



## Modelling and Analysis of GPS Error Effect on the Zone and Energy Aware-AODV (ZEA-AODV) Protocol

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**ABSTRACT:** The Zone and Energy Aware protocol based on the Ad hoc On demand Distance Vector (AODV) protocol (ZEA-AODV) provides a superior performance compared to the classic AODV protocol when number of nodes is less than 70 [1]. ZEA-AODV protocol is using location and energy information to reduce energy consumption and routing overhead. It is a combination of the two proposed protocols, Zone-aware AODV (Z-AODV) protocol and Energy-Balanced AODV (EB-AODV) protocol. In [1], we assumed that each host knows its current location precisely. In this paper, Global Positioning System (GPS) error is considered, therefore, the standard GPS error is modelled by generating two samples for movement of a terminal by simulation. One of the movements is as a simulation of the actual movement, and the other one as a simulation of the error. Then both movements are provided to the terminal. This GPS error modelling is considered in the case of ZEA-AODV protocol to investigate the effect of such error on its performance. Using the simulation, it is found that, although the overall performance of ZEA-AODV protocol is degraded when GPS error is considered, but energy conservation is noticeably still better than that of normal AODV protocol.

**Keywords:** AODV, ZEA-AODV, Location aware protocols, GPS error modelling, Mobile Ad hoc Network MANET

### 1. INTRODUCTION

The proposed protocol ZEA-AODV is using location information to reduce energy consumption and routing overhead. This location information used in the ZEA-AODV protocol are supposed to be provided by the Global Positioning System (GPS) [1]. With the availability of GPS, it is possible for a mobile host to know its physical locations. In reality, position information provided by GPS includes some amount of error, which is the difference between GPS-calculated coordinates and the real coordinates.

For instance, the accuracy for longitude and latitude coordinates is of 10-15 meters in 95% of the readings. Sometimes, it is more precise, but it depends on a variety of factors that include the deviation or the delay of the signal when crossing the atmosphere, the bouncing of the signal in buildings or its concealment due to the presence of trees, low accuracy of clocks and noise in the receiver [2][3].

GPS is a Mobile Ad Hoc Networks Positioning system that uses radio navigation technique to explore devices or environments. GPS consists of 24 satellites within the six orbital planes that operate in a circular manner of 10,900 nautical miles (20,200 km) orbits with an inclination angle of 55 degrees and with a 12-hour period. GPS operates in an L-band frequency (1575.42 and 1226.6 MHz), and is useful in all spheres of life both in the Agro business, the taxi cab system, crude oil refining, military, intelligence, and public sectors. Orbital messages are transmitted from the satellites in the sky and this contains some elements, clocks, and statuses which are useful to the GPS receiver to trace its positioning and the speed rate in terms of velocity. Three satellites are required in determining the latitude and longitude from the transceiver and also the receiver's height and elevation [4].

The exactness of some readings is supported by the provision of additional satellites. This will also ensure an adequate accuracy From the readings and to support ground station operations.

To improve its accuracy, assistance from ground stations can be applied. Such systems, called differential GPS (DGPS), can reduce the error to less than a few meters [5].

In this paper, GPS error is modelled to analyse its effect on ZEA-AODV protocol. Also, as zoning concept can affect the GPS error, 18 zones ZEA-AODV will be compared to 9 zones ZEA-AODV with GPS error and without GPS error.

Assuming that, standard GPS is used, although more accurate GPS can be used, its error is modelled by generating two samples for movement of a terminal by simulation. One of the movements is a simulation of the actual movement, and the other one is a simulation of the error. Then both movements are provided to the terminal. This GPS error modelling is provided with ZEA-AODV protocol to discover how the performance of ZEA-AODV protocol is affected.

In our study, the exact location of the sending or receiving node is not the main concern, the concern is the zone where the node resides. The intended area for Mobile Ad hoc Network (MANET) is 600 x 600 m<sup>2</sup> which was divided into 18 zones with 200 x 100 m<sup>2</sup> for each zone. Each node supposed to realize its location as nodes are GPS enabled. The zone is defined as a virtual area used to identify approximate location of a node, so any nodes belong to the same zone are certainly close to each other even if we consider the GPS location error.

In the proposed algorithm Zone and Energy Aware AODV (ZEA-AODV) protocol, using the of the zoning concept this way can decrease the effect of GPS location error as the objective is to recognize the area close to the sender node so as to block Route Request (RREQ) messages from close neighbours within the zone of the sender node.

For example, if node (i) resides in zone (x) but with GPS it appears as it resides in zone (y) where both zones are adjacent, this means that this node is close to the boarder of zone (x) which makes the node within the range of GPS location error. According to the proposed algorithm, the RREQ messages contain a field which identify the zone number, in this case this field will contain the value (y). Therefore RREQ messages broadcasted from this node will not be received by nodes reside in zone (y). But neighbours reside in zone (x) and other zones would be able to receive the RREQ messages.

This will affect the performance of ZEA-AODV protocol and the flooding mechanism might be controlled with some errors. Hence, the energy consumption and the overhead will be affected.

## 2. LITERATURE REVIEW

According to [6], Location based routing protocols works best in the case of given performance parameters if the location information is known. Getting updated location information is very critical task as there are limitations on using GPS in MANET. GPS cannot be used to get location information of nodes within the MANET in some cases. For indoor network GPS cannot be used because there is a problem of GPS range inside the houses or offices. For smaller wireless devices or sensor node it is difficult to install GPS hardware and antenna over it. GPS is very expensive for such small devices or networks. In standard GPS there is location error up to 20-30 meters. For MANET such error cannot be tolerated. If MANET is highly dense, that means nodes are very close to each other within network then GPS can't be used in such cases.

Also, in [7] 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. Simulation results indicate that using location information results in significantly lower routing overhead, as compared to an algorithm that does not use location information. Also, LAR schemes use location information to attempt to improve routing performance. Intuition suggests that when location error is very large, such schemes would not be very effective. Further work is needed to determine at what location error levels proposed LAR schemes become ineffective.

Moreover, there are many studies that had suggested methods to enhance the positional accuracy of GPS systems.

In [2], techniques are introduced to determine the magnitude and direction error of GPS system. With this error vector it is possible to correct any low cost standard GPS receiver to improve the positional accuracy. DGPS requires a base station with a GPS receiver in a precise known position. The base compares its known position with that calculated by the satellite signal. The estimated difference in the base is applicable then to the mobile GPS receiver as a differential correction with the premise that any two receivers relatively near experiment similar errors [3]. The experiment carried out is based on the principle of the adopted methodology by the DGPS but with a low cost standard GPS receiver. The technique developed allows to obtain magnitude and direction error of the GPS system. This correction is used by another receiver to correct its own position and thus increase the positional accuracy with the aim of measuring the most precise distances. The experiments carried out with different sets of data provide positions that are used to measure distances and error fluctuates in  $\pm 1$  meter in the 95% of measurements and in some cases about  $\pm 0.20$  meters. In addition, with the techniques used it is possible to prevent peak error measures over 15 meters.

Also in [8], the static-mode of GPS measurement technique has been utilized to establish a precise geodetic network in Khartoum State. The network was referenced to a single control station that is related to the International Terrestrial Reference Frame (ITRF 2005). A number of six points have been constructed and observed around Khartoum State. In particular, seven observation sessions were conducted that gave an over determined system. The least-squares method was used in the adjustment of the GPS network. Two methods were utilized for the adjustment, namely, the parametric and the condition equation methods. The most probable values of the coordinates of the newly-established points were computed from both methods and they were found to be identical. The average standard deviation of the X, Y, and Z coordinates are  $\pm 1.36$  cm,  $\pm 1.12$  cm, &  $\pm 0.69$  cm respectively.

Furthermore, some studies have discussed the Internet of Thing (IoT) concept with MANET networks. As in [9], Internet of things (IoT), is an innovative technology which allows the connection of physical things with the digital world through the use of heterogeneous networks and communication technologies. IoT in smart environments interacts with wireless sensor network (WSN) and mobile ad-hoc network (MANET), becoming even more attractive and economically successful. Interaction between wireless sensor and mobile ad hoc networks with the internet of things allows the creation of a new MANET-IoT systems and IT-based networks. Such systems give the user greater mobility and reduce costs. At the same time new challenging issues are opened in networking aspects.

Alameri[9] proposed a routing solution for the IoT system using a combination of MANET protocols and WSN routing principles. The presented results of solution's investigation provided an effective approach to efficient energy consumption in the global MANET-IoT system. That is a step forward to a reliable provision of services over global future internet infrastructure.

According to [10], positioning is an essential element in most Internet of Things (IoT) applications. Global Positioning System (GPS) chips have high cost and power consumption, making it unsuitable for long-range (LoRa) and low-power IoT devices. Previous studies related to LoRa signal-based positioning systems, including those addressing proximity, a path loss model, time difference of arrival (TDoA), and fingerprint positioning methods were summarized. A LoRa signal-based positioning method was proposed. This method uses a fingerprint algorithm instead of a received signal strength indicator (RSSI) proximity or TDoA method. The main objective of this study was to evaluate the accuracy and usability of the fingerprint algorithm for large areas in the real world. The locations were estimated using probabilistic means based on three different algorithms that use interpolated fingerprint RSSI maps. The average accuracy of the three proposed algorithms in experiments was 28.8 m. This method also reduced the battery consumption significantly compared with that of existing GPS-based positioning methods.

## 3. ANALYSING OF GPS LOCATION ERROR

In random-based mobility models, the mobile nodes move randomly and freely without restrictions. To be more specific, the destination, speed and direction are all chosen randomly and independently of other nodes. This kind of model has been used in many simulation studies [11].

In this study, when a terminal is to move from a point to another point a direction angle in the range  $(-\pi, \pi)$  is generated and also a distance in the range  $(0, a)$  is also generated. Most likely the angle and distance are independent uniformly distributed random variables,  $\phi$  and  $x$  respectively. Then the Probability Density Function (p.d.f.) of  $\phi$  and  $x$  are:

$$p_{\phi}(\phi) = \frac{1}{2\pi}, \quad -\pi < \phi < \pi \quad (1)$$

$$p_X(x) = \frac{1}{a}, \quad 0 < x < a \quad (2)$$

As for the GPS error we can assume similar distributions with the angle in the range  $(-\pi, \pi)$ , but the distance range might be shorter i.e.,  $(0, b)$ , i.e.

$$p_{\theta}(\theta) = \frac{1}{2\pi}, \quad -\pi < \theta < \pi \quad (3)$$

$$p_Y(y) = \frac{1}{b}, \quad 0 < y < b \quad (4)$$

The effective terminal movement can be given by the sum of these two variables, i.e. the distance variable will be  $Z$ , with a magnitude  $Z_M$ , direction angle  $Z_A$  and two quadrature components  $Z_I$  and  $Z_Q$  i.e.

$$z_I = x \cos \phi + y \cos \theta \quad (5)$$

$$z_Q = x \sin \phi + y \sin \theta \quad (6)$$

$$z_M = \sqrt{z_I^2 + z_Q^2} = \sqrt{x^2 + y^2 + 2xy \cos(\phi - \theta)} \quad (7)$$

$$z_A = \text{atan}\left(\frac{z_Q}{z_I}\right) \quad (8)$$

The probability distributions of  $Z_M$  and  $Z_A$  can be used in the simulation instead of the distributions of  $x$  and  $\theta$  to find the effect of the GPS measurement error.

This can be simulated by generating two samples for each movement of a terminal and add them; one of the movements as a simulation of the actual movement and the other movement as a simulation of the error.

In this study, the actual movement of the terminal, is modelled by the Random Walk model And the GPS error is modelled by the Random Waypoint mobility model.

According to [12], in the network simulator (NS-2) distribution, the implementation of Random Waypoint mobility model is as follows: as the simulation starts, each mobile node randomly selects one location in the simulation field as the destination. It then travels towards this destination with constant velocity chosen uniformly and randomly from  $[0, V_{\max}]$ , where the parameter  $V_{\max}$  is the maximum allowable velocity for every mobile node. The velocity and direction of a node are chosen independently of other nodes. Upon reaching the destination, the node stops for a duration defined by the 'pause time' parameter  $T_{\text{pause}}$ . If  $T_{\text{pause}}=0$ , this leads to continuous mobility. After this duration, it again chooses another random destination in the simulation field and moves towards it. The whole process is repeated again and again until the simulation ends.

The Random Walk model has similarities with the Random Waypoint model because the node movement has strong randomness in both models. The Random Walk model can be thought as the specific Random Waypoint model with zero pause time [11].

#### A. 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

For the simulation model the number of nodes has been varied from 30 to 70 in steps of 10. The nodes are placed in an area 600 m by 600 m in specified locations using coordinates. All nodes are moving randomly and by using scheduled time most of them start to send to a sink node. The packet size was 1000 byte generated at interval of 2 packets per second and a rate of 0.1 Mb. The transmission range was 250 m and the bandwidth was 0.1 Mbps.

In the first part of simulation, a comparison between ZEA-AODV (18 zones) and ZEA-AODV (9 zones) was held. The simulation was run for 700 seconds. The results were taken to AODV, ZEA-AODV (18 zones) and ZEA-AODV (9 zones).

In the second part of simulation, the effect of the standard GPS measurement error on the performance of ZEA-AODV protocol is modelled, although more accurate GPS can be used. Two samples for movement of a terminal were generated by simulation. One of the movements is a simulation of the actual movement, and the other one is a simulation of the error. Then both movements are provided to the terminal. Both models for movements are selected to be random-based mobility models.

For the actual movement of the terminal, The Random Walk model is used. And to represent the GPS error, the Random Waypoint Model is used with a random set of destination values that can be represented by a Gaussian distribution for all nodes. 95% of destination values are between [10-15] meters while the GPS accuracy in longitude and latitude coordinates is of 10-15 meters 95% of the readings [2].

The simulation was run for 700 second. The results were taken to AODV, ZEA-AODV (18 zones) and ZEA-AODV (9 zones) with GPS error.

The following simulation parameters are set to run the experiment. 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	200
Length (ifq) (ifqlen)	
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.

$$E_{\text{tot}} = \sum E_i \quad (9)$$

Where  $n$  is the number of nodes and  $E_i$  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

$$E_{\text{avg}} = \sum E_{\text{tot}}/n \quad (10)$$

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

$$PDF = (\text{Received Packets} / \text{Generated Packets}) * 100 \quad (11)$$

- 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.

$$NRL = (\text{Total numbers of routing packets sent over the network} / \text{Total number of data packets received}) \quad (12)$$

- 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).

$$\text{Throughput} = (\text{recvdSize} / (\text{stopTime} - \text{startTime})) * (8 / 1000) \quad \text{in Kbps} \quad (13)$$

#### 4. RESULTS

##### A. ZEA-AODV with different zones

In this part, the performance of the AODV protocol is compared to the proposed ZEA-AODV with (9, 18) zones respectively without considering the GPS error. In the simulation, the number of nodes is increased from 30 to 70. Also, the initial energy is set to be 250 Joules, and the simulation time is 700s. The results compare AODV and ZEA-AODV with (9, 18) zones respectively without considering the GPS error, using the following parameters, Etot, Eavg, PDF, NRL, Average End-To-End Delay, Dropped data (packets) and Throughput.

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

Fig.1 and Fig.2 show that, as the number of nodes increases from 30 to 70, the average energy consumed by a node Eavg has slightly decreased, and the total energy consumed Etot has increased for all scenarios as expected.

From these figures, the energy consumption for ZEA-AODV with (9, 18) zones is less than the normal AODV, which is due to decrease in broadcast storm achieved by ZEA-AODV.

Also, in ZEA-AODV protocol 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.

Also, ZEA-AODV with 18 zones has decreased energy by up to 9.28% whereas ZEA-AODV with 9 zones has decreased energy by up to 8.99%. This slight difference is due to more zones in ZEA-AODV with 18 zones which leads to more controlling for broadcast storm, which leads to less congestion and error through the network.

##### 1) Packet Delivery Function (PDF)

Fig.3 shows that 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.

##### 1) Normalized Routing Load (NRL)

Fig.4 shows that, when the number of nodes is less than 70, NRL in the ZEA-AODV with (9, 18) zones is better than normal AODV.

The ZEA-AODV protocol with (9, 18) zones, has a better flooding mechanism because they decrease the number of routing messages using either Zone Aware mechanism or Energy Balanced mechanism.

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

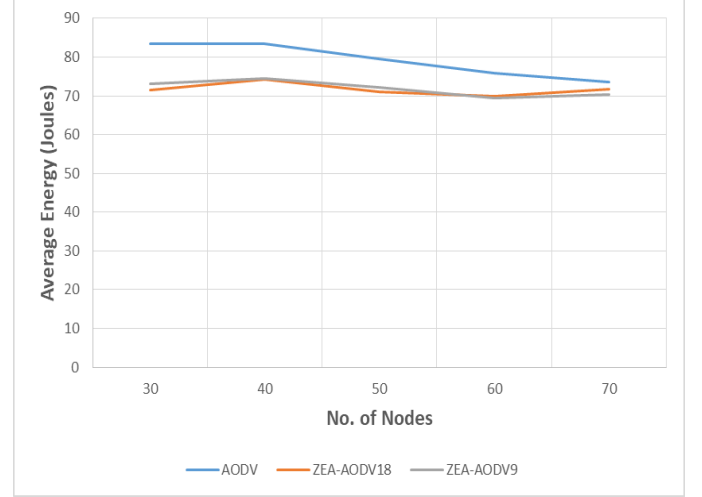


Fig. 1. Average Energy VS Number of Nodes

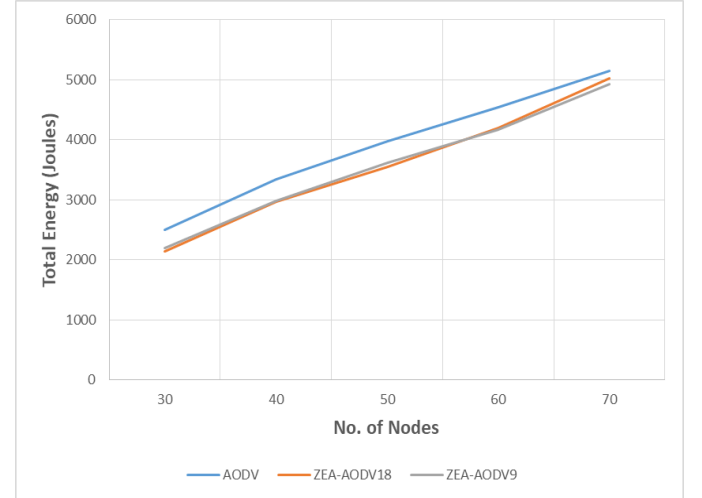


Fig. 2. Total Energy VS Number of Nodes

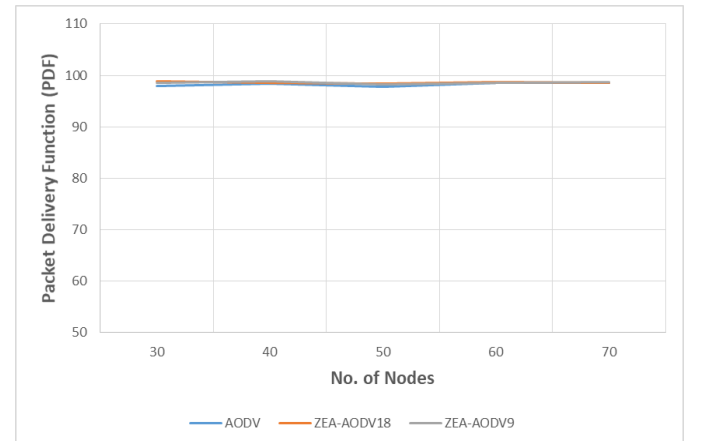
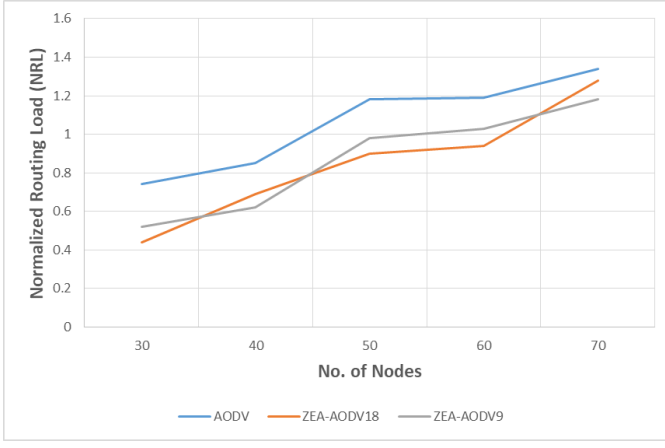


Fig.3. PDF VS Number of Nodes



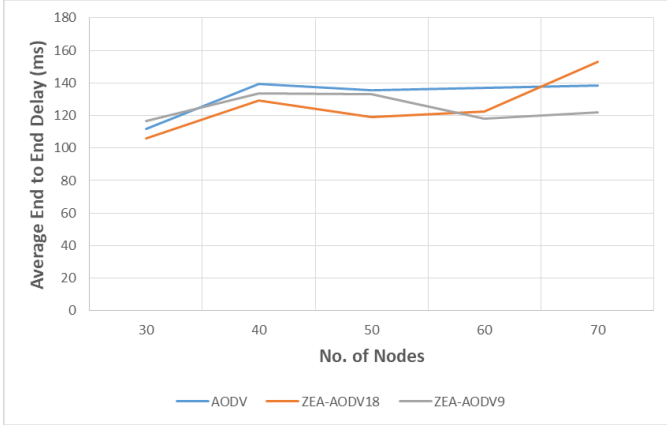


**Fig. 4. NRL VS Number of Nodes**

## 2) Average End to End Delay

In Fig.5, 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.

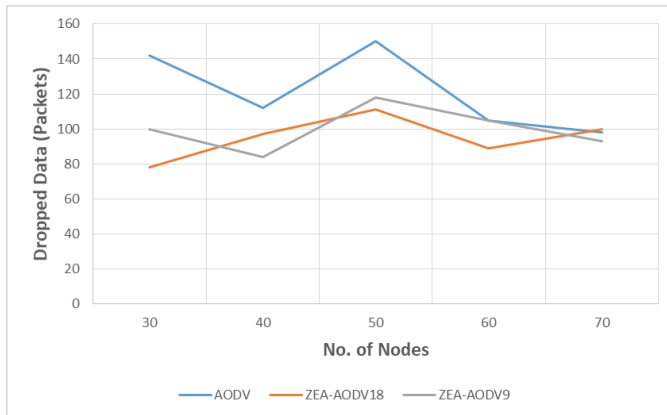
For the overall performance, ZEA-AODV with 18 zones has decreased the average end-to-end delay by up to 5%, whereas ZEA-AODV with 9 zones has decreased the average end-to-end delay by up to 5.5% compared to normal AODV protocol.



**Fig. 5. Average End to End Delay VS Number of Nodes**

## 3) Dropped Data (Packets)

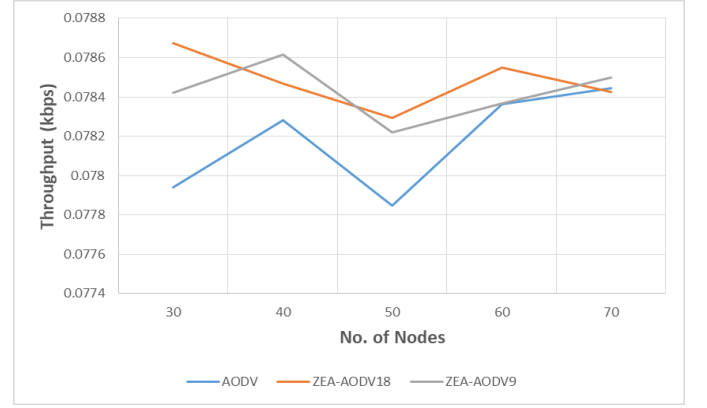
Fig.6 shows that, when the number of nodes is less than 70, dropping in AODV is more than it in ZEA-AODV with (9, 18) zones. In ZEA-AODV less dropping is achieved because of less routing messages and congestion in the network.



**Fig. 6. Dropped Data VS Number of Nodes**

## 4) Throughput

Fig.7 illustrates that, Throughput is the best in ZEA-AODV with (9, 18) zones respectively compared to AODV 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. 7. Throughput VS Number of Nodes**

## B. Modelling and Analysis of the GPS error on ZEA-AODV Protocol

In this part, as ZEA-AODV protocol make use of location information provided by GPS, considered by the GPS error. Assuming that, standard GPS is used, although more accurate GPS can be used, its error is modelled by generating two samples for movement of a terminal by simulation. One of the movements is a simulation of the actual movement, and the other one as a simulation of the error. Then both movements are provided to the terminal. This GPS error modelling is provided with ZEA-AODV protocol to discover how the performance of ZEA-AODV protocol is affected. In the simulation, the number of nodes is increased from 30 to 70. Also, the Initial energy is set to be 250 Joules, and the simulation time is 700s. The results compare AODV and ZEA-AODV (9, 18) zones with GPS error, 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.8 and Fig.9 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 protocols as expected.

From graphs, the energy consumed by ZEA-AODV with 9 zones is the lowest, whereas the energy consumed by the normal AODV is the highest. This is due to decrease in broadcast storm achieved by ZEA-AODV, and when the GPS error is considered, the less number of zones implies less GPS error effect.

As the number of zones is increased in ZEA-AODV protocol, more location information is needed which leads to more errors, congestion and dropping through the network.

### 1) Packet Delivery Function (PDF)

Fig.10 shows that PDF is almost the same for all scenarios. ZEA-AODV with (9, 18) zones has a slight decrease in PDF when the number of nodes is less than 70. ZEA-AODV with GPS error has decreased PDF due to more dropping provided by GPS error. When the number of zones is 18, ZEA-AODV provides the least PDF.

### 1) Normalized Routing Load (NRL)

Fig.11 shows how overhead is increased when number of nodes is increased. ZEA-AODV with 18 zones has the highest overhead

due to extra information required by GPS which leads to extra GPS errors. GPS error leads to extra flooding, dropping, and congestion in the channel.

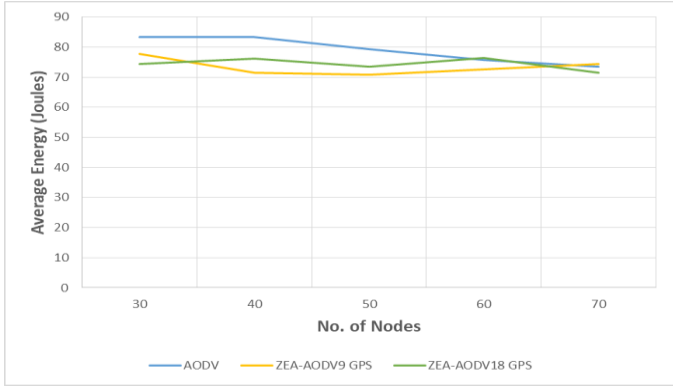


Fig. 8 Average Energy VS Number of Nodes

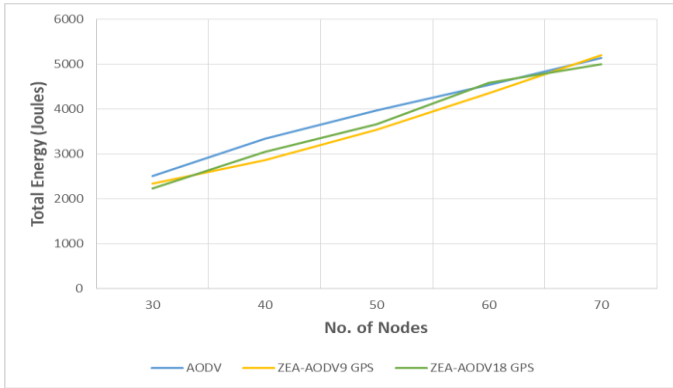


Fig. 9. Total Energy VS Number of Nodes

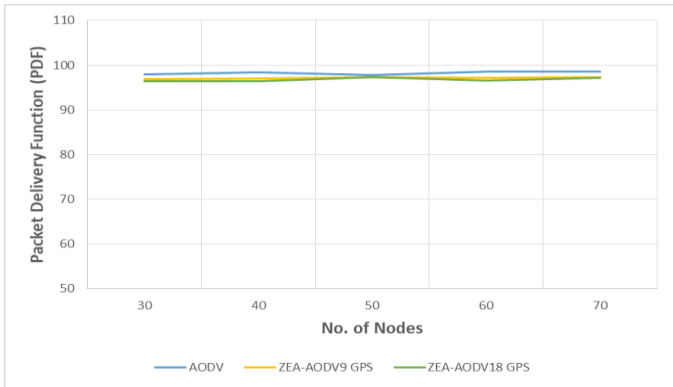


Fig.10. PDF VS Number of Nodes

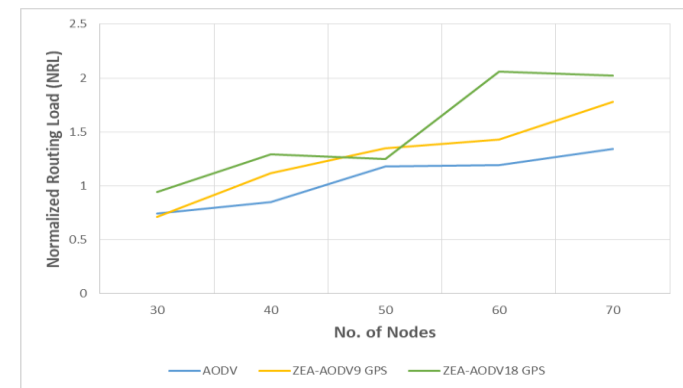


Fig. 11. NRL VS Number of Nodes

## 2) Average End to End Delay

In Fig.12, ZEA-AODV with 18 zones has the highest end-to-end delay, because more zones means more GPS errors which leads to extra overhead then more congestion through the network. Packet

losses, Congestion and overhead provide more delay through the network.

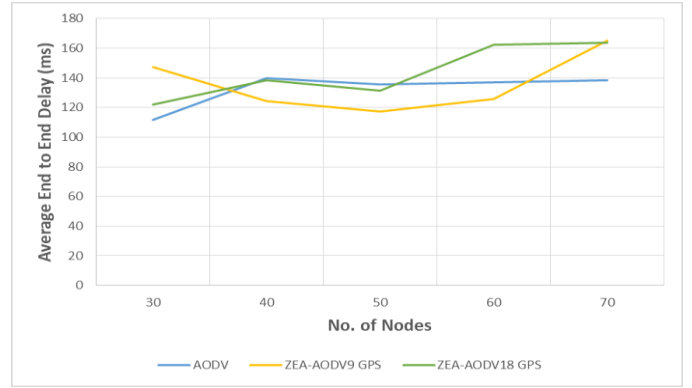


Fig.12. Average End to End Delay VS Number of Nodes

## 3) Dropped Data (Packets)

Fig.13 shows that dropped data is noticeably increased by ZEA-AODV protocol compared to AODV protocol. When the number of zones is 18, ZEA-AODV provides the highest dropping. This is due to more GPS errors which create extra overhead and congestion that lead to more packets dropping.

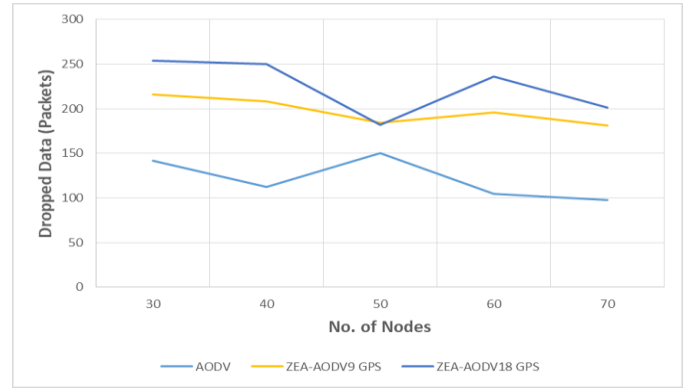


Fig. 13. Dropped Data VS Number of Nodes

## 1) Throughput

Fig.14 illustrates that, when considering the standard GPS error, throughput has generally decreased. GPS error leads to extra flooding, congestion, delay, overhead and dropping through the network. Throughput is the lowest when the number of zones is 18, this is due to more delay and packet drop through the network.

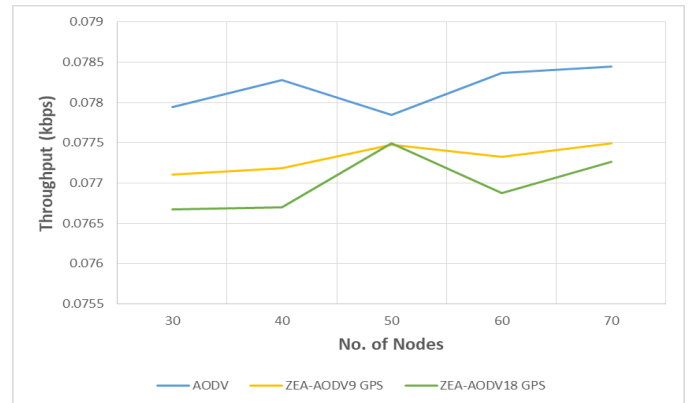


Fig. 14. Throughput VS Number of Nodes

## 5. CONCLUSIONS

When the GPS error is not considered, Zone Energy Aware AODV (ZEA-AODV) either with 9 or 18 zones shows more reliable and

consistence performance than AODV protocol when the number of nodes is less than 70. Simulation results show that, when the number of nodes is less than 70, ZEA-AODV with (9, 18) zones 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 with 18 zones, when GPS error is not considered and when nodes is less than 70, simulation results show that energy consumption has reduced by up to 9.28%, drop has decreased by 20%, delay has lowered by 5% and overhead has decreased by up to 22%. However, there is no significant improvement in throughput which has increased only by 0.32% compared to normal AODV.

Also, in ZEA-AODV with 9 zones, when GPS error is not considered and when nodes is less than 70, simulation results show that energy consumption has reduced by up to 8.99%, drop has decreased by 16%, delay has lowered by 5.5% and overhead has decreased by up to 20%. The throughput has improved in the same way as that of ZEA-AODV with 18 zones by 0.32% compared to normal AODV.

Generally, when GPS error is ignored, simulation results show that, ZEA-AODV with 18 zones provides better performance than that of ZEA-AODV with 9 zones, although, the throughput has improved the same percentage for both of them.

Moreover, the previously proposed protocol ZEA-AODV is a zone aware protocol that depends on GPS to identify the node's zone. The initial discussion for ZEA-AODV protocol, assumed that each mobile node knows its current location precisely (with no error). However, the ideas suggested can also be applied when the location is known only approximately.

In ZEA-AODV with 18 zones, when GPS error is considered, simulation results show that energy consumption has reduced by up to 6%, whereas packet dropping has increased by 90%, delay has increased by 8.3%, overhead has increased by up to 41.7% and throughput has lowered by 1.5% compared to normal AODV.

In ZEA-AODV with 9 zones, when GPS error is considered, simulation results show that energy consumption has reduced by up to 7%, whereas packet dropping has increased by 66%, delay has increased by 3.7%, overhead has increased by up to 19% and throughput has lowered by 1.1% compared to normal AODV.

It can be concluded that, without considering the GPS error, ZEA-AODV with 18 zones provides better performance than ZEA-AODV with 9 zones. But when considering the GPS error, ZEA-AODV with (9, 18) zones performance has degraded generally, although, energy consumption is still less than that of AODV protocol.

When simulating GPS error as extra movement added to the actual terminal movement, ZEA-AODV with (9, 18) zones performance has degraded generally because extra mobility of the nodes in the network implies more traffic density, overhead, congestion, collision, dropping and delay.

Obviously, when considering the GPS error, ZEA-AODV protocol with 18 zones has lower performance than ZEA-AODV with 9 zones, this is due to extra effect of GPS error on ZEA-AODV with 18 zones as location information will be required more than that of ZEA-AODV with 9 zones. This extra GPS error would create more flooding, dropping and congestion through the network. The type and accuracy of used GPS can affect the performance of ZEA-

AODV protocol, so it should be compromised between number of zones in ZEA-AODV protocol and the effect of GPS error.

Also, using Differential Global Positioning System (DGPS) is recommended to be used with MANET's nodes. As according to [6] DGPS is an enhancement to the Global Positioning System (GPS) which provides improved location accuracy, in the range of operations of each system, from the 15-meter nominal GPS accuracy to about 1–3 cm in case of the best implementations.

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