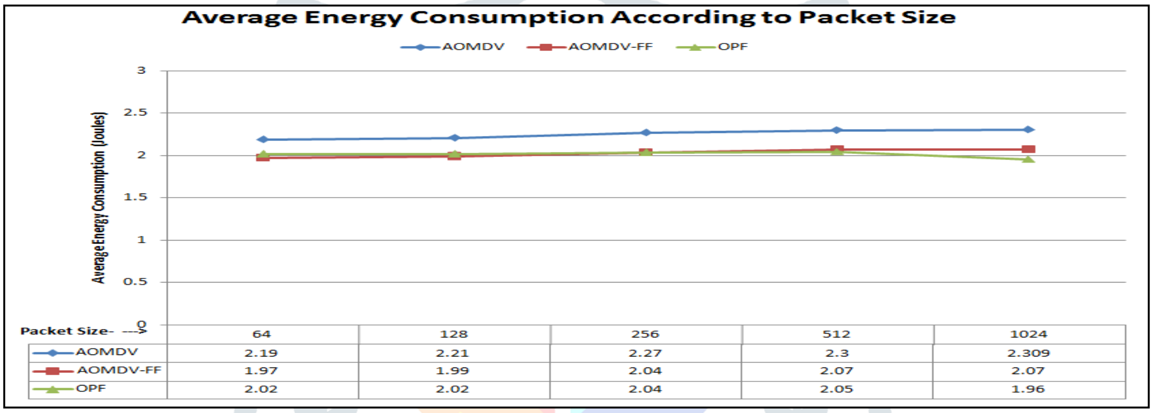


Figure 9: Average Energy Consumption

B Results according to Simulation Time

Following figure 10 shows the packet delivery ratio graph for all routing protocols considered in the experiment. The graphs shows the uniform PDR ratio for all routing protocols since the simulation time is set to 10 seconds of interval viz. 10 seconds, 20 seconds, 30 seconds, 40 seconds and 50 seconds. The graph clearly shows that proposed OPF-AOMDV protocol showed better performance with improvement of 4.011 % compared to FF-AOMDV protocol.

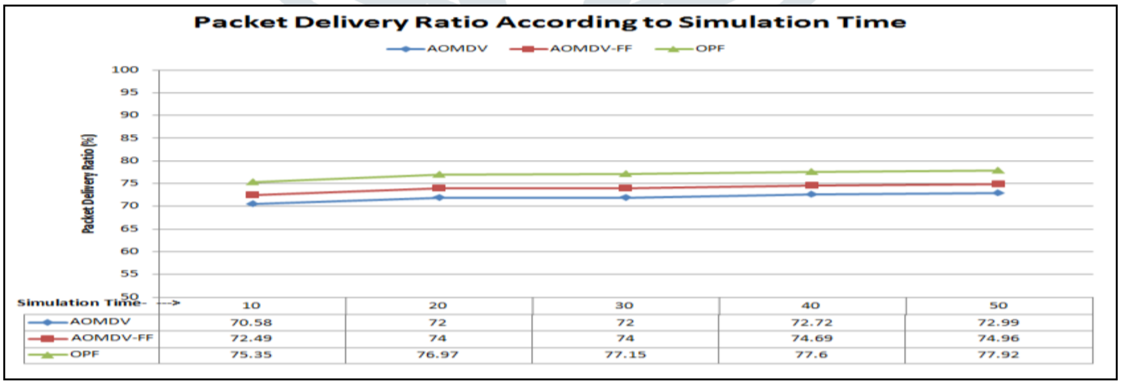


Figure 10: Packet Delivery Ratio

Figure 11 shows the graph obtained for average end to end delay for all routing protocols considered in the experiment. The graphs shows the uniform average end to end delay for all routing protocols since the simulation time is set to 10 seconds of interval viz. 10 seconds, 20 seconds, 30 seconds, 40 seconds and 50 seconds. The uniform way of graph is due to uniform interval of time slots allotted to all protocols in the experiment. Particularly for all the parameters with the uniform time interval gives the uniform graph always. The graph clearly shows that proposed OPF-AOMDV protocol showed better performance with improvement of 5.76 % compared to FF-AOMDV protocol.

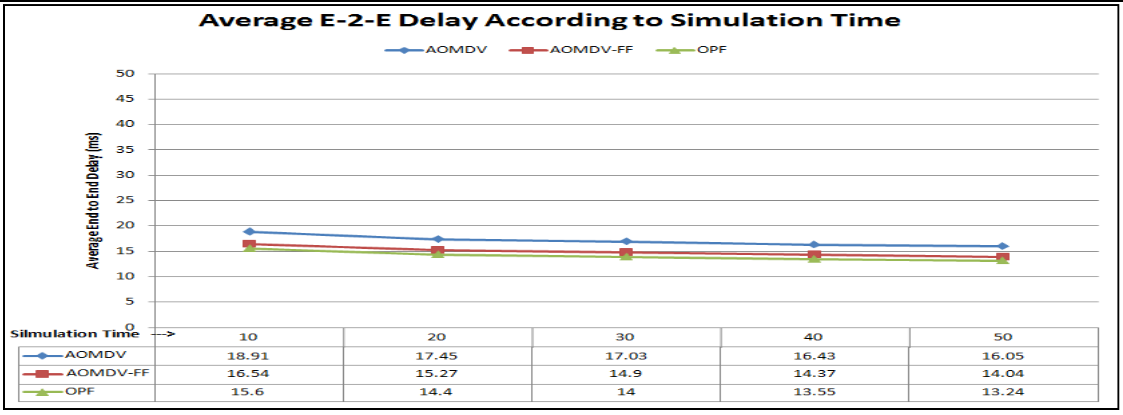


Figure 11: End to End Delay

Figure 12 shows the graph obtained for throughput for all routing protocols considered in the experiment. The graphs shows the uniform increasing throughput for all routing protocols since the simulation time is set to 10 seconds of interval viz. 10 seconds, 20 seconds, 30 seconds, 40 seconds and 50 seconds. The graph clearly shows that proposed OPF-AOMDV protocol showed better performance with improvement of 2.85 % compared to FF-AOMDV protocol.

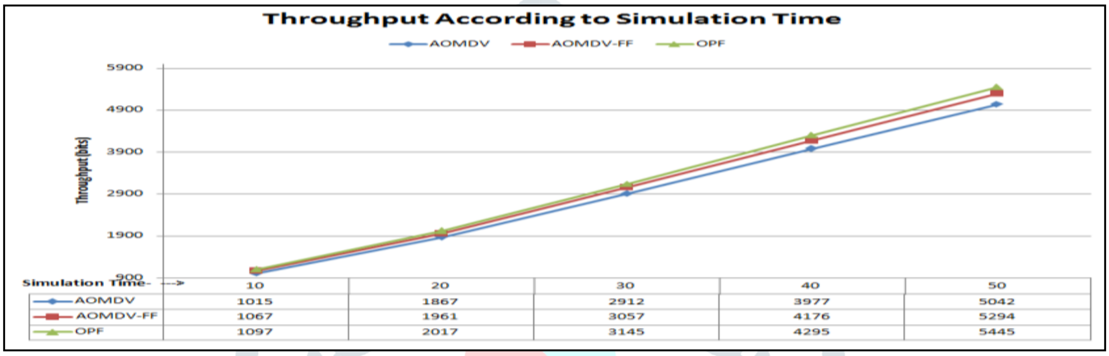


Figure 12: Throughput

Figure 13 shows the graph obtained for network lifetime for all routing protocols considered in the experiment. The graphs shows the uniform increasing network lifetime for all routing protocols since the simulation time is set to 10 seconds of interval viz. 10 seconds, 20 seconds, 30 seconds, 40 seconds and 50 seconds. The graph clearly shows that proposed OPF-AOMDV protocol showed better performance with improvement of 12.48 % compared to FF-AOMDV protocol.

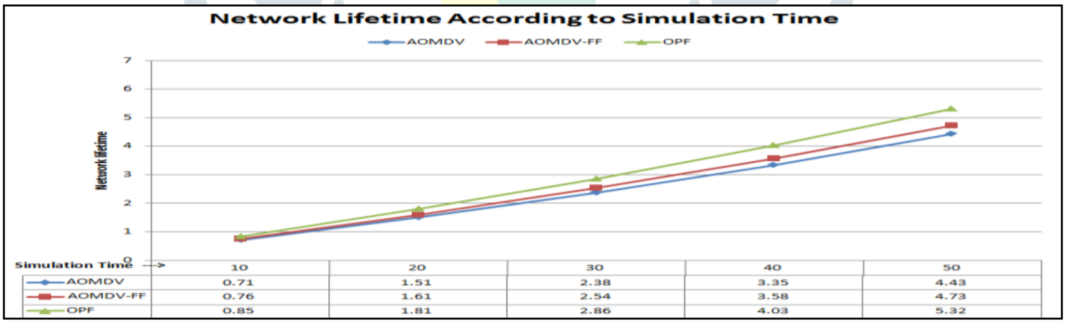


Figure 13: Network Lifetime graph

Figure 14 shows the graph obtained for routing overhead for all routing protocols considered in the experiment. The graph clearly shows that proposed OPF-AOMDV protocol showed better performance with improvement of 2.7 % compared to FF-AOMDV protocol.

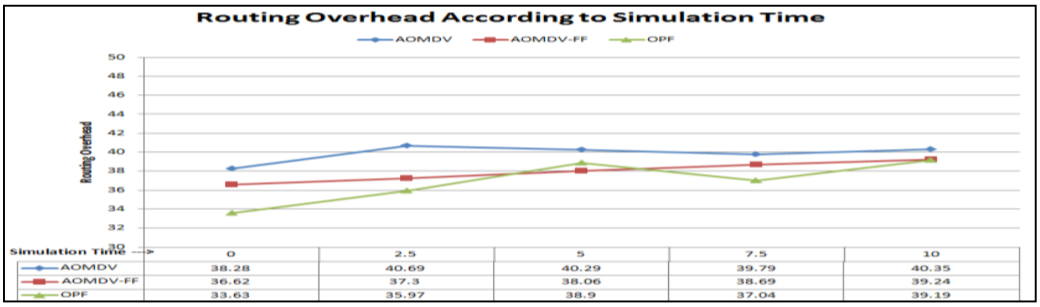


Figure 14: Routing Overhead

Figure 15 shows that proposed OPF-AOMDV protocol showed slightly better performance with improvement of 3.389 % compared to FF-AOMDV protocol.

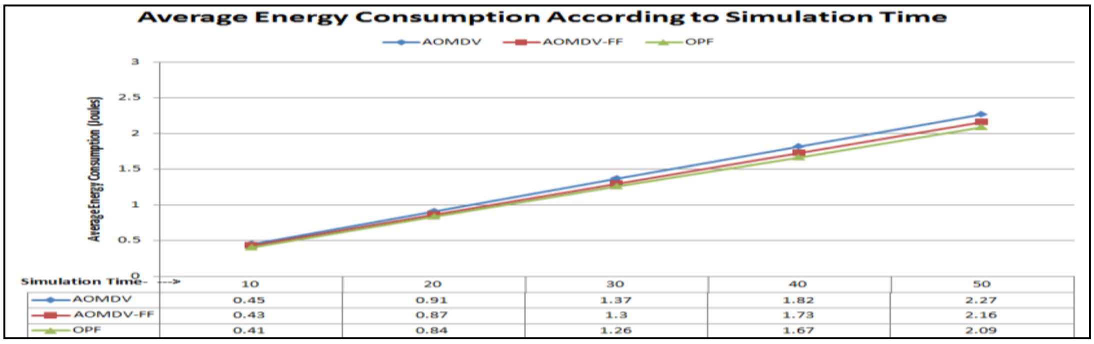


Figure 15: Average Energy Consumption

C. Results according to Velocity

Following figure 16 shows the packet delivery ratio graph for all routing protocols considered in the experiment. The graphs shows the PDR ratio is decreasing for all routing protocols since the velocity of nodes are varied as 0 m/s, 2.5 m/s, 5 m/s, 7.5 m/s and 10 m/s. The graph clearly shows that proposed OPF-AOMDV protocol showed better performance with improvement of 1.78 % compared to FF-AOMDV protocol.

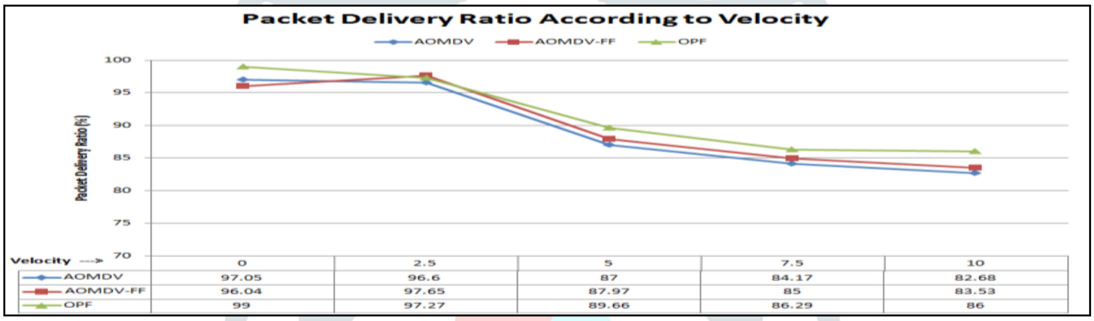


Figure 16: Packet Delivery Ratio

Following figure 17 shows the average end to end delay graph for all routing protocols considered in the experiment. The graph clearly shows that proposed OPF-AOMDV protocol showed better performance with improvement of 10.94 % compared to FF-AOMDV protocol.

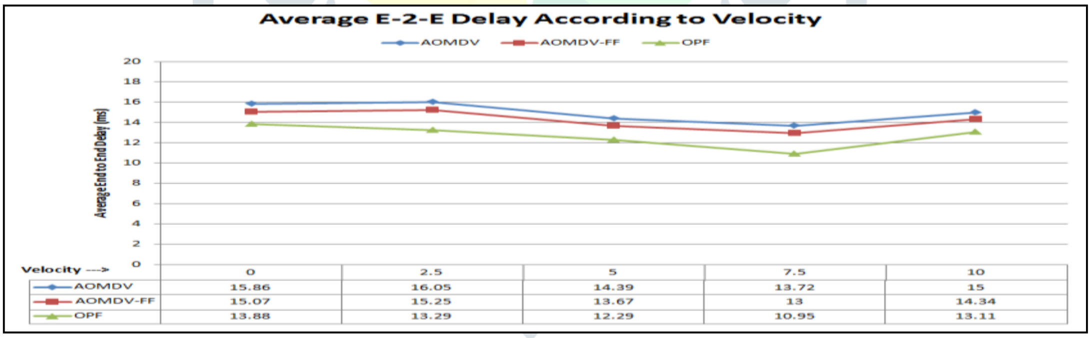


Figure 17: End to End Delay

Following figure 18 shows the average throughput graph for all routing protocols considered in the experiment. The graph clearly shows that proposed OPF-AOMDV protocol showed better performance with improvement of 2.265 % compared to FF-AOMDV protocol.

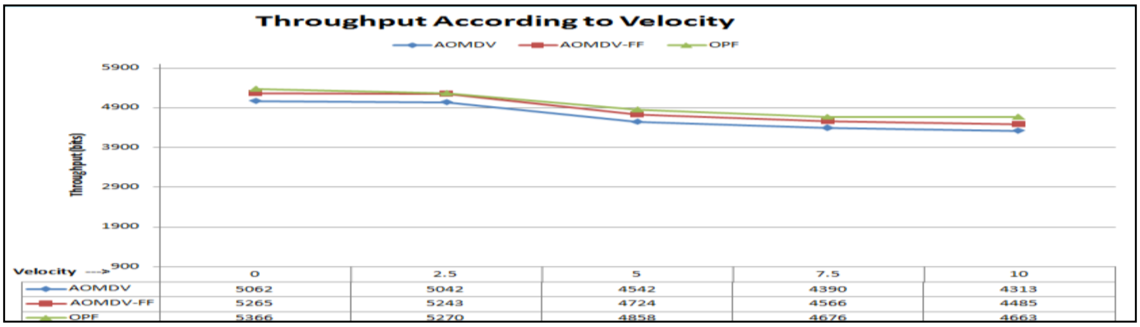
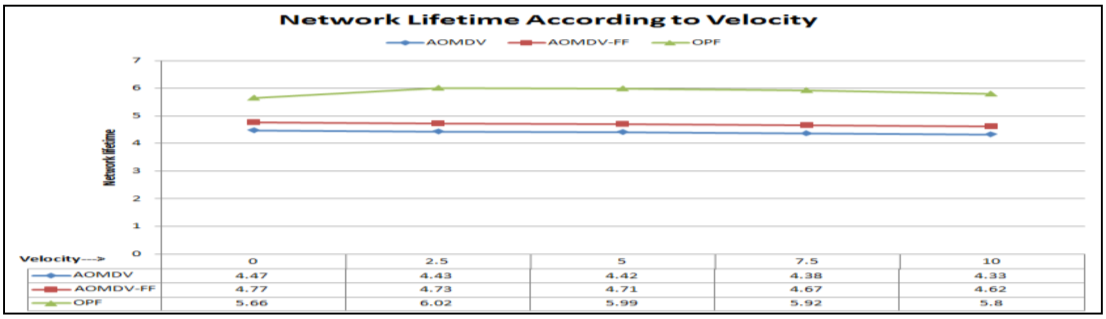


Figure 18: Throughput

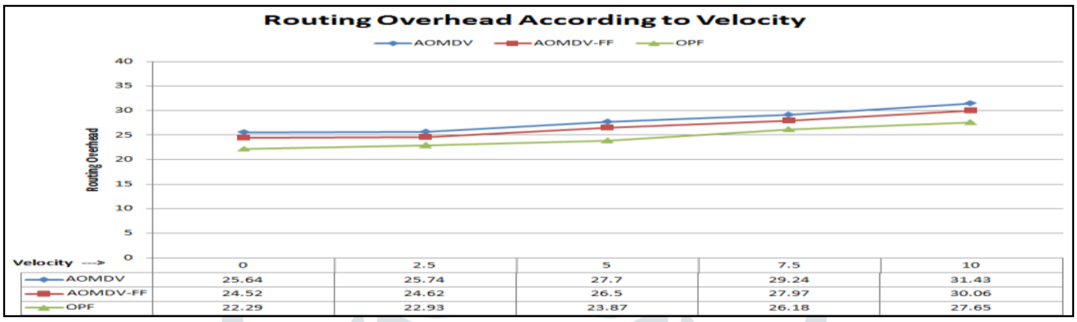
Following figure 19 shows the network lifetime graph for all routing protocols considered in the experiment. The graph clearly shows that proposed OPF-AOMDV protocol showed better performance with improvement of 25.06 % compared to FF-AOMDV protocol.



Velocity--->	0	2.5	5	7.5	10
AOMDV	4.47	4.43	4.42	4.38	4.33
AOMDV-FF	4.77	4.73	4.71	4.67	4.62
OPF	5.66	6.02	5.99	5.92	5.8

Figure 19: Network Lifetime graph

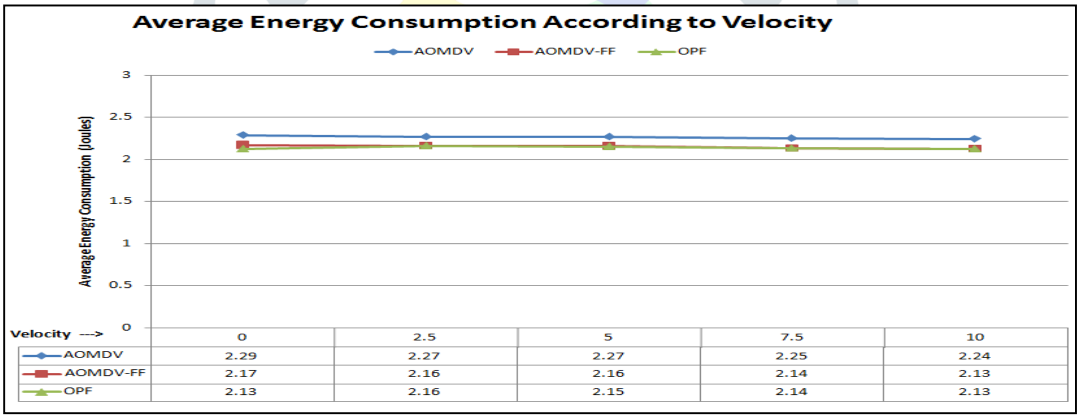
Figure 20 shows routing overhead graph for all routing protocols considered in experiment. The graph clearly shows that proposed OPF-AOMDV protocol showed better performance with improvement of 8.042 % compared to FF-AOMDV protocol.



Velocity --->	0	2.5	5	7.5	10
AOMDV	25.64	25.74	27.7	29.24	31.43
AOMDV-FF	24.52	24.62	26.5	27.97	30.06
OPF	22.29	22.93	23.87	26.18	27.65

Figure 20: Routing Overhead

Following figure 21 shows the average energy consumption graph for all routing protocols considered in the experiment. The graphs shows the average energy consumption is approximately uniform for all routing protocols since the velocity of nodes are varied as 0 m/s, 2.5 m/s, 5 m/s, 7.5 m/s and 10 m/s. The graph clearly shows that proposed OPF-AOMDV protocol showed better performance with improvement of 0.465 % compared to FF-AOMDV protocol.



Velocity --->	0	2.5	5	7.5	10
AOMDV	2.29	2.27	2.27	2.25	2.24
AOMDV-FF	2.17	2.16	2.16	2.14	2.13
OPF	2.13	2.16	2.15	2.14	2.13

Figure 21: Average Energy Consumption

VI. Conclusion & Future work

The ad hoc mobile network (MANET) is a collection of wireless mobile nodes that dynamically form a temporary network without depending on any infrastructure or central administration. Energy consumption is considered one of the main limitations of MANET, as mobile nodes do not have a permanent power supply and must depend on batteries, which reduces the useful life of the network, since the batteries discharge very quickly while the nodes move and quickly change position in MANET.

This research work highlights the energy consumption in MANET by applying the Optimized Packet Forwarding (OPF) technique to optimize the energy consumption in ad hoc on demand multipath distance vector (AOMDV) routing protocol. The OPF function is used to find the optimal path from source node to destination node to reduce the energy consumption in multipath routing during the transmission of packets. The proposed method adjust it transmission range when its energy get exhausted to its one third and pursue for another path for packet forwarding. It is shown that use of variable range transmission approach achieves lower transmission power levels compared to using common-range transmission approach. Thus, the new schemes based on variable-range transmission increase the traffic carrying capacity of wireless ad hoc network, and at the same time, reduce the overall transmission power consumption in the network.

The performance of the proposed OPF_AOMDV protocol has been evaluated by using network simulator version 2, where the performance was compared with FF-AOMDV and AOMDV protocols, the two most popular protocols proposed in this area. The comparison was evaluated based on energy consumption, throughput, packet delivery ratio, end-to-end delay, network lifetime and network routing load performance metrics, varying the node speed, packet size, and simulation time.

The percentage of improvement is calculated by following equation:

$$\% \text{ of improvement} = \sum_{i=0}^{n} \left(\frac{\text{all values of FF\_AOMDV}}{\text{all values of OPF\_AOMDV}} \right) * 100\ \%$$

The simulative results given in table 2 according to Packet size shows that proposed OPF_AODV performed well and has 0.493 % of improvement in terms of energy consumption, 2.069 % of improvement in terms of throughput, 1.99 % of improvement in terms of packet delivery ratio, 9.41 % of improvement in terms of end to end delay, 10.46 % of improvement in terms of network lifetime and 2.727 % of improvement in terms of network routing load compared to existing FF- AOMDV protocol.

Table 2: percentage improvement according to Packet Size

Parameter	FF_AODV	OPF_AODV	% improvement
Packet Delivery Ratio	396.93	404.83	1.99 %
Throughput	49488	50512	2.069 %
Average Delay	132.61	120.13	9.41 %
Average Energy Consumption	10.14	10.09	0.493 %
Network lifetime	23.04	25.45	10.46 %
Routing Overhead	189.91	184.73	2.727 %

The simulative results given in table 3 according to Simulation time shows that proposed OPF_AODV performed well and has 3.389 % of improvement in terms of energy consumption, 2.85 % of improvement in terms of throughput, 4.011 % of improvement in terms of packet delivery ratio, 5.76 % of improvement in terms of end to end delay, 12.48 % of improvement in terms of network lifetime and 2.7 % of improvement in terms of network routing load compared to existing FF- AOMDV protocol.

Table 3: percentage improvement according to Simulation Time

Parameter	FF_AODV	OPF_AODV	% improvement
Packet Delivery Ratio	370.14	384.99	4.011 %
Throughput	15555	15999	2.85 %
Average Delay	75.12	70.79	5.76 %
Average Energy Consumption	6.49	6.27	3.389 %
Network lifetime	13.22	14.87	12.48 %
Routing Overhead	189.91	184.73	2.7 %

The simulative results given in table 4 according to Simulation time shows that proposed OPF_AODV performed well and has 0.465 % of improvement in terms of energy consumption, 2.265 % of improvement in terms of throughput, 1.78 % of improvement in terms of packet delivery ratio, 10.94 % of improvement in terms of end to end delay, 25.06 % of improvement in terms of network lifetime and 8.042 % of improvement in terms of network routing load compared to existing FF- AOMDV protocol.

Table 4: percentage improvement according to Simulation Time

Parameter	FF_AODV	OPF_AODV	% improvement
Packet Delivery Ratio	450.19	458.22	1.78 %
Throughput	24283	24833	2.265 %
Average Delay	71.33	63.52	10.94 %
Average Energy Consumption	10.76	10.71	0.465 %
Network lifetime	23.5	29.39	25.06 %
Routing Overhead	133.67	122.92	8.042 %

Table 2, table 3 and table 4 showed the percentage of improvement of proposed OPF-AOMDV with FF-AOMDV protocol according to packet size, simulation time and different node velocities respectively. At the right column of the table the percentage of improvement could be seen and OPF method is improvised successfully than existing FF-AOMDV.

This section highlights areas for potential future research, based on the contributions of this research paper. Many research ideas can be derived from our research work such as: Introducing similar algorithms on MANETs using the OPF method. Proposed method can be used as an underlying concept to design algorithms that can resist the other dangerous attacks such as wormhole attack, Blackhole attack. Examining this new algorithm in larger networks to confirm the success of their design and to discover and address their advantages and disadvantages in these networks. This is can be a key to enhance the OPF algorithm to achieve success in discovering and excluding only genuine faulty nodes.

REFERENCES

[1] Won-Suk Kim ; Sang-Hwa Chung, "Design of Optimized AODV Routing Protocol for Multi-interface Multi-channel Wireless Mesh Networks", IEEE 27th International Conference on Advanced Information Networking and Applications (AINA), Print ISBN: 978-1-4673-5550-6, IEEE 2013.

[2] Jung-Jae Kim ; Min-Woo Ryu ; Si-Ho Cha ; Kuk-Hyun Cho, "A Cluster Based Multi-Path Routing Protocol for Support Load-Balancing in Content-Centric Network", International Conference on Information Science and Applications (ICISA), Electronic ISBN: 978-1-4799-0604-8, IEEE, 2013.

[3] P. Selvigrija ; J. Premkumar, "Bandwidth shared acknowledgment (BSA) — A secure intrusion detection and multi path routing for MANETs", International Conference on Information Communication and Embedded Systems (ICICES2014), Electronic ISBN: 978-1-4799-3834-6, IEEE, 2014.

[4] C R Yamuna Devi ; B Shivaraj ; S. S. Iyengar ; S H Manjula ; K R Venugopal ; L M Patnaik," Multi-hop optimal position based opportunistic routing for wireless sensor networks", IEEE REGION 10 SYMPOSIUM, Electronic ISBN: 978-1-4799-2027-3, IEEE, 2014.

[5] Yiming Lin ; Weitian Huang ; Yuliang Tang, "Map-based multi-path routing protocol in VANETs", IEEE 9th International Conference on Anti-counterfeiting, Security, and Identification (ASID), Electronic ISSN: 2163-5056, IEEE, 2015.

[6] Sheng-Lung Peng ; Yan-Hao Chen ; Ruay-Shiung Chang ; Jou-Ming Chang, "An Energy-Aware Random Multi-path Routing Protocol for MANETs",IEEE International Conference on Smart City/SocialCom/SustainCom (SmartCity), Electronic ISBN: 978-1-5090-1893-2, IEEE, 2015.

[7] Gan-Gun Lee ; Hyung-Kun Park, "Partial multipath routing for mobile ad-hoc networks", Seventh International Conference on Ubiquitous and Future Networks, Electronic ISBN: 978-1-4799-8993-5, IEEE, 2015.

[8] Alexandros Ladas ; Nikolaos Pavlatos ; Nuwan Weerasinghe ; Christos Politis, "Multipath routing approach to enhance resiliency and scalability in ad-hoc networks", IEEE International Conference on Communications (ICC), Electronic ISBN: 978-1-4799-6664-6, IEEE, 2016.

[9] Bhagyashri R Hanji ; Rajashree Shettar, "Enhanced AODV Multipath routing based on node location", International Conference on Computation System and Information Technology for Sustainable Solutions (CSITSS), Electronic ISBN: 978-1-5090-1022-6, IEEE, 2016.

[10] Nagaraj M. Lutimath ; L Suresh ; Chandrakant Naikodi, "Efficient power aware multipath routing protocol for MANETs", International Conference on Circuits, Controls, Communications and Computing (I4C), Electronic ISBN: 978-1-5090-5369-8, IEEE, 2016.

[11] Mahmoud M. Shawara ; Amany M. Sarhan ; Nawal A. Elfishawy, "Energy aware Ad-Hoc On Demand Multipath Distance Vector (EA-AOMDV)", 13th International Computer Engineering Conference (ICENCO), Electronic ISBN: 978-1-5386-4266-5, IEEE, 2017.

[12] M.M. Goswami, "AODV based adaptive distributed hybrid multipath routing for mobile AdHoc network", International Conference on Inventive Communication and Computational Technologies (ICICCT), Electronic ISBN: 978-1-5090-5297-4, IEEE, 2017.

[13] Haijun Geng ; Xingang Shi ; Xia Yin ; Zhiliang Wang ; Shaoping Yin, "Algebra and algorithms for multipath QoS routing in link state networks", Journal of Communications and Networks (Volume: 19 , Issue: 2 , April 2017), Electronic ISSN: 1976-5541, IEEE, 2017.

[14] Abhay K. Meshram ; D.C. Mehetre, "Optimization of Multipath Routing for Delay and Data Integrity Using Clustering in Wireless Sensor Network", International Conference on Computing, Communication, Control and Automation (ICCUBEA), Electronic ISBN: 978-1-5386-4008-1, IEEE, 2017.