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# Performance Comparison of AODV and DYMO Routing Protocols for Boundary Detection in 3-D Wireless Sensor Networks

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***Abstract*****: *In order to track and detect continuous nature objects in wireless sensor networks, a large number of sensor nodes are involved. These continuous objects like biochemical diffusions, forest fires, oil spills usually spread over larger area. The nodes that sense the phenomena need to communicate with each other for exchanging the information and also send sensing information to sink, possibly by passing through many intermediate nodes. For many geometry based algorithms triangulation serves as the basis for wireless sensor networks. In this paper, we propose a distributed algorithm that produces a Delaunay triangulation for an arbitrary sensor network, for communication between the sensor nodes. The information of occurrence of an event is then passed to a control node. The communication is done both with and without using relay nodes and a comparison is made between the two methods in terms of battery, total unicast messages received, throughput and delay. The two protocols in which we have worked are AODV and DYMO.***

***Keywords: AODV, Boundary Detection, Delaunay Triangulation, DYMO, Event Boundary, Relays.***

## I. INTRODUCTION

In WSNs (wireless sensor networks), nodes on or near boundaries (termed *boundary nodes*) normally play a more important role than the other nodes. On the one hand, boundary nodes not only directly interact with the outside environment (such as events entering or leaving the region monitored by the WSN, any communication with the outside environment and so on), but also help to extract further information about the WSN structure (which is useful for routing, guiding and management purposes) [1]. On the other hand, due to the correspondence between the boundaries of a WSN and its physical environment, such as a building floor plan, a map of a transportation network, terrain variations, and obstacles (buildings, lakes, etc), boundary nodes are important for keeping track of the WSN shape which indicates significant features of the underlying environment. In contrast to the outer boundary of a WSN, boundaries of inner holes (termed *inner boundaries*) are critical indicators of the general health of a WSN, such as insufficient coverage and connectivity. Therefore, boundary detection is of great importance for various WSN applications.

A wireless sensor network can be represented by a graph, where a node corresponds to a sensor and an edge indicates the communication link between two sensors [2]. A network graph under practical experiment settings or theoretical communication models usually exhibits undesired randomness and intractability, calling for effective techniques that yield a well-structured network subgraph to support target applications.

For example, triangulation [3] serves as the basis for many geometry-based routing, [4]-[6], localization [7], coverage [8], segmentation and data storage and processing [9] algorithms in wireless sensor networks.

Rest of the paper is organized as follows:

Section II consists of the related work done on boundary detection. In section III, we have discussed the protocols in which the performance comparison is done. Section IV elaborates our proposed work, where we have set-up the network with the use of Delaunay triangulation.

## II. RELATED WORK

### *A. Detection of Event Boundary*

The research on boundary detection started from the estimation and localization of events in sensor networks. The spatially distributed sensors usually report different measurements in respond to an event. For instance, in the case of fire, the sensors located in the fire are likely to be destroyed (and thus resulting in a void area of failed nodes), while the sensors that are close to the fire region show higher temperature and smoke density than those that are far away. Boundary detection is used to define the regions of distinct behavior in a sensor network [10].

It is challenging to get accurate detection because the sampling density is limited, the sensor readings are noisy, the delivery of sensor data is unreliable, and the computation power of individual sensors is extremely low [10], [11]. To this end, a series of studies has been carried out to explore efficient information processing and modeling techniques to analyze sensor data in order to estimate the boundary of events [10]–[15].

### *B. Detection of Network Boundary*

Usually, the network boundary detection algorithms are grounded on 2-D graphic tools. For example, Voronoi diagrams are employed in [16] and [17] to discover coverage holes in sensor networks. Delaunay triangulation is adopted in [18] to identify communication voids. In contrast to [16]–[18] that exploit sensor locations, other two distributed algorithms are proposed in [19] by utilizing distance and/or angle information between nodes to discover coverage boundary.

Note that if global coordinates are available, boundary detection would become straightforward. However, this approach is often overkilling because the process of establishing global coordinates itself results in significant computation and communication overhead [20]. In addition, while boundary extraction has been extensively studied in 3-D imaging, the algorithms developed therein always assume grid-like 3-D pixels as inputs, which are in sharp contrast to network settings where nodes are randomly distributed, and thus are not applicable in 3-D wireless networks. This work (partially presented in [15]) proposes the first algorithms for efficiently discovering boundary nodes and constructing boundary surface in 3-D wireless sensor networks.

Following [21], several relevant research works have been carried out recently. For example, an effective algorithm is proposed in [21] to timely track dynamic network boundaries. It transforms a notched surface into a convex one to support of fast online boundary detection. However, the performance of the algorithm is determined by two important parameters required by the transformation. Unfortunately, both of them are model-dependent. Different models have different optimal parameters for achieving the best results. A set of sealed triangular boundary surfaces is produced based on this structure to separate non-boundary nodes and boundary node candidates. The former are hollowed out immediately, while the latter are further refined to yield the final boundary nodes and fine-grained boundary surfaces. However, the connectivity- based approaches cannot differentiate nodes within 1 hop, and thus are less accurate compared to the performance of methods based on distance or coordinates.

## III. PROTOCOLS USED

If communication between wireless equipped devices is desired, the reliance upon an existing infrastructure as well as its implied limitations on mobility can be a major obstacle. In such cases, the wireless-equipped devices themselves must operate autonomously to provide connection such that a device not directly within transmission range of another device is able to communicate. Each wireless capable device must function as a router and forward packets. Thus, communication can be via multiple wireless hops. In the following, such wireless equipped devices are referred to as nodes. Additional challenges arise as nodes may move around arbitrarily resulting in networks with constantly changing, random multi-hop topologies. Such a network is called a mobile ad hoc network (MANET) because the nodes in the network are mobile and communicate without a pre-established fixed infrastructure, but instead form a routing infrastructure in an ad hoc fashion.

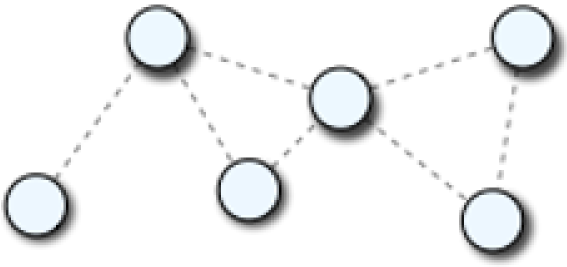

**Fig. 1 Nodes in MANET independently forming a routing infrastructure**

### *A. AODV*

The Ad-Hoc On-Demand Distance Vector routing protocol is described in [22]. Like all other reactive protocols, the philosophy in AODV is that the topology information is transmitted by nodes only on-demand. It will generate a route request (RREQ) message when a node wishes to transmit traffic to a host to which it has no route and that will be flooded in a limited way to other nodes. This causes control traffic overhead to be dynamic and results in an initial delay when devising such communication. A route is considered found when the RREQ message reaches either an intermediate node with a valid route entry for the destination or the destination itself. AODV remains passive for as long as a route exists between two endpoints. AODV will again issue a request when the route becomes invalid or lost.

### *B. DYMO*

DYMO routing protocol is a successor of the AODV routing protocol and is the present engineering focus for reactive routing in the IETF MANET working group. It operates just like AODV. It does not add extra features or extend the AODV protocol, but rather it simplifies the AODV protocol while retaining the basic mode of operation.
DYMO consists of two protocol operations:

1. Route discovery, and
2. Route maintenance.

When a node needs to send a packet to a destination currently not in its routing table, routes are discovered on-demand. A route request message is flooded in the network using broadcast and if the packet reaches its destination, a reply message is sent back containing the discovered path. Every single node maintains a routing table with information about nodes.

## IV. PROPOSED WORK

There are increasing interests in 3-D wireless networks, with several areas such as routing, localization, nodal placement, physical-layer investigation, and applications, being explored recently. This research aims to develop distributed and localized algorithms for precise boundary detection in 3-D wireless networks. Our objectives are twofold.

1) Firstly, we aim to identify the 3-D network boundary nodes based on local information.

2) Second, we make the nodes communicate with each other in order to pass on the information of event occurrence at the boundary.

We have implemented an algorithm that constructs locally planarized triangular meshes on the identified 3-D boundaries. We have adopted the method proposed in [23] that can produce a 2-D planar subgraph (which, however, is not a triangular mesh) and extended it to 3-D surfaces to achieve complete triangulation without degenerated edges [22]. The algorithm is localized and based only on connectivity. It consists of the following five steps:

### *A. Landmark selection:*

The boundary nodes employ a distributed algorithm to select a subset of nodes as "landmarks." Any two landmarks must be k hops apart determines the fineness of the mesh. A non-landmark boundary node is associated with the closest landmark.

### *B. Construction of Combinatorial Delaunay Graph (CDG):*

Each non-landmark boundary node checks if it has a neighbouring boundary node that is associated with a different landmark. If it has, a message is sent to both landmarks to indicate that they are neighbouring landmarks. If we simply connect all neighbouring landmarks, we arrive at a CDG.

### *C. Construction of Combinatorial Delaunay Map (CDM):*

Each landmark node decides whether it connects to a neighbouring landmark as follows. It sends a packet to a neighbouring landmark through the shortest path (based on the identified boundary nodes only). The packet records the nodes along the path. The two landmarks are said to be connected if and only if the following two conditions are satisfied. First, all nodes visited by the packet are associated to these two landmarks only. Second, assume the packet is sent from Landmark to Landmark. Then, the packet must visit the nodes associated with Landmark first, and then followed by the nodes associated with Landmark, without interleaving.

### *D. Construction of triangular mesh:*

The CDM obtained so far is planar, but not always a triangular mesh. Polygons with more than three edges may exist. To achieve complete triangulation, appropriate edges should be added between some neighbouring landmarks. If a landmark, e.g., Landmark, has a non-connected neighbouring landmark (e.g., Landmark), it sends a *connection* packet to the latter (via the shortest path based on the identified boundary nodes). The packet will be dropped if it reaches an intermediate node that is already on the shortest path between two connected landmarks in order to avoid crossing edges.

## V. SIMULATION AND RESULTS

We have created a scenario in 100 by 100-metre range. A 3-D network has been created with the help of Delaunay triangulation in MATLAB.
That scenario is then implemented in QualNet version 6.1. The wireless scenario is deployed and checked as follows:

- IEEE 802.15.4 wireless standard for PHY and MAC layer.
- AODV routing
- DYMO routing

**Table 1. Simulation**

| | |
|---|---|
| Simulator | QualNet version 6.1 |
| No. of nodes | 100 |
| No. of Base Stations | 1 |
| Topology | Star, Mesh |
| Fixed setup | RSU, VANET Authority |
| Mac type | 802.15.4 |
| Antenna type | Omnidirectional |
| Routing protocol | AODV,DYMO |
| Transport agent | UDP |
| Application agent | TRAF-GEN |
| Simulation time | 1000 seconds |
| Energy Model | Generic (user defined) |

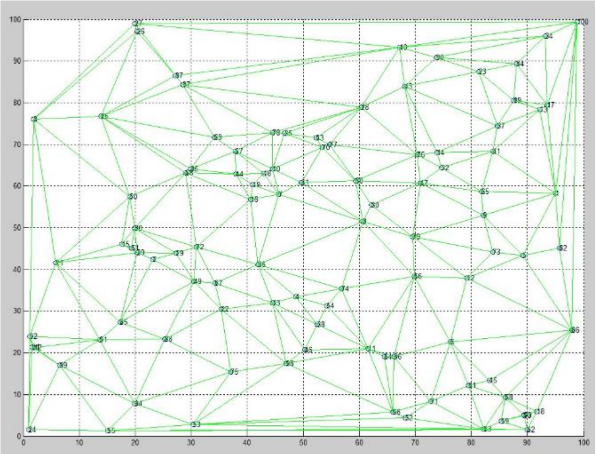

**Fig. 2(a) Delaunay triangulation in 2-D.**

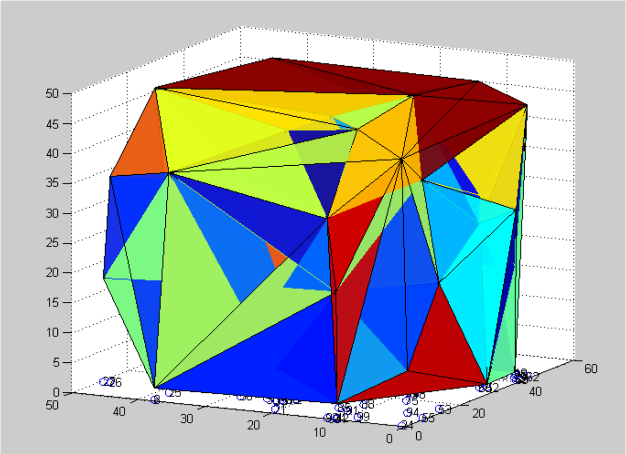

**Fig. 2(b) Delaunay triangulation in 3-D.**

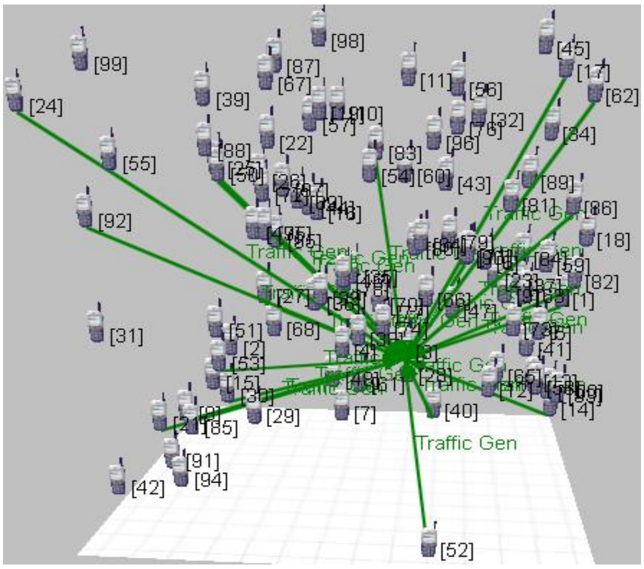

**Fig. 2(c) 3-D scenario of the network**

The boundary nodes are discrete. They serve as sample points that depict the network boundaries. Two protocols AODV and DYMO are used to analyse the system performance based on the total unicast message received, throughput and time delay and battery residual capacity.

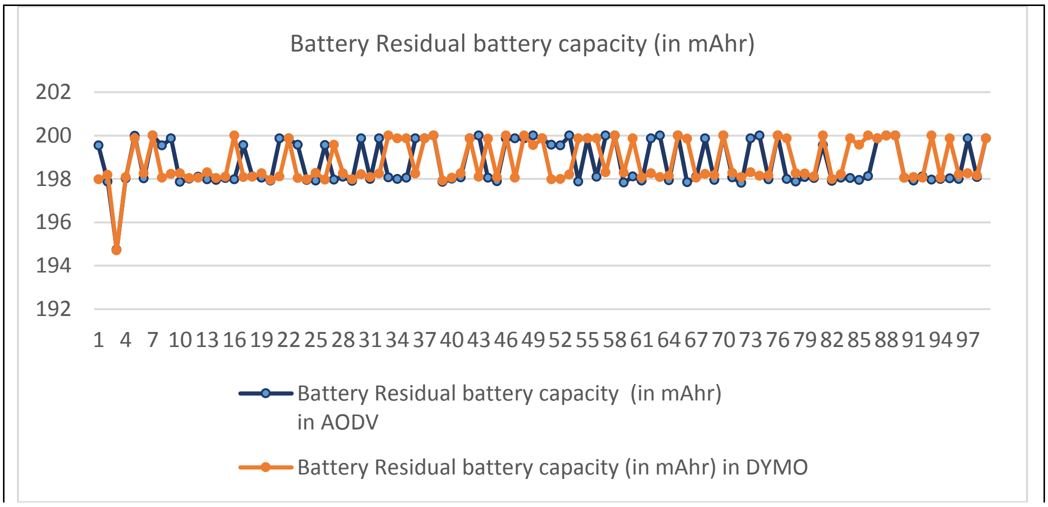

**Fig. 3(a) Comparison between Battery residual capacity in AODV and in DYMO.**

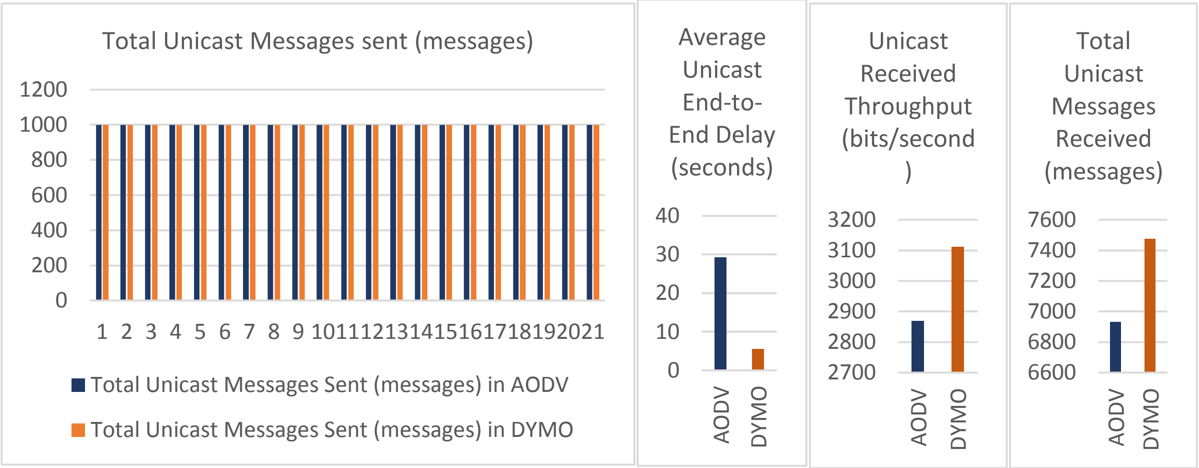

**Fig. 3(b) Comparison between the network parameters- Total unicast messages sent, messages received, Unicast received throughput and average unicast End-to-end delay.**

Sensors usually have short transmission range since long transmissions consume more energy, and the sensors have limited power. Therefore, network partitions may occur or more sensors must be placed to maintain connectivity. In some case, simple sensors may not be able to do more complex work such as data aggregation and storage. Here, deploying more sensors is not the solution. The number of sensors distributed in the area is usually large, hence deploying sophisticated wireless nodes instead is costly. In order to solve this problem, we have placed high capability relay nodes. Due to the higher cost of relay nodes, the number of relay nodes used is kept minimum while maintaining network connectivity and functionality.

We aim at placing the minimum number of relay nodes in the wireless sensor network such that:

1. Each sensor node can communicate with minimum one relay node, and
2. The network of relay nodes is connected to the central control node.

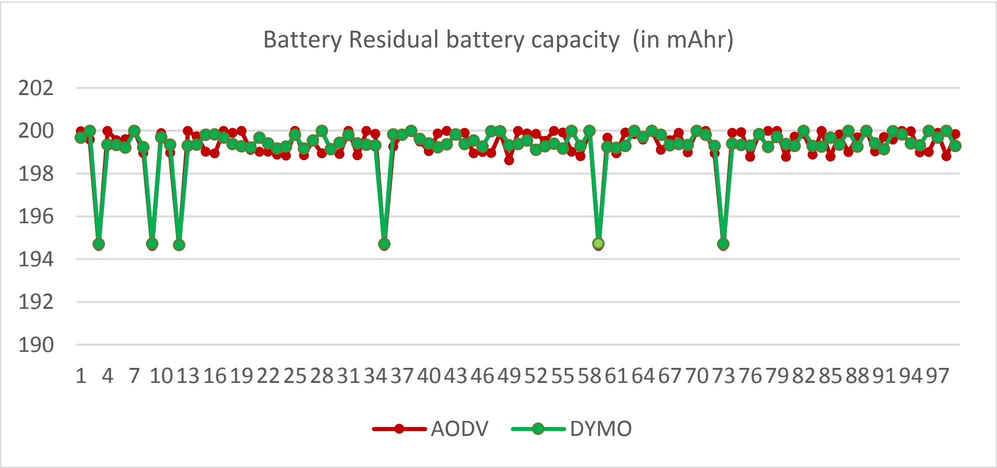

**Fig. 4(a) Comparison between Battery residual capacity in AODV and in DYMO.**

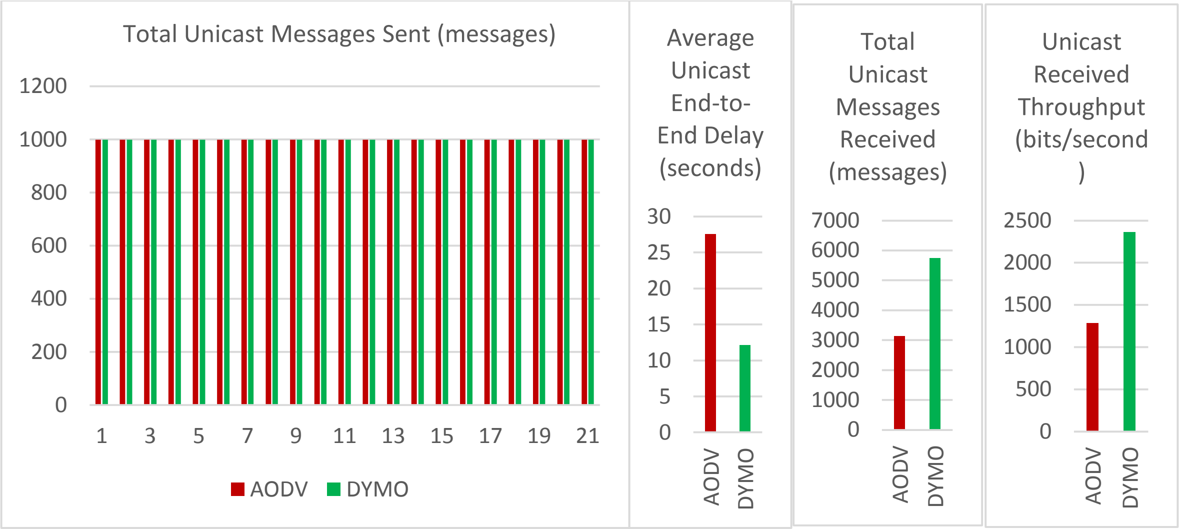

**Fig. 4(b) Comparison between the network parameters- Total unicast messages sent, messages received, Unicast received throughput and average unicast End-to-end delay.**

## CONCLUSION

From the comparison show between all the four techniques, it can be concluded that Residual capacity is better for the network with relays and either protocol, AODV or DYMO can be used. The residual battery capacity drops down for relay nodes. Total unicast messages received in AODV are 1.078 times more than DYMO. The results for a message received are better without the use of relay nodes. Next parameter consider is throughput, which can be defined as the maximum rate of production or the maximum rate at which anything can be processed. In our setup, throughput is maximum for the network without relays, using DYMO protocol. It is 1.085 times more than that of AODV without a relay. The lowest throughput is the network with a relay that uses AODV protocol. Average unicast delay of the network with DYMO is very low, it is 5.22 times lesser than AODV which has the highest delay. For a system with relays, the delay is considerable.

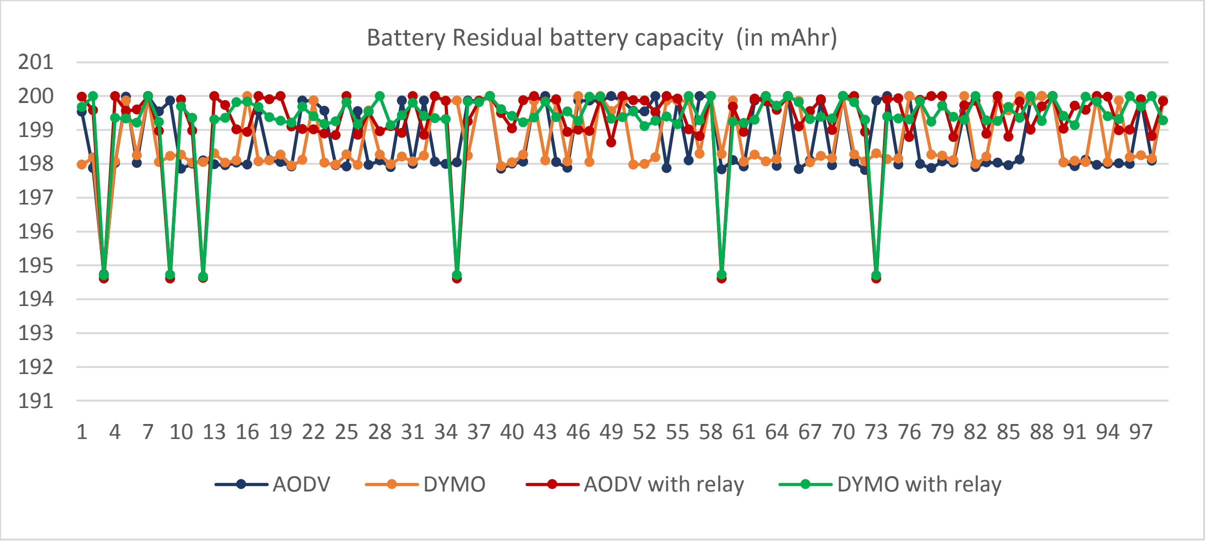

**Fig. 5(a) Comparison between Battery residual capacity in AODV and in DYMO with and without relay nodes.**

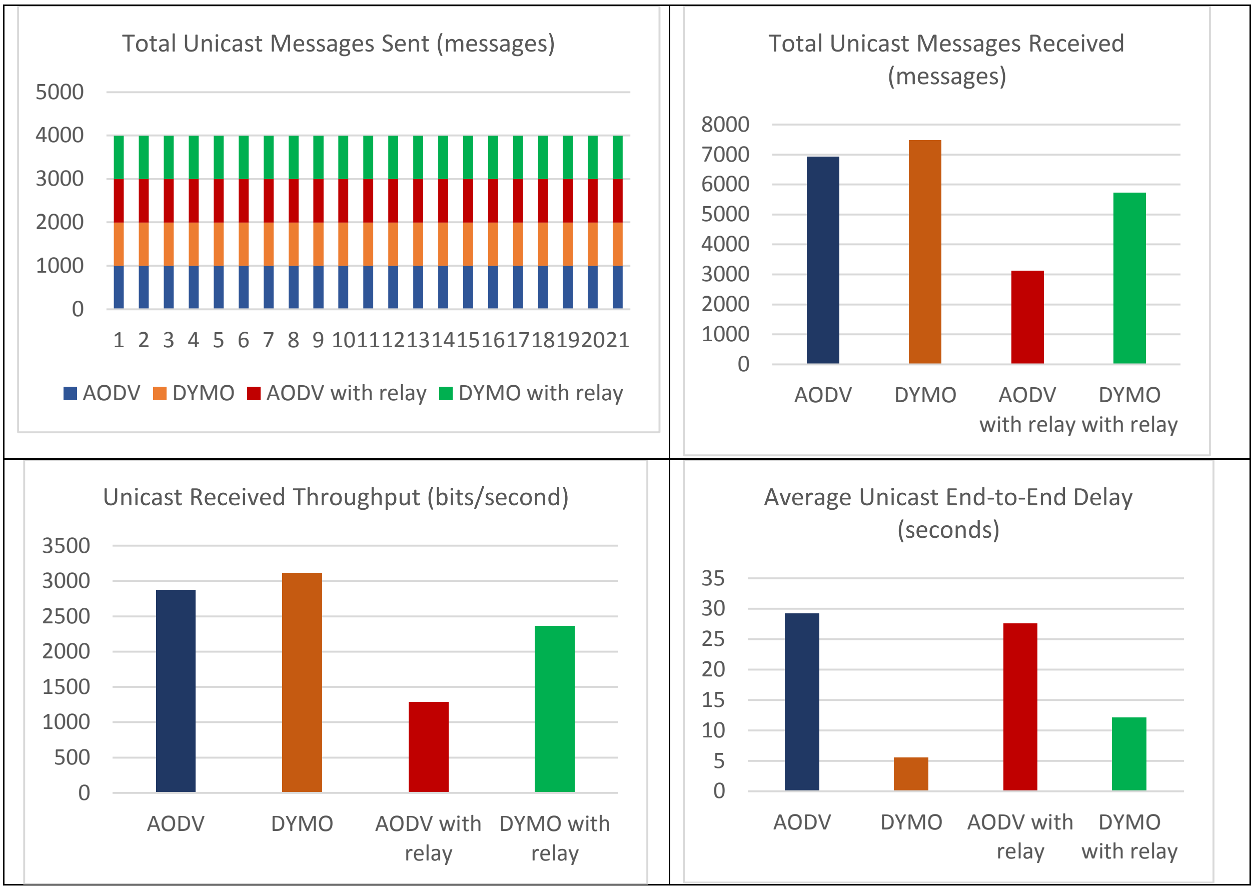

**Fig. 5(b) Comparison between the network parameters- Total unicast messages sent, messages received, Unicast received throughput and average unicast End-to-end delay in both AODV and DYMO protocols, with and without using relay nodes.**

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