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Energy Efficient Multipath Routing Protocol For Mobile Ad-Hoc Network Using Fitness Function

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Abstract*—*Mobile Ad-hoc Network (MANET) consists of wireless mobile nodes that dynamically form a temporary network without depending on any fixed infrastructure. MANET's are distributed and the routing functionalities are carried out by mobile nodes. Energy consumption is considered as one of the major challenge as the mobile nodes do not possess permanent power supply and they rely on batteries. The paper highlights the protocols in MANET which acts as solution to the energy consumption problems. In this paper the reactive MANET protocols; Ad-hoc on-demand Distance Vector (AODV), Ad-hoc on-demand Multipath Distance Vector (AOMDV) and improved AOMDV named as Ad-hoc On-demand Distance Vector with Fitness Function (FF-AOMDV) are proposed. Fitness function is an optimization technique used for optimal route selection for data transmission. The protocols are implemented using Network Simulator (NS2). Secured data transmission is established with RSA algorithm. The performance of AODV and AOMDV routing protocols are compared with different performance metrics. The FF-AOMDV is compared with existing system. The performance metrics considered for comparison are packet delivery ratio, end-to-end delay, energy consumption, throughput and routing overheads. The results show that AOMDV protocol out-performs AODV and improved AOMDV performs better than existing system under majority of network parameters.

Keywords: Energy efficient protocol, Mobile ad-hoc network, Multipath routing, Fitness function, RSA algorithm.

I. Introduction

Nowadays Wireless Sensor Networks (WSN's) are at higher popularity in the research area. WSN belongs to ad-hoc wireless system consisting of small units known as sensors, which are distributed in space. The random spreading of nodes, sometimes gives serious impact in network coverage and connectivity. For a complete monitoring of the whole area, it must be guaranteed that an appropriate coverage with connectivity between the nodes is available. WSN plays a key role in several application scenarios such as agriculture, environment monitoring, military applications, health care, marine and so on.

Conventional methods are not good for networks like WSN for direct data transfer;

hence a protocol based approach including the conventional methods must be appropriate. Networks have been categorized into infrastructure based and infrastructure less networks. WLAN cellular network is infrastructure based, which is base station centralized. The infrastructure less includes ad-hoc networks that have no centralized access points. MANET is a wireless decentralized network that does not have any built in (or) fixed infrastructure format.

Ad-hoc networks provide optimization of bandwidth, enhancement of transmission quality and control of power which is inherited directly. It supports robust and effective operations for mobile wireless networks. In MANET's, the network topologies are dynamic, random, multi-hop and rapidly changing [1]. The topology consists of bandwidth-constrained wireless links. The network existence is affected by the battery capacity. The links gets disconnected when battery is exhausted. In most of the MANET protocol it has been noticed, the issues regarding the energy consumption and optimal route selection. The design of the protocols is necessary that dynamically adopt itself for the change in the system.

The routing through multipath protocol increases the lifetime of the network and the route, by choosing a best route during single route discovery process from many available routes. Even though the routing with multiple paths is efficient, there are many issues. Optimal path finding from source to destination is one among them, for the larger networks most of the energy is consumed for route discovery process and data transfer. The protocols in MANET transfer the data using intermediate nodes.

In MANET there are various routing protocols that are proposed considering the residual energy and energy consumption (or) both. They permit the establishment of multiple paths between two entities for data transfer [2]. Protocols in multipath routing sends a route request from sender to entire network to know all the routes that are available to the destination. But source node will not find the optimum (or) shortest path to the destination always. So, an energy efficient protocol for MANET's with multiple path routing need to be proposed.

II. Background & Related work

A. AODV Routing Protocol

AODV stands for Ad-hoc On-demand Distance Vector which self-adapts quickly and dynamically for different link conditions of the network. Figure 1 shows AODV routing table format. New route between two nodes will be discovered with the use of Route Request (RREQ) control message. Route Reply (RREP) confirms the path, and is received by sender after the predetermined amount of time once the RREQ's have been spread over the network. If a particular RREQ has been already spread over the network, and if it is broadcasted again then such RREQ will be discarded. If fresh requisition is received by any node which does not contain a strong route to the receiver, then RREQ hop-count is increased and route requisition is forwarded to the neighbors. AODV protocol has two mechanisms for route recovery for a case with failed route. When a link breakage occurs the data is transmitted using some active link in the network using Route Error (RERR) control message and it is called as local repairing of the route. The node which gets the error message will decide whether to continue (or) to stop the data transmission and it needs to update its routing table.

Destination
Sequence number
Hopcount
Nexthop
Expiration_timeout

Figure 1: Routing table for AODV

During link failure, the node will increase the sequence number and spreads the RREQ to find an additional link to destination. The packets are discarded when a time for finding a new route expires. If the time does not expire, then the data will be delivered through a new route. This may lead to delay and packet losses but overheads are reduced.

B. AOMDV Routing Protocol

Ad-hoc On-demand Multipath Distance Vector (AOMDV) routing protocol is based on AODV. AOMDV finds a route between source and destination by a route discovery process by creating a more extensive AODV protocol. AOMDV protocol is a multipath protocol that guarantees a path to be link-disjoint and loop-free and it provides two functions; discovery of route and its maintenance. The route discovery phase is used by nodes in the network to get the paths ‘on-demand’. AOMDV protocol has less overhead as it can discover multiple routes compared to AODV based on the route information [3]. The routing table for AOMDV is as shown in figure 2.

Destination
Sequence number
Advertised_hopcount
Route_list {(nexthop1,hopcount1), (nexthop2,hopcount2),...}
Expiration_timeout

Figure 2: Routing table for AOMDV

C. Route Discovery & Maintenance

Route discovery and route maintenance involve finding multiple routes from a source to a destination node. Multipath routing protocols can try to discover the link-disjoint, node-disjoint or non-disjoint routes. AOMDV’s primary idea is in discovering multiple routes during the process of route discovery. The design of AOMDV is intended to serve highly dynamic ad-hoc networks that have frequent occurrences of link failure. A new process of route discovery is necessary in the event when all paths to the destination break.

AOMDV utilizes three control packets: RREQ; RREP; and RERR. Initially, when a source node is required to transmit data packets to a specific destination, the source node broadcasts a RREQ [4]. Because the RREQs are flooded network-wide, several copies of the same RREQ may be received by a node. In the AOMDV, all duplicate copies undergo an examination to determine the potential alternate reverse path.

However, of all the resulting set of paths to the source, only the use of those copies, which preserve loop-freedom and disjointedness, get to form the reverse paths. In the event the intermediate nodes get a reverse path through a RREQ copy, it conducts a check to determine the number of valid forward paths to the destination, if RREP is generated by the node and the request is sent back to the source using the reverse path. In route discovery, the RREP has a forward path that was not employed in any prior RREPs. The RREQ is not further propagated by the intermediate node. Otherwise, the node would broadcast the RREQ copy again in case any other copy of this RREQ has not been previously forwarded and this copy has led to the updating (or) the formation of a reverse path.

Like intermediate nodes, the destination likewise forms reverse paths when it receives RREQ copies. As a response to each RREQ copy arriving through a loop-free path towards the source, the destination produces a RREP, despite forming reverse paths that use only RREQ copies arriving through loop-free and disjoint alternate paths towards the source.

A RERR packet is used in AOMDV route maintenance. In the event when link breaks it generates a RERR message listing lost destinations. The RERR is sent upstream by the node towards the source node. In the case of the existence of the previous multiple hops, which were using this link, the RERR is broadcast by the node. If there are no previous multiple hops, the request is unicast. Upon getting a RERR, the receiving node initially checks whether the node which sends the RERR is its own next hop towards any of the destination that is listed in the RERR [5]. If the sending node is indeed the recipient node's next hop, the receiving node makes this route table invalid, after which it propagates the RERR back to the source. In this manner, the RERR continues to be forwarded until the source receives the request. Once this happens, it can initiate the route discovery again if it still requires the known routes.

D. Disjoint path

Node-disjoint and link-disjoint are the two types of paths available in a network. Route with zero common nodes is called as node-disjoint path except sending and receiving node. And if no common link is found for any two (or) more routes, then such a path is called as link-disjoint path. The figure 3 represents the node-disjoint and link-disjoint paths in a network. In figure 3 (a), there is no node (or) link in common for any of the routes ABE, ACE, and ADE and hence it is a disjoint path for both node and link. The figure 3 (b) represents a path which is link-disjoint not involving a node disjoint path as the route ABCDE and ACE have node 'C' as a common node but have no common link in both the routes. The figure 3 (c) is not a disjoint path as the ABCE and ABE have node 'B' and link 'AB' as common.

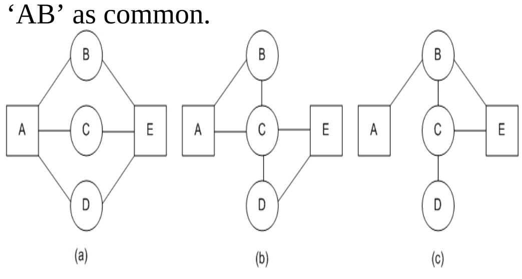

Figure 3: Disjoint path. (a) Path with link and node disjoints (b) Path showing link disjointness (c) Path which is not disjoint

E. Fitness function

It is an optimization technique that finds the crucial factors in the optimization process. The fitness factors in MANET's are energy level, distance between nodes, delay in the process of data transmission and the bandwidth of the system. In the proposed system, part of Particle Swarm Optimization (PSO) is used as a fitness function. Then optimization is achieved by sending the data via a route with shortest distance and highest energy, when energy and distance are the two factors taken for consideration. So that energy consumption by network is minimized. The fitness function is used in the network during primary route failure to optimize an alternate route. Choosing the optimal route depends on the following factors:

- Residual energy of the nodes.
- Link distance connecting neighbor nodes.
- Energy drawn by nodes in the network.
- Communication delay of the nodes.

F. Neighbor node

The nodes which have shortest distance between one another are considered to be the neighbors and are considered in the implementation for choosing an optimal route. If (x_1, y_1) is considered as the position of the node 'A' and (x_2, y_2) is considered as the position of the node 'B' in the network , then the distance 'd' between the nodes 'A' and 'B' is given by equation (1):

$$d = [(x_2 - x_1)^2 + (y_2 - y_1)^2]^{1/2} \quad (1)$$

G. Hop-count

The hop-count refers to total intermediate nodes in a path through which packets are transmitted from one point to another. Each link in the network also corresponds to the hop. Along the route, each router is a hop. In each path, if the node receives the data then hop-count is incremented by one. The destination receives the data from the path with lesser hop-count and eliminates the data from a path with highest hop-count.

H. RSA Algorithm

RSA algorithm is a cryptographic algorithm which is asymmetric, used over the computer networks to secure the data sent through internet. To encrypt the message, it uses both private and public keys. Decryption is with the opposite key. The RSA algorithm has been widely used as it provides non-repudiation, integrity, confidentiality, and authentication. The security with RSA lies in factorizing large integers which are the products of two prime numbers. The key generation is complex with the algorithm. The primality test algorithm by Robin-Miller is used for generating two prime numbers (p & q). The product of 'p' and 'q' is used for finding modulus 'n', used for both private and public keys. Public key is based on modulus 'n' and exponent 'e'. Private Key is with respect to exponent'd' and modulin'. Multiplicative inverse is obtained for the totient using Extended Euclidian algorithm. The encryption is carried using the equation (2) with 'M' being the message. And decryption is with the equation (3) with 'C' being an encrypted data.

$$C = M^e \bmod n \quad (2)$$

$$M = C^d \bmod n \quad (3)$$

In paper [6], an idea for the design of the optimizing protocol based on remaining energy of the node is discussed for MANET using genetic algorithm. It is carried by selecting a path with decreasing value of residual energy from each route, to find a node with lesser residual energy. Author in [7], defines an on-demand protocol for power awareness in the network. It is implemented by introducing power awareness to AOMDV protocol, so that path with shortest distance and high level of energy could be determined. In paper [8], researchers gave a protocol for efficiency of power in wireless systems. It is used for routing and maintenance. Protocol based on power aware is proposed that consumes minimum transmission power.

DYMO protocol with its issues and solution are discussed in this paper [9], by Yogesh and Rajesh. Each and every node in MANET must perform all the routing functions and must adjust quickly and efficiently to the network changes. The proposed protocol maximizes the data transmission reliability to provide load balancing. Improving the MANET efficiency with the use of Omni directional antennas [10] is discussed. Distinct paths between two entities are discovered for simultaneous data transfer. It is based on neighbors count in the selected route. The mechanisms in wireless networks are based on shared channel access and the data transfer via node disjoint paths is completely independent.

In paper [11], the author developed an energy-conserving protocol for improving the network lifetime. AOMR-LM protocol enhances lifetime of the network by preserving the node residual energy and by balancing the consumption of energy. Node energy level was calculated using the nodes residual energy. The PSO algorithm is used for recovery of routes that helps to predict lifetime of links. The route discovery process affects data loss, overheads and energy consumption [12]. So, a new technique is introduced that predicts the lifetime of the network based on relative nodes mobility and energy drain rate in the available bandwidth.

Prasanta Kumar and Niranjan proposed EAOMDV protocol for energy efficiency [13]. The single path routing protocol limitations are over taken with the design of multipath protocols. The idea of routing through multipath has many advantages that increased the throughput during data transmission, energy efficiency and lifetime and lowered the overall delay. Poonam and Preeti proposed an algorithm for packet forwarding [14], due to uncontrolled mobility of nodes and limitations in channel bandwidth. The proposed protocol reduces the energy consumption and avoids packet loss in wireless sensor networks. The proposed algorithm has better throughput and delay. Energy efficient multipath routing protocol with fitness function [15] is studied and its ideas are utilized for the implementation of the protocols which are discussed in this paper.

III. Proposed Protocols

In this paper, the on-demand routing protocols; AODV, AOMDV and improved AOMDV (FF-AOMDV) are implemented. The algorithm and working principles for AODV and AOMDV routing protocol implementation are as stated below.

AOMDV protocol working principles:

1. It uses the process of route discovery for making the node to be disjoint. And it aims to find the routes which are disjoint with link and are loop-free.
2. AOMDV protocol is based on destination advertised hop-count. Hop-count depends on the sequence number. The count changes if there is change in sequence number.
3. Alternate reverse paths are examined based on the copies of route requests (RREQ's).The frequent link failures are eliminated.
4. The selection of disjoint paths in AOMDV improves the fault-tolerance.
5. All the nodes in the network have a separate address and the links are two directional.
6. Source node initiates the RREQ and RREQ is sent to destination using the intermediate nodes.
7. The destination node will send the reply to the starting node using multiple paths.
8. The route with higher sequence number is used at destination.
9. Additional paths are maintained, after advertising the lengthiest path.

Algorithm for AODV routing protocol:

1. Start.
2. If routing table contains a valid route, update the table and transfer the data to intended node.
   Else
   Broadcast a signal to find another node in the network. If node found, transfer data.
3. To check whether a node is ready for transmission (or not), the destination node sends a ready signal.
   Else
   Maintain routes and activate the local route repair.
4. If the reply is from the intended destination, transmission begins.
   Else
   Go to step 3.
5. If alternate route available, go to step 3.
   Else
   Activate the local route repair and move to step 2.
6. If transmission successful, go to step 2.
   Else
   Go to stage 2.

The improved AOMDV is a multipath routing protocol called as AOMDV with fitness function (FF-AOMDV). It is a combination of the AOMDV and the fitness function. Usually in normal scenarios, a source node sends a RREQ in the network to find more than one paths to the destination. And the data will be sent over these paths without knowing route quality. So, with the proposed protocol the routes from one point to another will be chosen differently. With the proposed protocol when RREQ is broadcasted and received by intended nodes, the source will contain three types of data. With the use of this information's a shortest best route with minimum energy consumption could be found. The information that the source node contains are:

- Information regarding energy level of each node.
- Information about the distance of every link in the route.
- Information regarding the amount of energy consumed in the route discovery process

The path that consumes low level of energy could be a route with shortest distance, highest energy level (or) may be both. The source node will calculate its energy consumption, once it transfers packets through a route with high energy level. When all the routes to a destination fail, the protocol will initiate the new route discovery process. If a particular selected route only fails, then the alternate route will be chosen based on the data stored. And source will choose alternate path from routing table that has shortest distance with less energy consumption. The route which has shortest distance will consume limited amount of energy and is calculated by equation (4):

$$Optimal\ route1 = \frac{\sum_{v(n) \in r} ene(v(n))}{\sum_{v \in V} ene(v)} \quad (4)$$

Where, ‘v’ is a vertex in the optimal path ‘r’ and ‘V’ is total nodes in network. A route with highest energy level is chosen by comparing the energy among all the routes in the network. The alternate route selection is based on the distance. The proposed protocol maintains the list of links with minimum hop-count after the selection of a route with highest energy. The information about the routes with shortest distance is recorded in the routing table. The shortest path is obtained by equation (5):

$$Optimal\ route2 = \frac{\sum_{e(n) \in r} dist(e(n))}{\sum_{e \in E}} \quad (5)$$

Where, ‘e’ is links in optimal route ‘r’ and ‘E’ is total links of network.

The figure 4, represents optimal path selection process in FF-AOMDV routing protocol. The fitness function scans the entire network to locate the nodes with highest energy. A RREP will be received by the source that contains information about the available routes to a particular destination and also information about the energy levels. From the available information the fitness function will find a path with high energy and also considering route distance. The best route is the one which has high energy and shortest distance.

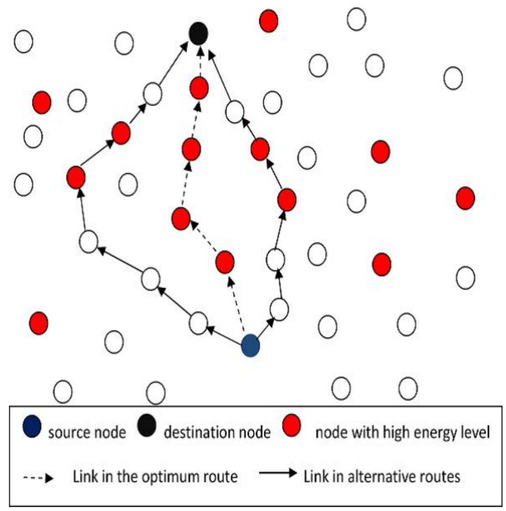

Figure 4: Optimal path selection process

The block diagram for proposed system and its work flow are as shown in figure 5 and 6 respectively.

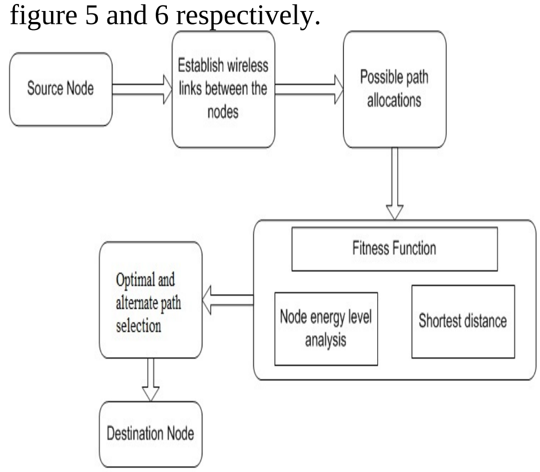

Figure 5: Proposed system working

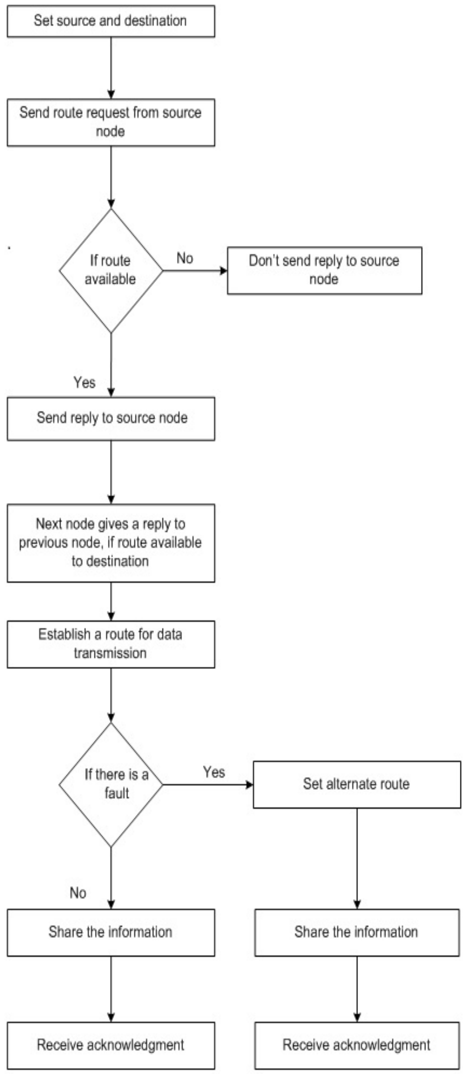

Figure 6: Proposed system work flow

IV.Results & Evaluation

A. Simulation model and parameters

To evaluate the performance of the proposed protocols the simulation parameters chosen are as represented in table I. The simulation is performed using NS2 and for all the three protocols, the parameters are studied with simulation time.

Table I: Simulation parameters

Parameters	Value	Unit
Operating system	CentOS 6.9	
Simulator	NS2.5	
Number of nodes	25,50	Nodes
Channel used	Wireless	Channel
Model of propagation	Two ray ground	Model
Queue format	DropTail	
Type of antenna	Omni Antenna	Model
Topology	Flat grid	
Queue size	50,100,340	Packets
Routing protocols	AODV,AOMDV,FF-AOMDV	Protocol
Type of data traffic	CBR	
Initial energy	10,100	Joules
Reception power	0.15,0.036	Watts
Transmission power	0.25,0.02	Watts
Sleep power	0.005,0.001	Watts

In specific for AODV protocol design, a network with 25 nodes is built with 50 packets as its queue size. For AOMDV protocol a network with 25 nodes with 100 queue size is setup. The initial energy of the nodes is 10 joules. FF-AOMDV protocol is implemented with a network of 50 nodes with 340 packets as queue size. The initial energy of the nodes is 100 joules.

B. Performance metrics

The simulations in NS2 are measured with the metrics discussed below. Implemented protocols are analyzed with the following metrics:

1. **Packet delivery ratio:** Fraction of data received at end node to data sent

by source. If the ratio is high, then the routing protocol performance and route quality are good. It is calculated by equation (5).

$$PDR = \frac{Recieved\ packets}{Sent\ packets} * 100 \quad (5)$$

2. **Throughput:** Measure of total packets received successfully at destination in terms of kilobits per second (Kbps). It helps to know the protocol efficiency and is obtained by equation (6).

$$T = \frac{Recieved\ data\ in\ bytes*8}{Duration\ of\ simulation} * 1000\ Kbps \quad (6)$$

3. **End-to-End delay:** It is the average duration taken for transmission of data successfully across the entire network between two devices. It includes total delays in the network and is given by equation (7).

$$Avg\ delay = \frac{Overall\ network\ delay}{Sent\ packets} \quad (7)$$

4. **Energy Consumption:** It is the total energy exhausted within simulation time by the nodes. It is obtained by subtracting the each node energy level from initial energy at the end of simulation, as shown in equation (8).

$$E = \sum_{i=1}^{n} (\mathrm{Initial}(i) - \mathrm{Espent}(i)) \quad (8)$$

5. **Load for normalized routing:** It is the fraction of sum of packets involved in routing to the total packets delivered. It indicates the extra bandwidth utilization during data delivery. It is formulated as in equation (9).

$$Overhead = \frac{Packets\ used\ in\ routing}{Packets\ used\ in\ routing + Sent\ packets} * 100 \quad (9)$$

V. Experimental Results

The performance of AODV and AOMDV protocols are analyzed by the AWK scripts based on the trace files. The parameters such as packets sent, packets received, PDR, throughput, average E2E delay and normalized routing overheads are formulated and are as in table II.

Table II: Performance evaluation

Metrics	AODV protocol	AOMDV protocol
Network size	25 nodes	25 nodes
Number of packets sent	606 bytes	2105 bytes
Number of packets received	480 bytes	2048 bytes
PDR	79.207 %	97.292%
Average throughput	323.18 kbps	572.40 kbps
Average E2E delay	397.621 ms	154.461 ms
Normalized routing overheads	0.904	0.00

The energy consumption, PDR and delay for AOMDV protocol are analyzed graphically as shown below.

From the performance evaluation of AODV protocol, it is evident that for a network with 25 nodes, the amount of data sent to the received ratio is around 79.207%. PDR shown by the AODV is good, as it is a protocol used for data transfer through single path. The average network delay is quite high and average throughput is quite low. It concentrates to transfer the data over a single path at a time. The normalized routing overheads are high. The AODV performs better when used for single path routing, but designing a multipath routing protocol with same concept is a better option to improve the working efficiency. And hence, a multipath routing protocol AOMDV is implemented.

The performance evaluation of AOMDV protocol shows a PDR of

The average delay and overheads are reduced. The graphical analysis of AOMDV protocol performance parameters shows that AOMDV has a constant PDR and delay is reduced with the time as shown in figure 7 and 8 respectively. But energy consumption by the devices in network is constantly decreasing with simulation time as shown in figure 9.

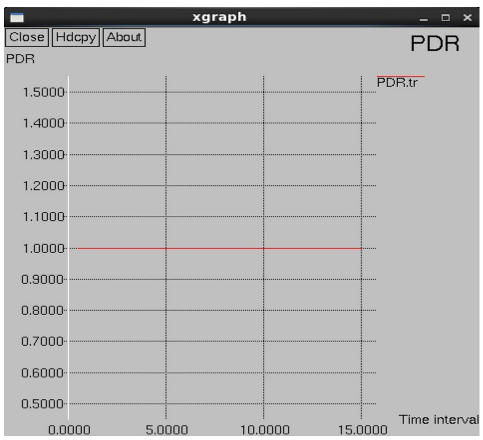

Figure7: Packet delivery ratio

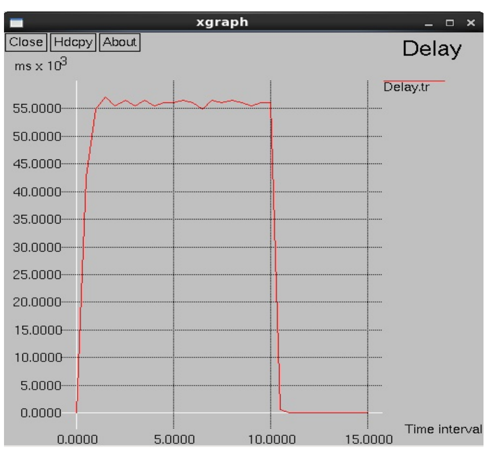

Figure8: End-to-End delay

97.2922%, that makes AOMDV a highly efficient protocol. The average throughput of AOMDV for a network with 25 nodes is high, that makes the protocol the best.

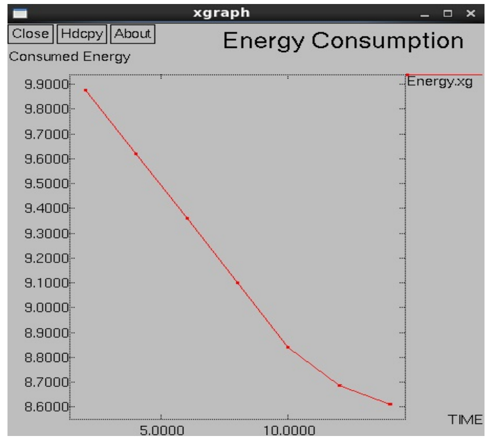

Figure 9: Energy consumption

AODV has higher routing overheads than AOMDV. As AOMDV has better performance metrics, it outperforms the AODV protocol. Energy consumption is a challenge faced by the protocols in MANET as seen for AOMDV. Hence, an improved AOMDV known as FF-AOMDV is designed to overcome energy consumption problem by the nodes and intern to improve the lifetime by choosing the most efficient path for transmission with fitness function.

The figure 10 gives the comparison of proposed system with the existing in terms of PDR. It is evident from the comparison that, PDR shown by the proposed protocol is higher than the existing system. The figure 11 is for comparison of FF-AOMDV with the existing protocol with respect to throughput. Throughput provided by the proposed protocol is very much higher than the existing, that makes the proposed more efficient. Figure 12, shows energy consumption of proposed and existing protocol. The energy consumed by the existing protocol decreases constantly with the simulation time, whereas the energy consumption of proposed protocol is constant with the time that makes it efficient with energy consumption.

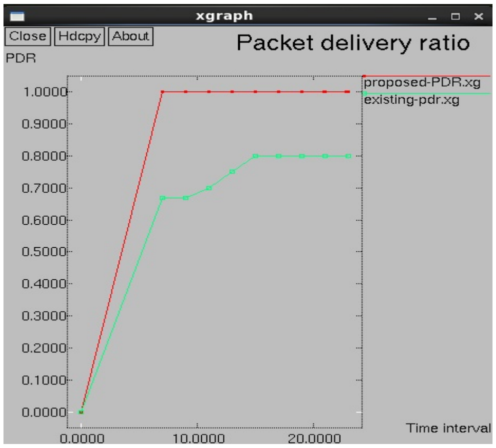

Figure 10: Packet delivery ratio

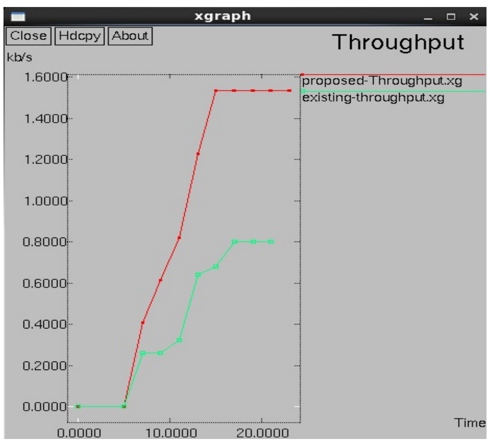

Figure 11: Throughput

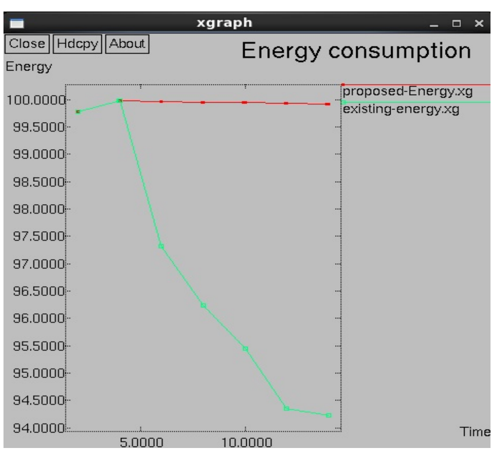

Figure 12: Energy consumption

The FF-AOMDV shows good results with PDR providing the constant delivery of the data and also good throughput of 1.5 kbps that goes constant with simulation time. The issue with energy consumption is solved with the use of the proposed protocol, as it provides a good value of residual energy with the nodes after the end of the simulation. This indicates the increased network lifetime with the use of fitness function to the AOMDV protocol.

VI.Conclusion and Future work

In this research, the proposed protocols are simulated using NS-2 with respect to simulation time. These scenarios were tested for different performance metrics. Simulation results showed that the AOMDV routing protocol outperforms AODV protocol under majority of network parameters. Conclusion can be drawn as routing protocols with multiple paths are efficient than the routing protocols with single path based on the analysis of various network metrics. The issue with the energy consumption in AOMDV is solved with design of improved AOMDV protocol. The energy consumption by the FF-AOMDV is reduced over AOMDV and also provides good results with other networking parameters. Highly secured data transmission is established as the message is encrypted using RSA algorithm before transmission and it is decrypted back to original message at the destination.

As a future work, there are several scenarios that could be implemented with this study to enhance the energy consumption and network lifetime. Further the same idea can be applied to the nodes with mobility. The fitness function can be applied to cluster based network, so that the performance of the network can further be enhanced. Along with the fitness parameters considered in the work, the bandwidth can be added as a new fitness parameter. The fitness function can be applied to other protocols in MANET and their performance can be analyzed.

References

[1]S. Giordano, “Mobile ad hoc networks,” Handbook of wireless networks and mobile computing, no. 325-346, 2002.

[2] S. Zheng, W. U. Weiqiang, and Q. Zhang, “Energy and link-state based routing protocol formanet,” IEICE Transactions on information and systems, vol. 94(5), no. 1026-1034, 2011.

[3] M. K. Marina and S. R. Das, “Ad hoc on demand multipath distance vector routing,” Wireless communications and mobile computing, vol. 6(7), 9, 2006.

[4] M. Uddin, A. Taha, R. Alsaqour, and T. Saba, “Energy efficient multipath routing protocol for mobile ad-hoc network using fitness function,” May.

[5] S. Giordano, “Mobile ad hoc networks,” Handbook of wireless networks and mobile computing, no. 325-346, 2002.

[6] B. Sun, C. Gui, and P. Liu, “Energy entropy multipath routing optimization algorithm in manetbased on ga,” Fifth international conference, IEEE, September 2010.

[7] A. Rajaram and J. Sugesh, “Power aware routing for manet using on-demand multipath routing protocol,” Journal of computer science issues, vol. 8(4).

[8] C. W. Chen and C. C. Weng, “Power efficiency routing and maintenance protocol in wireless multi-hop network,” Journal of systems and software, vol. 85(1), no. 62-76, 2012.

[9] Y. Chaba, R. B. Patel, and R. Gargi, “Issues and challenges involved in multipath routing with dymo protocol,” Journal of information technology and knowledge management, vol. 5(1), Jan-June.

[10] H. Nasehi, N. T. Javan, A. B. Aghababa, and Y. G. Birgani, “Improving energy efficiency in manet by multi-path routing,” Journal of information technology and knowledge management,2013.

[11] O. Smail, B. Cousin, R. Mekki, and Z. Mekkakia, “Multipath energy-conserving routing protocol for wireless ad-hoc networks lifetime improvement,” Journal on wireless communication and networking, EURASIP, vol. 1, no. 1-12, 2014.

[12] D. Manickavelu and R. U. Vaidyanathan, “Particle swarm optimization (pos) based node and link lifetime prediction algorithm for route recovery in manet,” Journal on wireless communication and networking, vol. 1, no. 1-10, 2014.

[13] P. K. Manohari and N. K. Ray, “Eaomdv: An energy efficient multipath routing protocol for manet,” IEEE Power, Communication and Information Technology Conference (PCITC), 2015.

[14] M. Poonam and D. Preeti, “Packet forwarding using aomdv algorithm in wsn,” International Journal of Application or Innovation in Engineering &Management (IJAIEM), vol. 3(5), pp.456-459, May.

[15] M. Uddin, A. Taha, R. Alsaqour, and T. Saba, “Energy efficient multipath routing protocol for mobile ad-hoc network using fitness functions,” May.