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Enhancing Ad hoc Networks Performance by Using Location and Energy Information

Enas Abdalla Elhaj, Mohammed Ali Abbas

The Department of Electrical and Electronics Engineering, University of Khartoum, Khartoum, Sudan

(E-mail: enas.abdalla@gmail.com, mabbas@uofk.edu)

ABSTRACT: Mobile ad hoc network (MANET) is considered to be a promising technology for the near future. This calls for more efficient mechanisms and methods to fulfil the expectation of end users and at the same time make the best use of resources. Although of its variety of applications and potentials, MANET has issues such as resource limitation, routing overhead and changing of wireless link. This paper proposes three algorithms that can diminish the overhead and energy consumption of MANET and at the same time improve the overall performance of the network. By Controlling the Route Request (RREQ) broadcasting in the Ad-hoc On-Demand Distance Vector (AODV) routing protocol using location and energy information, a better resource management and hence a better performance for the overall network is achieved.

***Keywords**: AODV, Energy aware protocol, flooding in Location based routing, Mobile Ad hoc Network MANET, RREQ.*

1. INTRODUCTION

Mobile ad hoc network (MANET) consists of a collection of mobile devices connected by wireless link, but has no any fixed infrastructure and predefined topology of wireless links. MANET nodes act as data-generating points as well as transferring data for other nodes in a multi-hop environment. The limited energy source in addition to increased computation and memory usage, makes maintaining Quality of Service (QoS) hardly applicable in Ad hoc networks.

Flooding mechanism in route setup phase consumes network resources such as energy and bandwidth. Many studies have suggested methods to enhance flooding performance in ad hoc networks by reducing the overhead messages and controlling resources such as energy. However, the overall performance of the network might be affected. So, a compromise between the overall performance of the network and overhead should always be considered. Basic flooding has been proven to cause high retransmissions, packet collisions and media congestion that can significantly degrade the network performance [1].

This paper proposes three algorithms that can diminish the overhead and energy consumption of the network, and at the same time improve the overall performance of the network. The first proposed algorithm, a method called Zone-aware ad hoc network. This method utilizes location information to enhance flooding mechanism in the AODV protocol.

The network covered area is divided into zones. Each node in the network is considered to be Global Positioning System (GPS) enabled. All nodes are moving randomly and are aware by their current zone. The algorithm allows a node to broadcast RREQ messages outside the current zone only and hence decrease the broadcast storm. The second algorithm suggested is called Energy-Balanced Ad hoc network. By distributing the energy consumption fairly among network nodes, energy consumption and overhead has noticeably decreased. The last proposed algorithm, is a mechanism that combines the first and the second algorithms. This method is called Zone and Energy Aware Ad hoc network. This method is expected to leverage the overall performance of Ad hoc network by decreasing energy, overhead and increasing throughput.

2. SURVEY OF RELATED WORK

In [1], the author had suggested a technique called the Candidate Neighbours to Rebroadcast the RREQ (CNRR) approach as a way to reduce the overhead in MANETs. The CNRR routing protocol utilizes the nodes' location information to select four neighbour nodes for rebroadcasting received RREQ messages when there is no information in the routing table for the intended destination in the RREQ packet. Two versions of CNRR were introduced and labelled: Further Candidate Neighbours to Rebroadcast the RREQ (F-CNRR) and Closest Neighbours to Rebroadcast the RREQ (C-CNRR). In order to implement these two versions, the AODV routing protocol was selected for modification. The standard AODV 'hello' message was modified in both versions of the above-mentioned protocols to enable the (x, y) coordinates of each node to be carried/shared. Author claimed that, C-CNRR selects those nodes that are closest to the sender/forwarder but not falling within the first 20% of its transmission range. This provides a greater coverage area, good channel quality and reduces redundancy because very close nodes will have similar coverage areas.

In [2], the AODV protocol was modified in order to reduce the impact of the flooding of the RREQ messages at the route discovery stage. The modified AODV (MAODV) utilizes preferred locations to rebroadcast the routing information messages. A timer is used to make the nodes that are close to the preferred locations broadcast the RREQ first. The simulation results showed that the MAODV reduced the dissemination of RREQ packets in the network.

Furthermore, paper [3] describes how location information may be used to reduce the routing overhead in ad hoc networks. Two location-aided routing (LAR) protocols are presented. These protocols limit the search for a route to the so-called request zone, determined based on the expected location of the destination node at the time of route discovery. LAR defines two schemes: scheme-1 and scheme-2. The difference resides in the way the request zone is specified within the request message. In scheme-1, the source node explicitly specifies the request zone by including the coordinates of the zone's four corners in the RREQ. Those receivers located outside the specified rectangle discard the RREQ. On the other hand, in scheme-2 the source node includes the destination's coordinates in the RREQ as well as the distance, Dists, to the destination. The receiving nodes will then calculate their distance from the destination node, and only those nodes whose distance is greater than Dists will forward the RREQ. Simulation results indicate that using location information results in significantly lower routing overhead, as compared to an algorithm that does not use location information.

In [1] another technique considering residual energy of a node and Link Life Time (LLT) is proposed. The new technique is called Link Stability and Energy-Aware (LSEA) routing protocol. It considered the Link Lifetime (LLT) between the source/forwarder node and the node receiving a RREQ packet. In addition, the protocol simultaneously considered the Residual Energy (RE) of any node in the process of receiving or sending an RREQ message. Considering these two parameters when establishing a route can help with solving MANETs' problems under mobility and energy constraints. Applying this protocol to MANETs guarantees that the selected route will be the best available route in the network with respect to the LLT and RE parameters. LSEA was developed to increase the stability of selected routes and reduce broken links, which arise from selecting an end-to-end route without any knowledge of how long the links will remain valid. LSEA was developed into two phases: as a Fixed Link Stability and Energy-Aware (F-LSEA) protocol and as an Average Link Stability and Energy-Aware (A-LSEA) protocol. The fixed threshold parameters (LLT, RE) are pre-defined in the F-LSEA routing protocol. The A-LSEA is designed to overcome the fixed thresholds for both parameters in the F-LSEA routing protocol as these two parameters should be flexible in relation to the network's condition and status.

Paper [4] proposes a new mechanism for route selection combining the AODV protocol with Ant Colony Optimization (ACO) to improve Quality of Service (QoS) in MANET. Based on the mechanism of ant colony with AODV, the finest route for data delivery is selected using the pheromone value of the path. In the proposed work, pheromone value of a route is calculated based on end to end reliability of the path, congestion, number of hops and residual energy of the nodes along the path. The path which has highest pheromone value will be selected for transmission of the data packet. The simulation result shows that the proposed scheme outperforms AODV, Dynamic Source Routing (DSR) and Enhanced-Ant-DSR routing algorithms.

In [1], a technique called Position-based Selective Neighbours (PSN) is proposed. It took advantage of both of the proposed CNRR and LSEA routing protocols. Position-based Selective Neighbours (PSN) is an intelligent routing protocol that can reduce overhead in the network to a minimum without losing reachability among the nodes. The advantages of LSEA and CNRR have been improved upon even more to achieve better routing paths that can apply a zoning concept and select four candidate nodes from each zone based on their REs and LLTs with respect to the sender/forwarder node. The proposed routing protocol gives advantages over previously introduced routing protocols by reducing unnecessary RREQs and hence their dissemination in the global network.

Moreover, Energy Aware Zone Routing Protocol (ZRP) For MANET is proposed in [5]. It uses zone and cluster-based routing to minimize the weaknesses of reactive and proactive approaches. The ZRP is a hybrid routing protocol that divides the network into contiguous zones. The proposed protocol uses a one hop clustering algorithm that splits the network into zones managed by reliable leaders that are mostly static and have abundant battery resources.

3. PROPOSED PROTOCOLS

A. Zone-aware AODV (Z- AODV) protocol

The aim of this algorithm is to decrease routing overhead in reactive routing protocols, i.e. AODV protocol.

In the Z-AODV MANET, the intended area is divided into zones where a zone is an area specified by its coordinates. In this study an area of 600 x 600 m^2 is divided into 9 zones and 18 zones respectively, as shown in Fig.1 and Fig. 2 respectively.

Each node in the network is GPS enabled. All zones areas are assumed to be equal.

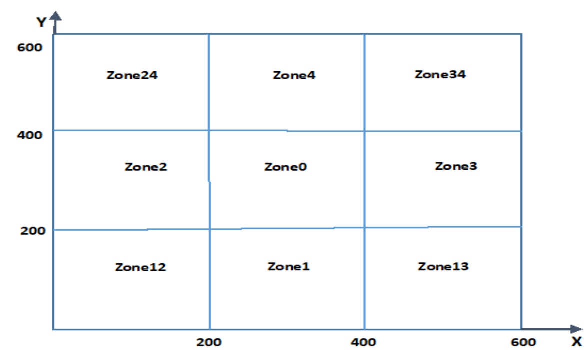

Fig .1. Nine Zones in Zone-aware MANET.

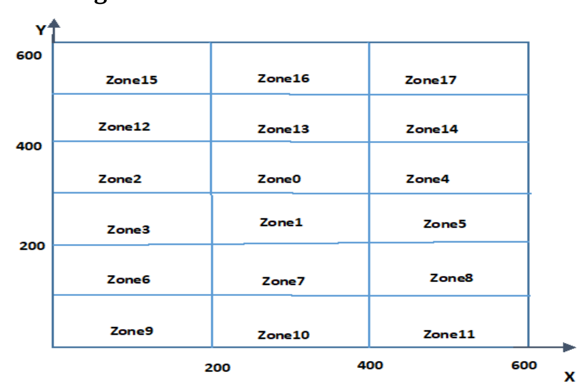

Fig .2. Eighteen Zones in Zone-aware MANET.

When a node receives a RREQ message, it checks its location using the built-in GPS to identify its zone. In this study a new field is added to RREQ message to identify node's zone as shown in Fig. 3. Although adding a new field might increase the required bandwidth for RREQ message, but a better utilization of bandwidth might be achieved if the number of RREQ messages are decreased.

Type	J	R	G	Reserved	Hop Count
RREQ ID					
Destination IP Address					
Destination Sequence Number					
Originator IP Address					
Originator Sequence Number					
Zone Value of Node rq_zone					

Fig .3. Modified Route Request (RREQ) Message Format.

When an area of 600 x 600 m^2 is divided into 9, 18 zones, zone area is almost 200 x 200 m^2 or 200 x 100 m^2 successively. A node transmission range is set to be 250m. Node transmission range reaches outside the boarders of its zone to guarantee the success of this algorithm. A node can reside anywhere in the zone. Using this approach will extend the lifetime of the network, decrease overhead message and increase the overall performance of the network.

1) Z-AODV Algorithm

An area of XY m^2 is divided into (9, 18) Zones, each zone consists of a set of nodes.

When a node decides to rebroadcast a RREQ message, it should first recognize its current zone and add the zone value in the RREQ message. Nodes that will be able to receive the RREQ message should first identify its zone value. If the zone value is the same as the one included in RREQ, this RREQ will be dropped, otherwise the RREQ message will be received by nodes in different zones.

With 18 zones Z-AODV, if a node lies around the corners of the zone, RREQ can be distributed in all directions because the diagonal of the zone is less than the transmission range of the node as shown in Fig. 4 (a). But with 9 zones Z-AODV the diagonal of the zone is greater than the transmission range of the node as shown in Fig. 4 (b).

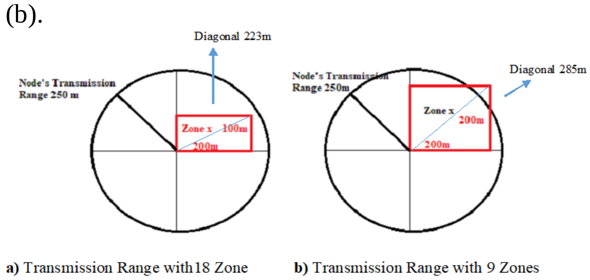

Fig .4. Transmission Range and Zones.

1) Flow chart of modified algorithm

At sender node

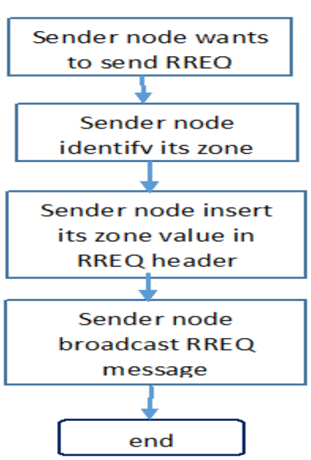

Fig .5. The algorithm for sending RREQ at the sender node.

At receiver node

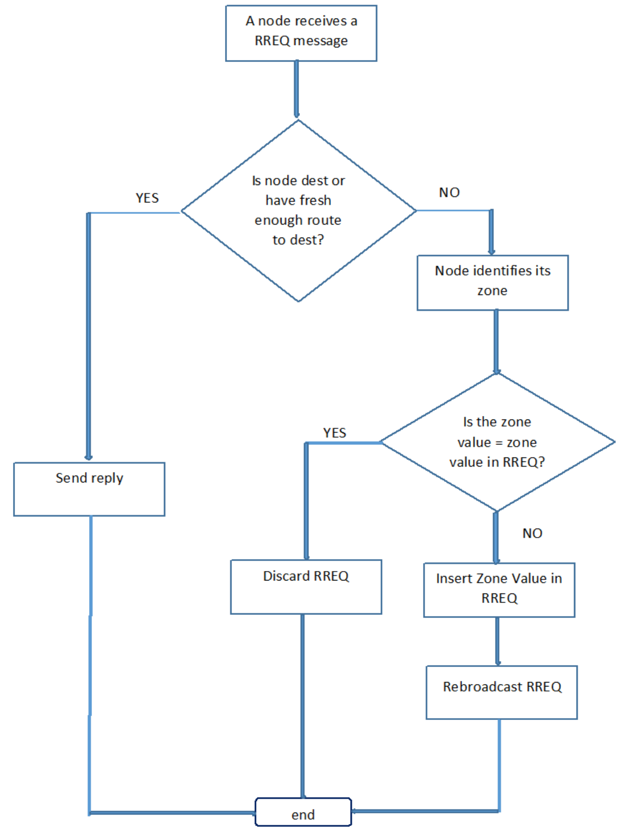

Fig .6. The algorithm for receiving RREQ at the receiver node.

B. Energy Balanced AODV (EB-AODV) Protocol

In this part, the intention is to extend the life time and make the best use of the ad hoc network. Also, using this method decreases routing packets and hence it is expected to leverage the overall performance of the network.

The proposed protocol is a modified version of the existing AODV protocol called Energy Balanced (EB-AODV). The sending node in EB-AODV is capable of calculating the Residual Energy (E_s) of the nodes in the route setup phase, then it should make it known for receiving nodes. Also, a receiving node should first determine its residual energy (Er), then compare it with (Es). Receiving nodes will not be able to receive routing packets unless their (Er) exceed a predetermined threshold that is a fraction of (Es). If Er is greater than the specified threshold, the path would be setup.

1) EB-AODV Algorithm

EB-AODV is efficient in that, it extends the life time of ad hoc network and guarantees that most important data is given priority and precedence of network resources.

Also, it prevents network partitioning that happens when some of the nodes run out of their energy earlier.

The RREQ packet has been modified. A new field is added, this field in called (rq_Es), it represents the residual energy of the sending node as shown in Fig. 7. This new field is used to provide for the receiving nodes a reference to compare the calculated residual energy against and see if it exceeds the required threshold to receive RREQ messages.

The Receive Request function is modified, so that, when the RREQ receiving node is not the destination itself, or it has no 'fresh enough' route to the destination, it should first calculate its residual energy (Er) and if Er is less than a predefined threshold that is a fraction of sending node energy, the packet would be dropped otherwise the packet would be forwarded as shown in Fig. 7.

Type	J	R	G	Reserved	Hop Count
RREQ ID					
Destination IP Address					
Destination Sequence Number					
Originator IP Address					
Originator Sequence Number					
Residual Energy of Sending Node rq_Es					

Fig .7. Modified Route Request (RREQ) Message Format

2) Flow chart of modified algorithm

At sender node

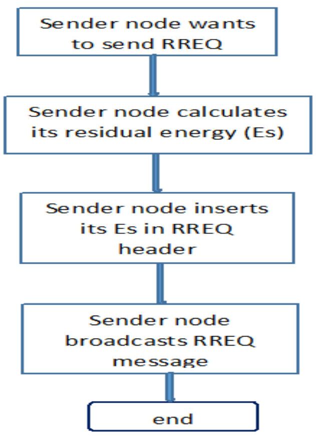

Fig .8. The algorithm for sending RREQ at the sender node

At receiver node

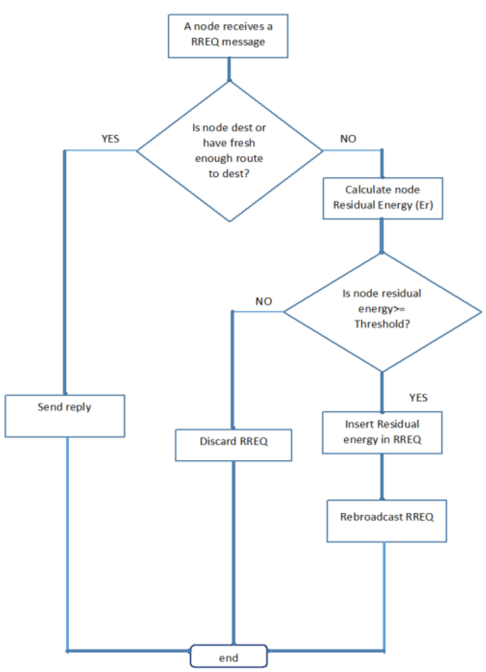

Fig .9. The algorithm for receiving RREQ at the receiver node

3) Threshold values

If the node receiving the RREQ message is not the destination, or if it does not have a fresh enough route to the destination; its remaining energy should fulfil a minimum threshold to be able to rebroadcast the RREQ messages. In this study, two cases are considered as regards the energy threshold value.

In the first case the threshold of Er is set to be equal to or greater than Es

(I.e. Er threshold >=Es).

In the second case, the threshold of Er is to be equal to or greater than two third of Es

(I.e. Er threshold >=Es/1.5).

C. Zone and Energy-Aware AODV (ZEA-AODV) Protocol

In Ad hoc networks, there are many studies that focus mainly on saving resources like energies, besides other studies which mainly highlights location information for the nodes in ad hoc networks. Previously, a method called Z-AODV protocol is proposed. This method utilizes location information to enhance flooding mechanism in ad hoc protocol (AODV).

Furthermore, an algorithm called EB-AODV is suggested. This method decreases energy consumption and overhead. In this section, a new protocol that combines the above methods is proposed. This method is called Zone and Energy-Aware AODV (ZEA-AODV) protocol. This method is expected to leverage the overall performance of ad hoc network by decreasing energy, overhead and increasing throughput. The aim of this protocol is to decrease energy consumption and routing overhead in reactive routing protocols, i.e. AODV protocol.

As rebroadcasting RREQ messages will be decided based on zone and residual energy for node, the performance may be enhanced by using the ZEA- AODV protocol. Also, in normal AODV operation, some nodes might resides in locations with more traffic. These nodes might die earlier causing link breakages and increase the overhead of the network by creating RERR messages. This inconvenience can be reduced by evenly distributing the energy load among the entire nodes in the network.

In the ZEA-AODV MANET, the intended area is divided into zones where a zone is an area specified by its coordinates. In this study an area of 600 x 600m^2 is divided into 18 zones, as it shows better performance than 9 zones division as shown in Fig.1. In each node in the network the GPS is enabled. All zones are assumed to be equal.

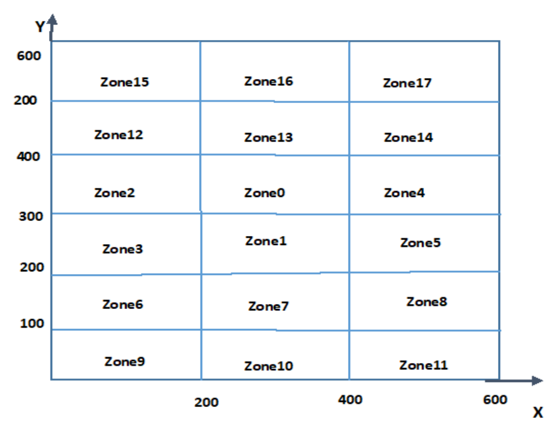

Fig .10. Eighteen Zones in ZEA-AODV Protocol

1) ZEA-AODV Algorithm

The Receive Request function is modified, that when the RREQ receiving node is not the destination itself, or it has no 'fresh enough' route to the destination, it checks its location using the built-in GPS to identify its zone. Also, it should calculate its residual energy (Er) and if Er is less than a predefined threshold, the packet would be dropped otherwise the packet would be forwarded.

In this study two fields are added to RREQ message to identify node's zone, and residual energy for sending node as seen in Fig. 11.

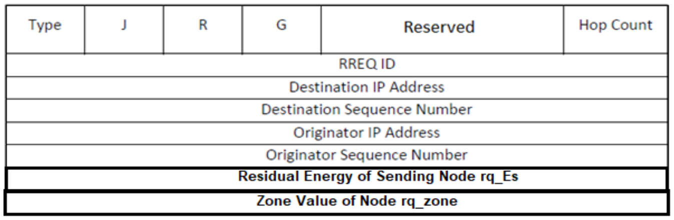

Fig .11. Modified Route Request (RREQ) Message Format

Using this approach will extend the lifetime of the network, decrease overhead message and increase the overall performance of the network.

2) Flow chart of modified algorithm

At sender node

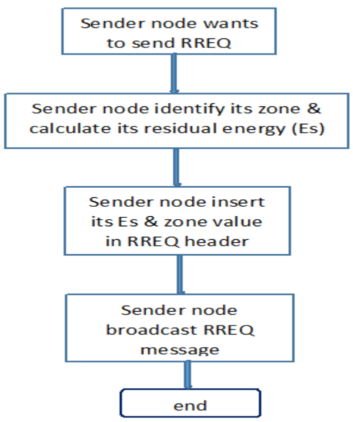

Fig .12. the algorithm for sending RREQ at the sender node

At receiver node

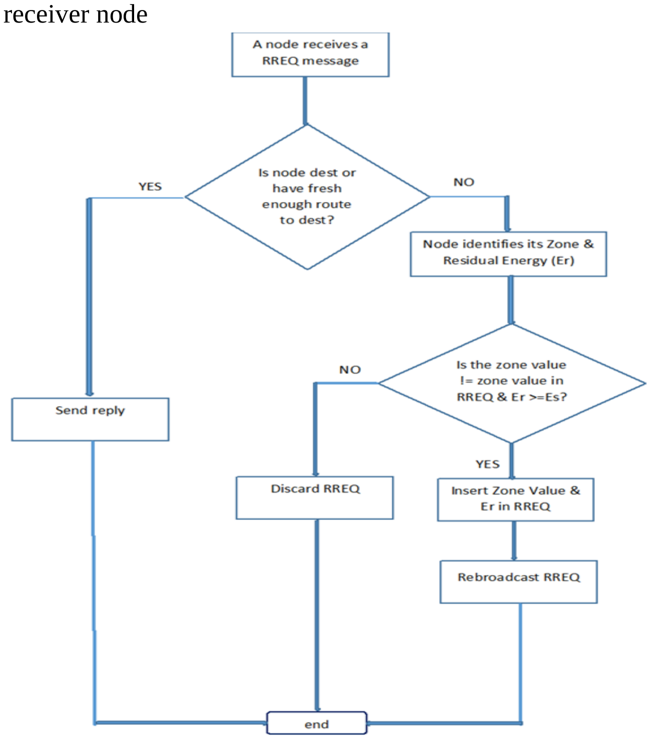

Fig. 13 The algorithm for sending RREQ at the sender node

D. Performance Evaluation

In order to evaluate the performance of the proposed protocols, mechanisms were simulated using Network Simulator NS2. The simulation environment, performance metrics and results are discussed in the subsequent sections.

1) Simulation Environment

Evaluations of the network's performance were conducted for 30 to 100 mobile nodes that were distributed in an area of 600 x 600 m^2. The communication range of the wireless nodes is set at the default distance of 250m. The transmission range of the node can be adjusted from the two ray ground formula, as below [6]:

$$P_r = (P_t * G_t * G_r * (h_t^2 * h_r^2)) / d^4 L \quad (1)$$

Pr and Pt are the receive power and transmit power respectively, Gt and Gr is transmit and receive antenna gain, ht and hr are transmit and receive antenna height, L is the system loss and d is the distance (transmission range of the node). The default radio coverage range of the node is 250 meter.

The following simulation parameters are set to run the experiment as shown in Table 1. These are some of the options available in the NS2 simulator.

Table 1. Simulation Parameters.

Channel type	**WirelessChannel**
Radio-propagation model	TwoRayGround
Network interface type	Phy/WirelessPhy
MAC type	Mac/802_11
Interface queue (ifq) type	Queue/DropTail/PriQueue
Antenna model	Antenna/OmniAntenna
Max packet in Interface Queue Length (ifq) (ifqlen)	200
Number of mobile nodes	30-100
Routing protocol	AODV
X dimension of topography	600
Y dimension of topography	600
Traffic Type	UDP traffic (CBR)

2) Performance Metrics

- Total consumed Energy (Etot): the total amount of energy consumed by all nodes in the network during the simulation time.

$$Etot = \sum_{i=0}^{n} Ei \quad (2)$$

Where n is the number of nodes and Ei is the energy consumed by the node i.

- Average consumed Energy (Eavg): the average energy consumed by a single node in the network during the simulation time

$$Eavg = \text{Etot}/\text{n} \quad (3)$$

- Packet Delivery Function (PDF): the ratio of those data packets successfully delivered to the destinations to those generated by the CBR sources.

*PDF= (Received Packets /Generated Packets) * 100* (4)

- Normalized Routing Load (NRL): it is the ratio between the total numbers of routing packets sent over the network to the total number of data packets received.

- Total End-to-End Delay: the total delay, which includes all possible delays caused by buffering during the route discovery and link recovery phases, queuing at the interface queues and retransmission delays at the MAC layer.
- Total Data Dropped: the total amount of data dropped in the network.
- Throughput: or network throughput is the rate of successful message delivery over a communication channel. Throughput is usually measured in bits per second (bit/s or bps).

Throughput =(recvdSize/(stopTime-startTime))*(8/1000) in Kbps (5)

4. RESULTS

a. Z-AODV Protocol

In this part the performance of the proposed Z-AODV protocol is compared with that of the AODV protocol. In the simulation, the number of nodes is increased from 30 to 100. Also, the Initial energy is set to be 250 Joules, and the simulation time is 700 S. The results compare Z-AODV protocol to AODV protocol using the following parameters, Etot, Eavg, NRL, Average End-To-End Delay, Dropped data (packets) and Throughput.

2) Total consumed Energy (Etot) and Average consumed Energy (Eavg)

Fig. 14 and Fig. 15 show that, as the number of nodes increases from 30 to 100, the average energy consumed by a node (Eavg) is slightly decreased. Furthermore, the total consumed energy (Etot) increases gradually as the number of node increases for all scenarios as it is expected. From graphs, the energy consumption for Z-AODV is less than the normal AODV, this is due to decrease in broadcast storm achieved by Z-AODV.

Also, with 18 zones, Z-AODV make less consumption than 9 zones Z-AODV in most cases. With 18 zones Z-AODV, if a node lies around the corners of the zone, RREQ can be distributed in all directions because the diagonal of the zone is less than the transmission range of the node, Fig.4 (a). But with 9 zones Z-AODV the diagonal of the zone is greater than the transmission range of the node, Fig.4 (b), hence it provides less coverage than 18 zones Z-AODV which leads to more errors, rebroadcasts and energy consumption, Fig.4. When the number of nodes exceeds 70, the performance of the three scenarios is almost the same. This is due to extra broadcasts in Z-AODV, hence extra errors, drop and congestions.

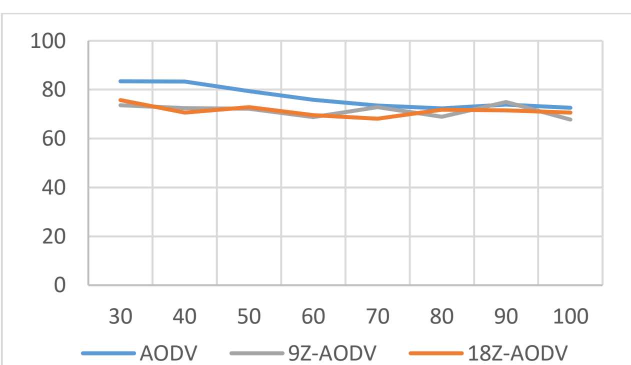

Fig .14. Average Energy VS Number of Nodes

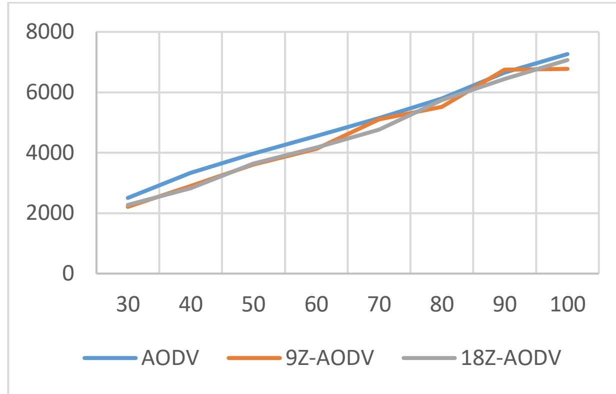

Fig .15. Total Energy VS Number of Nodes

3) Normalized Routing Load (NRL)

When the number of nodes is around 70, NRL in the new approach is better than normal AODV. The new approach has better flooding mechanism because it decreases the number of routing messages as all zones would rebroadcast RREQ messages out the range of their zones and hence decrease NRL. In normal AODV all neighbours rebroadcast RREQ message. The redundancy of RREQs affects the performance of the whole network in terms of the packet delivery ratio, throughput, delays and overhead.

When nodes are beyond 70, Z-AODV shows increase in NRL due to extra probable neighbours, rebroadcasting, errors and overhead.

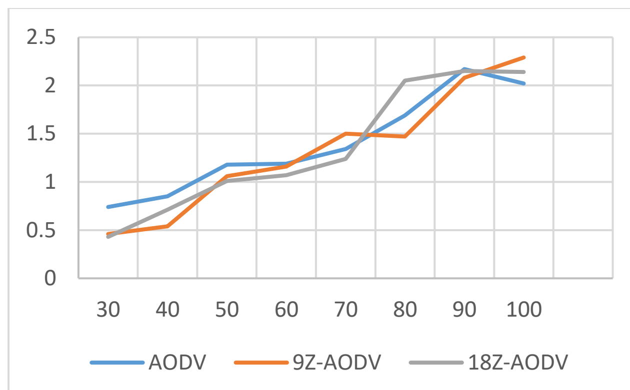

Fig .16. NRL VS Number of Nodes

4) Average End to End Delay

Fig.17 shows that Z-AODV has a slight increase in delay than AODV. This is due to decrease in routing messages which leads to more delay as finding the best route might consumes extra time.

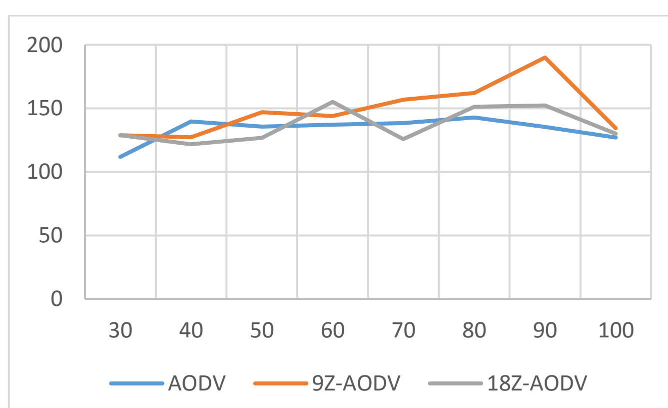

Fig .17. Average End to End Delay VS Number of Nodes

5) Dropped Data (Packets)

It is obvious that, when the number of nodes is less than 70, dropping in AODV is more than it in Z-AODV. But as the number of nodes increases, dropping of packets increases in Z-AODV.

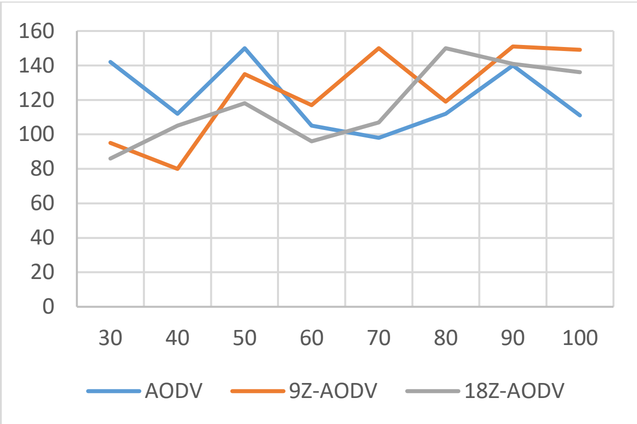

Fig .18. Dropped Data VS Number of Nodes

6) Throughput

Throughput is better in Z-AODV compared to AODV as the number of nodes is less than 70. As the number of nodes increases, AODV makes better throughput than Z-AODV. This is due to the increased drop and delay in Z-AODV when the number of nodes is more than 70.

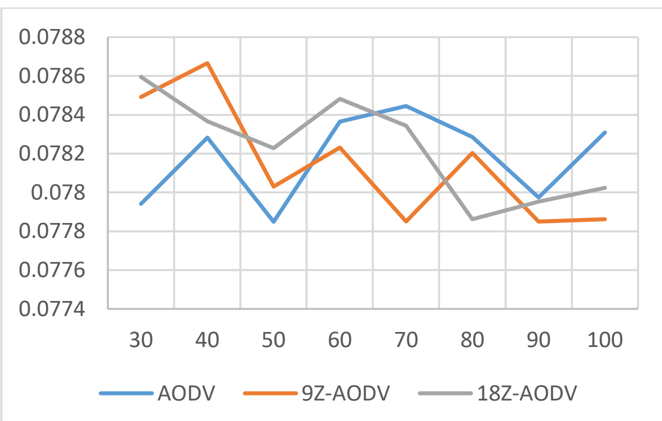

Fig .19. Throughput VS Number of Nodes

b. EB-AODV Protocol

In this part, the performance of the proposed EB-AODV protocol is compared with that of the AODV protocol. In the simulation, the number of nodes is increased from 30 to 100. In addition, the Initial energy is set to be 250 Joules, and the simulation time is 700s. The result compares EB-AODV to AODV using the following parameters Eavg, NRL, Dropped data (packets) and Throughput.

1) Average consumed Energy (Eavg)

Fig. 20 shows that, as the number of nodes increases from 30 to 100, the average energy consumed by a node (Eavg) is slightly decreased as it is expected.

From graphs, the energy consumption for EB-AODV is less than the normal AODV, this is due to decrease in broadcast storm achieved by EB-AODV. Furthermore, EB-AODV-S1 makes less consumption than EB-AODV-S2. EB-AODV-S1 makes best energy saving because it makes the most decreases in flooding of RREQ messages, hence, it provides fair energy distribution among all nodes which leads to better performance as it decreases congestion and errors in the network.

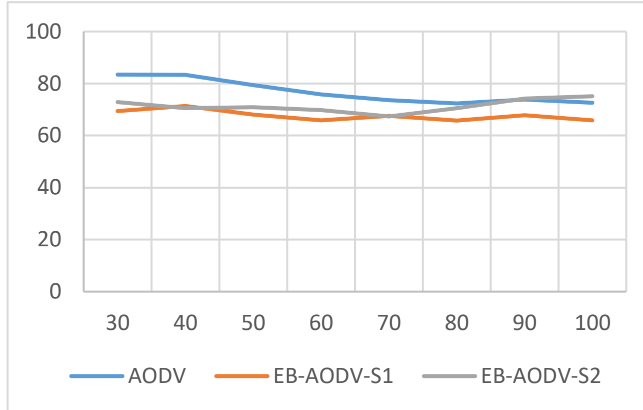

Fig .20. Average Energy VS Number of Nodes

2) Normalized Routing Load (NRL)

NRL in EB-AODV approach is better than normal AODV. The new approach has better flooding mechanism because it decreases the number of routing messages as nodes would rebroadcast RREQ messages with specified condition. In normal AODV all neighbours rebroadcast RREQ message. The redundancy of RREQs affects the performance of the whole network in terms of congestion and overhead.

EB-AODV-S1 shows the lowest routing overhead as it provides the least flooding for RREQ messages. When Er (threshold) is greater than or equal to Es, this means only higher energy neighbours would be able to rebroadcast RREQ and hence a smaller number for neighbour nodes than in EB-AODV-S2.

When the number of nodes increases, EB-AODV-S2 shows higher NRL. This is due to the larger number for neighbouring nodes to rebroadcast RREQ compared to EB-AODV-S1.

Therefore, EB-AODV-S1 provides more available bandwidth for real data, less congestion and error.

Moreover, in normal AODV operation, some nodes might reside in locations with more traffic. These nodes might die earlier causing link breakages and increase the overhead of the network by creating Route Error (RERR) messages. This inconvenience can be avoided by distributing the energy load among the entire nodes in the network using EB-AODV-S1.

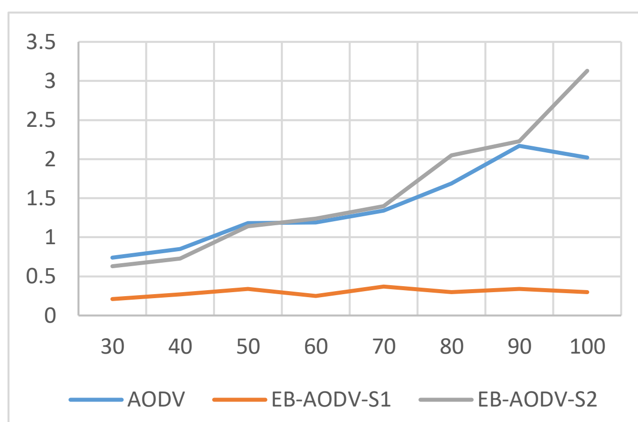

Fig .21. NRL VS Number of Nodes

3) Dropped Data (Packets)

It is obvious that, when the number of nodes is less than 70, dropping in EB-AODV-S1 is less than it is in AODV and EB-AODV-S2. But as the number of nodes increases, dropping of packets increases slightly in EB-AODV-S1. Dropping is less due to less number of routing overhead in EB-AODV-S1.

As number of node increases EB-AODV-S2 shows the worst delay due to more broadcasting, congestion and errors.

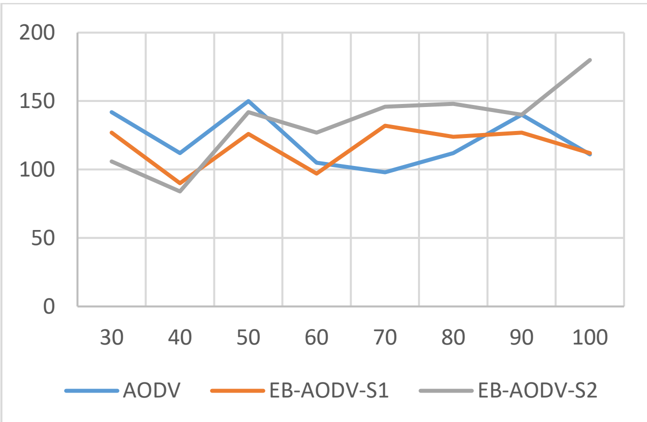

Fig .22. Dropped Data VS Number of Nodes

4) Throughput

For the overall performance, throughput is almost the same for the three scenarios with a slight increase in EB-AODV-S1. Fewer rebroadcasts result in less bandwidth consumption by redundant RREQ packets. Furthermore, this also reduces collisions and computations among the nodes when accessing a channel.

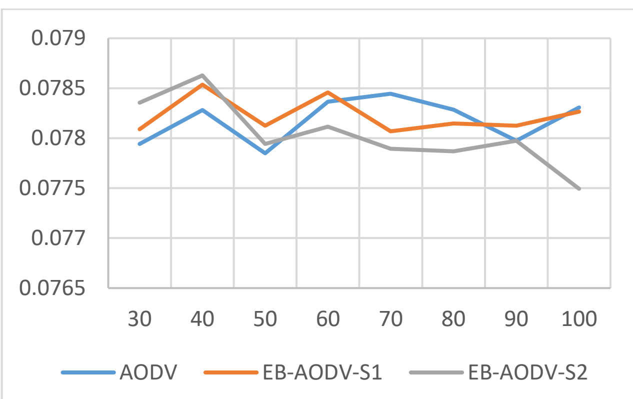

Fig .23. Throughput VS Number of Nodes

c. ZEA-AODV Protocol

In this part, the performance of the proposed ZEA-AODV protocol is compared with that of the AODV, Z-AODV and EB-AODV protocols. In the simulation, the number of nodes is increased from 30 to 70. In addition, the Initial energy is set to be 250 Joules, and the simulation time is 700s. The results compare ZEA-AODV to AODV, Z-AODV and EB-AODV protocols using the following parameters, Etot, Eavg, PDF, NRL, Average End-To-End Delay, Dropped data (packets) and Throughput.

1) Total consumed Energy (Etot) and Average consumed Energy (Eavg)

Fig. 24 and Fig. 25 show that, as the number of nodes increases from 30 to 70, the average energy consumed by a node Eavg is slightly decreased, and Etot is increased for all scenarios as it is expected.

From graphs, the energy consumption for ZEA-AODV is less than the normal AODV and other proposed mechanisms, this is due to decrease in broadcast storm achieved by ZEA-AODV. It is noticeable that, when the number of nodes is less than 70, decrease in energy consumption is greater than it when the number of nodes exceeds 70.

Using threshold for receiving node energy, leads to fair energy distribution among nodes leads to better performance as it decreases congestion and errors in the network.

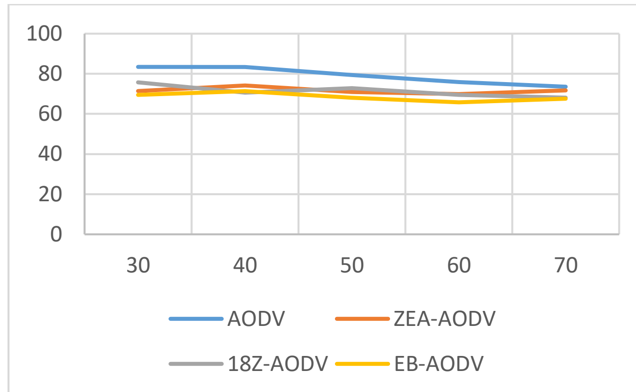

Fig .24. Average Energy VS Number of Nodes

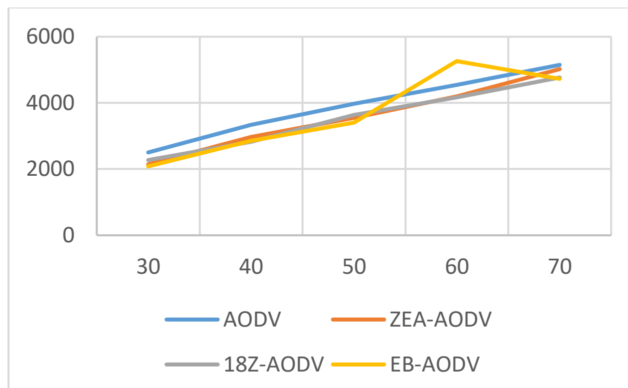

Fig .25. Total Energy VS Number of Nodes

2) Packet Delivery Function (PDF)

PDF is almost the same for all scenarios. ZEA-AODV has a slight increase in PDF when the number of nodes is less than 70. As the number of nodes exceeds 70, ZEA-AODV provides almost the same PDF as AODV.

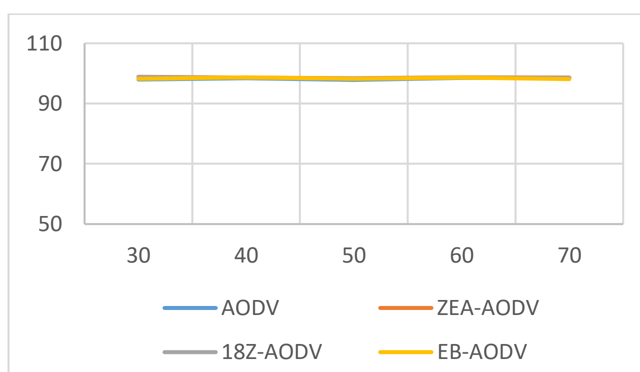

Fig .26. PDF VS Number of Nodes

3) Normalized Routing Load (NRL)

When the number of nodes is less than 70, NRL in the new approaches is better than normal AODV. The new approaches have better flooding mechanism because they decrease the number of routing messages using either Zone Aware mechanism or Energy Balanced mechanism. Besides, ZEA-AODV both previous mechanisms are considered before route setup.

In normal AODV all neighbours rebroadcast RREQ message. The redundancy of RREQs affects the performance of the whole network in terms of the packet delivery ratio, throughput, delays and overhead. EB-AODV shows the less NRL because only higher energy neighbour would be able to rebroadcast RREQ and hence a smaller range for neighbour nodes is given than in scenario 3.

As the number of nodes exceeds 70, ZEA-AODV has an increase in routing messages because the energy threshold would be achieved in most neighbours as the average consumed energy is decreased when the number of nodes increased. Also, when the number of nodes increases, more nodes outside the zones are increased too. This might leads to extra flooding and hence, more congestion and errors in the channel.

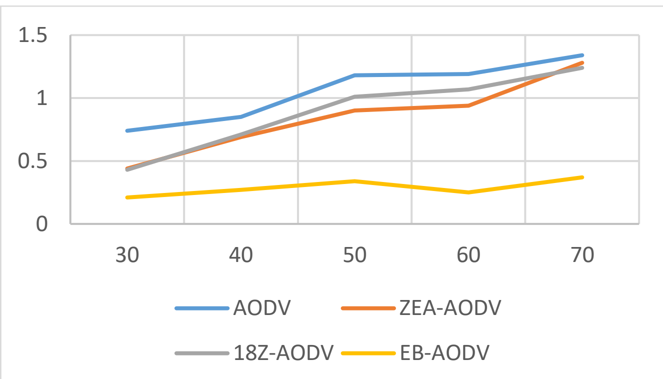

Fig .27. NRL VS Number of Nodes

4) Average End to End Delay

Fig. 28 shows that, when the number of nodes is less than 70, ZEA-AODV has a slight decrease in delay than AODV. This is due to decrease in flooding mechanism, which leads to less congestion and delay. When number of nodes is around 70, more congestion occurs which leads to extra delay.

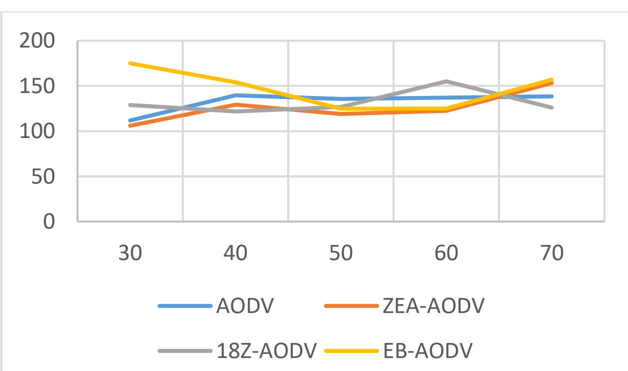

Fig .28. Average End to End Delay VS Number of Nodes Dropped Data (Packets)

5) Dropped Data (Packets)

It is obvious that, when the number of nodes is less than 70, dropping in AODV is more than it in other proposed scenarios. In ZEA-AODV less dropping is achieved because of less routing messages and congestion in the network.

But as the number of nodes increases, dropping of packets increases in ZEA-AODV due to extra congestion and error.

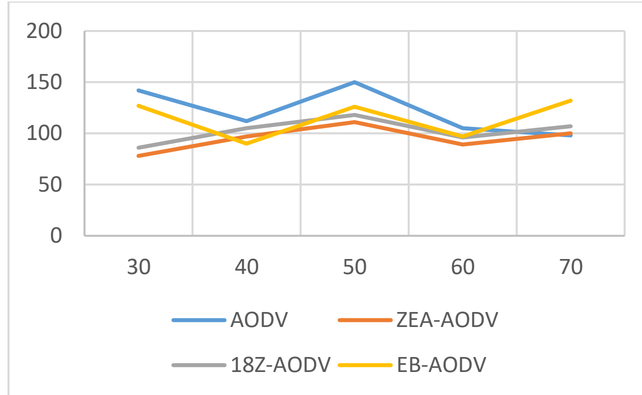

Fig .29. Dropped Data VS Number of Nodes

6) Throughput

Throughput is the best in ZEA-AODV compared to AODV and other proposed scenarios as the number of nodes is less than 70 nodes. This is due to less delay and dropping when the number of nodes is less than 70.

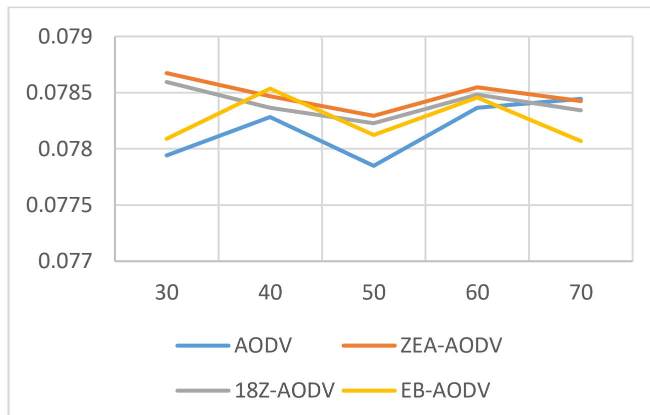

Fig .30. Throughput VS Number of Nodes

5. CONCLUSIONS

1. The concept of Zone-aware AODV (Z-AODV) is to divide the MANET area into zones to be able to control the flooding mechanism for the entire network. This leads to more consistence and efficient performance as simulation results show that, when the number of nodes is less than 70, Z-AODV noticeably provides less energy consumption, less overhead, better throughput, high packet delivery ratios and low levels of data drops.

   Fewer rebroadcasts result in less bandwidth consumption by redundant RREQ packets. Furthermore, this also reduces collisions and computations among the nodes when accessing a channel.

   When nodes are less than 70, the simulation results show that the proposed algorithm has a significant effect, as in 18 zones Z-AODV energy is reduced by up to10%, overhead is decreased by 18%, drop has decreased by 13% and throughput has a slight increase by up to 0.21% compared to AODV. Whereas in 9 zones Z-AODV energy is reduced by up to 9%, overhead is decreased by 15%, drop has decreased by up to 1.4% and throughput increased by 0.15% compared to AODV. Moreover, when nodes is less than 70, 18 zones Z-AODV delay has not affected, but with 9 zones Z-AODV delay has increased by 6.6%.

Even if the number of nodes is increased, Z-AODV provides better energy consumption and hence increases the life time of the network and provides an overall enhancement in the performance.

It is clear that, 18 zones Z-AODV, is better than 9 zones Z-AODV. Applications that require more bandwidth, more accuracy and longer lifetime can make use of the newly proposed protocol.

2. The Energy Balanced AODV (EB-AODV-S1) protocol shows a better performance compared to the other scenarios. It noticeably provides less energy consumption, less overhead, better throughput, low end-to-end delay, high packet delivery ratios and less level of data drops. Also, in normal AODV operation, some nodes might resides in locations with more traffic. These nodes might die earlier causing link breakages and increase the overhead of the network by creating RERR messages. This inconvenience can be exceeds by distributing the energy load among the entire nodes in the network.

   The simulation results show that the proposed algorithm has a significant effect as it reduces the energy by up to 12%. Also, the overall performance shows a decrease in the overhead by up to 76% in EB-AODV-S1.

   In general, EB-AODV-S1 provides less drop by up to 2%, and the throughput is slightly increased.

3. When the number of nodes is less than 70, Zone and Energy Aware AODV (ZEA-AODV) protocol shows more reliable and consistent performance than AODV and other proposed protocols. This mechanism combines both of the previously discussed methods EB-AODV and Z-AODV. It utilizes advantages of both methods in that, it decreases overhead as EB-AODV and control delay as Z-AODV. Simulation results show that, when the number of nodes is less than 70, ZEA-AODV noticeably provides less energy consumption, less overhead, better throughput, low end-to-end delay, high packet delivery ratios and low levels of data drops compared to AODV protocol.

   In ZEA-AODV, when number of nodes is less than 70, simulation results show that energy consumption has decreased by up to 9%, drop has decreased by 20%, delay has decreased by 5% and overhead has decreased by up to 22%. However, there is no significant increase in throughput which has increased only by 0.32% compared to normal AODV.

   Generally, ZEA-AODV provides better performance when the number of nodes is less than 70 compared to normal AODV. As the number of nodes increases beyond 70, more delay and drop is made by ZEA-AODV.

   Even if the number of nodes is increased, ZEA-AODV provides better energy consumption and hence increases the life time of the network.

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