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Modeling and Evaluating the Performance of A Highly Mobile Wireless Sensor Networks routing protocols

Mabrouka Abuhmida[1], Kapilan Radhakrishnan[1] and Ian Wells[2]

Abstract: Network modelling play an important role in many different disciplines. The broad scope of applicability of models results in a wide range of types of models for a given system component, a range of system components that are of interest to be modeled, and an assortment of levels of detail provided in models. In this paper, we present a model a highly mobility wireless sensor network (WSN). The model takes into consideration several parameters such as the node speed, Pause time. Performance evaluation of several WSN routing protocols is carried out in terms of variation in pause time and node speed under random Way point mobility model (RWM) in CBR Traffic. These protocols have been selected for simulation due to their edges over other protocols in various aspects.

Keywords: Wireless Sensor Network; high mobility; Swarm Intelligence; ANTMANET; Ant Colony Optimization; network modelling

1. INTRODUCTION

A wireless sensor network (WSN) is a decentralized network that requires no infrastructure. All devices in this network are equal and have similar hardware capabilities; all nodes can connect with any pair device within its wireless range, each node participates in routing by forwarding data to other nodes, following the rules of a basis classic protocol. Traditionally this type of networks is either static or semi-static, which makes it easier to deploy and reliable source of information. but when this network requires mobility-network devices change their rabidly change their location-therefore, some of the main features of WSN networks will change, consequently, the performance will be degraded [1]. The easy deployment factor will remain the same but the robustness of the network will largely be effected by the mobility of the network devices. Mainly the network performance is based on the performance of the routing protocol.

There are two main routing algorithm classes in MANET; link state and the distance vector algorithms. Recently, the new evolvement of the MANET applications has derived the creation of a new routing class, which is known as the bio-inspired or the swarm intelligent algorithms [2], this class has proven that it is a reliable and robust method to solve many homogeneous problems, such as routing in MANET, this could be implied at the explorative and exploitative nature of this class [3].

Recently, WSN has become an active area for research, due to their potentials impact especially in surveillance applications, such as habitat monitoring and Environmental control, for example using wireless sensor networks (WSN) to collect the measurements related to the sea surface [4]. Ranging from studies on network capacity and signal processing techniques, to algorithms for traffic routing, topology management and channel access control network modelling-abstractions or representations of a system plays an important role to analysis and evaluate the network performance.

[1] School of Applied Computing, University of Wales Trinity Saint David Swansea, United Kingdom, *Emails: Mabrouka.abuhmida@uwtsd.ac.uk, kapilan.radhakrishnan@uwtsd.ac.uk*

[2] School of Applied Computing, University of Wales Trinity Saint David, Swansea, United Kingdom, *Email: Ian.wells@uwtsd.ac.uk*

Network modelling may take many forms, and may be categorized by many different criteria [5]. For example, models may be characterized by how closely their structure matches that of the system they model, regardless of other properties of the model. Modelling, in the context of computing systems research, may be defined as abstractions of the functional behavior of a system or entity, in a form amenable to simulation or analysis. The term evaluation metric, or simply metric, is usually used to denote aspects of a model that may be measured, or quantities that a model predicts. The variables and constants that affect the behavior (or nature) of the model, are usually referred to as its parameters [5].

In this paper, we develop a simulation model which enables us to explore the trade-off of WSN routing protocols in the highly mobile network environment. In section II, we present an overview of network modelling. Section III gives a brief discussion on system design, description of the tested protocols and implementation followed by simulation results and summary. Section IV gives the conclusion and future work.

2. NETWORK MODELLING AND SIMULATION

The simulation experiments are widely used to evaluate WSN routing protocols. These experiments must model the network topology, network traffic, routing methodology and other network attributes. In addition, the wireless and mobile nature of WSNs requires consideration of node mobility, the radio frequency channel, terrain, antenna properties, and battery characteristics.

There is no doubt about how important it is to establish a testbed for a system to measure its reliability in real the world, but this step would come after a successful software implementation. Utilizing simulation software packages is valuable to the evaluating process of any new design. Simulation software packages save time and reduce the implementation cost compared to setting up a real network testbeds. They are required to realistically model and emulate the aforementioned network characteristics at the end of each simulation statistics and network performance measurements are available for collection for evaluation and analysis. For example, QualNet is a simulation package that simulates any communication system (i.e. wired or wireless networks) in a short time with guaranteed accurate statistics to help with evaluating the performance of any proposed system.

In this research, the experiment system is designed carefully to evaluate the proposed protocol performance through several network conditions. This is achieved by varying several factors to emulate realistic situations. The experiment system plan is shown in Figure 1.

1. The first condition is implemented to evaluate the effect of nodes velocity by varying the node’s speed. In order to guarantee different levels of route convergence several pause times is configured.
2. The second condition is implemented to evaluate the performance of the proposed protocol in a stressed network conditions such as high network load by varying the number of packets in each case of the above factors.

The aforesaid factors are organized in three experiments as follows:

1. Mobility experiments, which evaluates the effect of the different pause times to each node’s speed that is along with varying the number of packets sent by the application per second. This experiment generates 180 single simulations per tested protocol.
2. Network performance experiment, the main aim of this experiment is to benchmark the proposed protocol against other ACO based routing protocol. This experiment generates 60 single simulations per tested protocol.

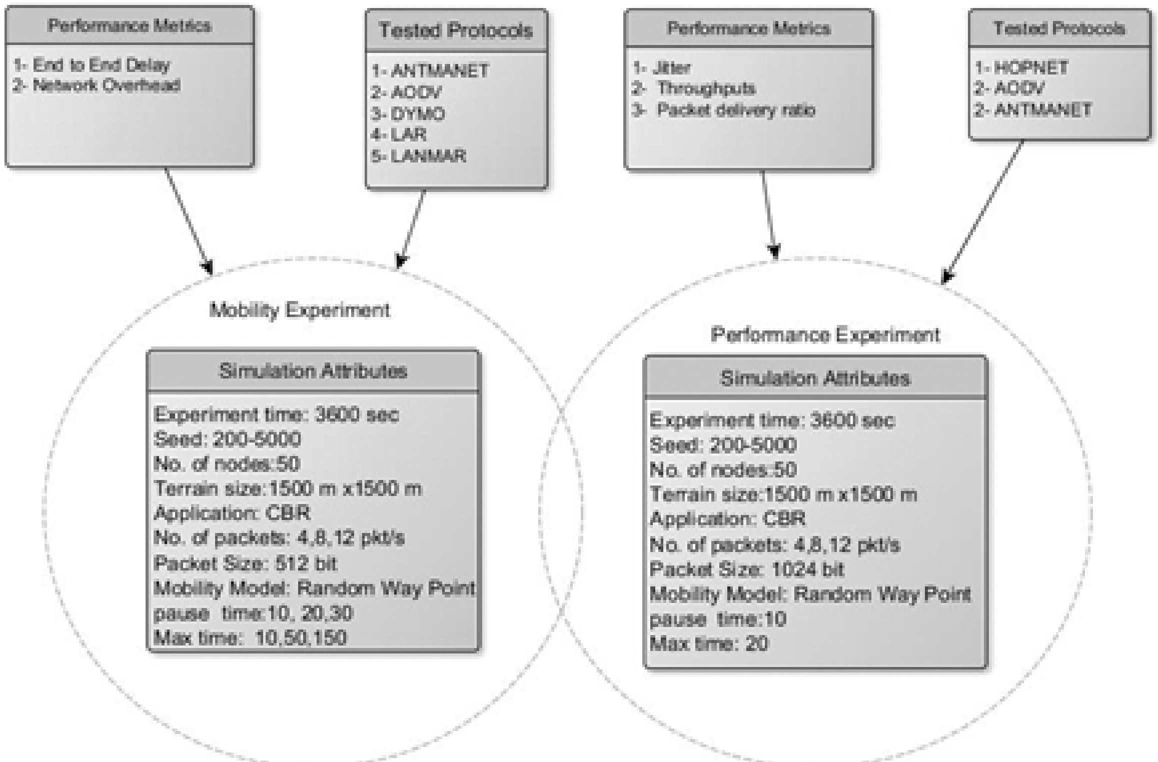

Figure 1: Experiment System plane

This experiment considers a network of 30 nodes placed randomly within area of 1500 (m^2). The data application used is the Constant Bit Rate (CBR) to establish data sessions among a chosen source-destination pairs (SDPs). Three different network loads is utilized to examine the proposed protocol performance in a normal, medium and high network loads, this is done by varying the number of packets sent per second to 4 packets. For example, 2 SDPs amongst 30 nodes are engaged in generating the traffic. However, during the data forwarding process, all of the 30 nodes including the SDPs will involve in generating background traffic to provide the necessary support for routing and data forwarding over the on-going communication session.

In order to emulate the mobility model to cause route convergence, fifteen levels of node mobility was examined, those performed by varying two key factors; node speed (10, 50, 100, 150, 200 m/s) and pause times (10, 20, 30 s). The following Figure 2 demonstrates a flowchart of the aforementioned mobility levels.

3. SIMULATION AND RESULTS

This paper presents performance analysis of MANET protocols such as DYMO, LANMAR, AODV and ANTMANET operating on WSN standards IEEE 802.15.4. These protocols have been chosen because of their adequate results in performance evaluation in [4]. The experiment have been carried using QualNet 7.3 simulator [6]. This paper explores the performance of parameters such as network overhead, average delay and throughputs. The operational scenario represents a typical WSN floating on the surface of steady water surface of a small lake, this system to monitor environmental parameters such as water temperature, water saintly and pressure therefore varying traffic load and random way point mobility model is used, the random waypoint model is a random model for the movement of mobile devices, representing the change of their location, velocity and acceleration over time [7], and the size of terrain 1500m*1500m. The following table shows the simulation attributes:

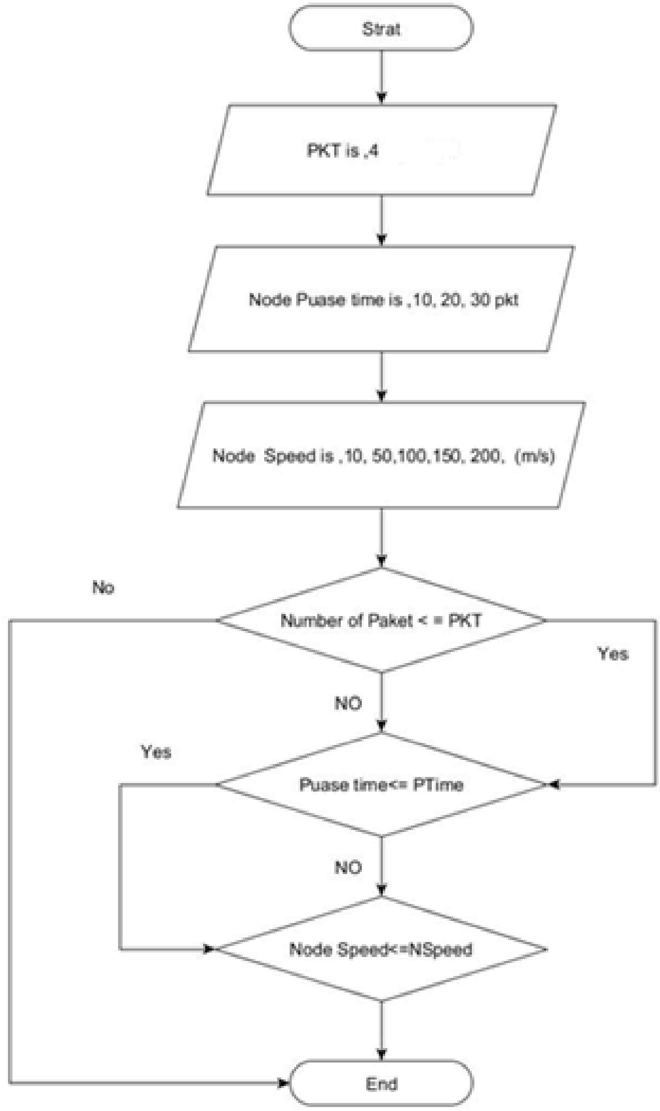

Figure 2: Mobility experiment Plane

Table 1
Simulation Model Attributes.

Parameters	*Value*
Experiment time	3600 sec
Number of nodes	30
Terrain size	1500 m × 1500 m
Application	CBR
Packet Size	512 bit
Number of packets (packet/s)	4, 10, 15
Mobility Model	Random Way Point
Pause time (s)	10, 20, 30
Speed (m/s)	10, 50, 100, 150, 200
Propagation model	Free Space
Channel frequency	2.4 GHz
Radio type	Accumulated noise model
Network protocol	IPv4

3.1. Protocols discription

ANTMANET is a hybrid routing protocol for MANETs which utilizes Swarm Intelligence to solve routing problems. Swarm Intelligence (SI) is the property of a system whereby the collective behaviors of simple agents interacting locally with their environment cause coherent functional global patterns to emerge [8]. Swarm intelligence has many powerful properties required by countless engineering systems, such as routing protocols, robotic and control systems[9]. ANTMANET has two different phases. First is the reactive phase, this phase is divided in to initial stage and the path finding. the initial stage is the network initialization process, this process occurs in a very early stage of the network life time, where the nodes begins to build their own local topology and each node will create its own unique node structure

Ad Hoc On demand Distance Vector Routing (AODV): is a MANET reactive protocol. Proactive means search for routes on demand [10]. AODV maintains a routing table with entries of routes to nodes that has been communicated with previously. The AODV nodes does not maintain information about the whole network, instead it keeps partial details of the previously used routing information. To avoid loops each node has predefined sequence numbers (SQ). The SQ and the respective route information have to be included by the nodes whilst finding the routes to certain destination. When a source node anticipating route establishment to a destination generally it broadcast a Route Request (RREQ) [10]. When an intermediate node receives the RREQ, first it checks the packet ID to grantee that this packet has not been received before to avoid duplication, second it checks the destination SQ field of the RREQ message. Routes with the greatest SQ are preferred in selecting the route to destination [11] in case the destination is found in the routing table, the freshness of the route will be examined using the SQ. Next a Route Reply (RREP) control packet is multicasted to confirm that the route to destination has been found. But in case there was no route known to the destination, the intermediate node increases the number of hops and broadcast new RREQ. In case a route has not been found for certain time or the route is not valid any more link failures message will be broadcasted. In this case the defective nodes are notified individually with a Route Error Packets (RERR). AODV uses a loop-free to avoid the counting to infinity problem. In what follows is a summary of the main operations of the AODV protocol as stated above.

Landmark ad-hoc routing (LANMAR): is an effective proactive based routing protocol which uses the same approach of Fisheye State Routing (FSR), LANMAR uses the number of hops to build its routing table, although LANMAR does not need any established hierarchic it uses some of the geographical land marks to keep track of its logical topology to figure the number of hops, LANMAR stores a specific address each node reflects its position within the hierarchy this enables the protocol to discover and maintain a specific route [12]. LANMAR consists of two complementary and cooperating routing schemes:

- The local “myopic” this is considered to be the proactive routing scheme that operates within a limited scope. This scope is centered at each node and the number of hops is limited.
- The “long haul” this considered to be the distance vector routing scheme that broadcasts the elected landmark of each logical subnet and the number of hops is not limited.

When a node requires sending a packet within its topology, the route information is identified from the routing table, stored within the hierarchical region. Otherwise, the node evaluates the logical subnet field of the destination and the packet is forwarded towards the landmark. Routeing information will be updated periodically in the hierarchical nodes within one hop distance [12].

Dynamic MANNET On demand (DYMO): is a reactive, multi-hop unicast routing protocol [13]. DYMO is defined as an enhanced version of AODV. The routing operation within DYMO is divided into route discovery and route maintenance. Routes are discovered on demand when the originator initiates hop-by-hop distribution of a RREQ message throughout the network to find a route to the target, currently not in its routing table. This RREQ message is swamped in the network using broadcast and the packet reaches its destination. The target then sends a RREP to the source. Upon receiving the RREP message by the source, routes have been established between the two nodes. For maintenance of routes which are in use, routers elongate route lifetimes upon successfully forwarding a packet. In order to react to changes in the network topology, routers monitor links over which traffic is flowing[13]. When a data packet is received for forwarding and a route for the destination route is broken, missing or unknown, then the source of the packet is notified by sending a route error (RERR) massage [13].

3.2. Performance metrics

In order to compare the protocols in question, the quantitative metrics were used to measure and evaluate the performance of the simulated routing protocols, for all metrics, the average over multiple experiments were determined. Each of these metrics parameters can be described briefly as follows.

- **Throughput**: Throughput is the number of correctly delivered data bits/sec or packets/sec over a specified time interval. It is a global index of performance, associated to the quantity of delivered service. Throughput is usually expressed as the sum of correctly delivered bits [14].
- **End-to-end delay for data packets (E-to-E):** E-to-E is the time consumed by a data packet to reach its final destination node. Average of this measurement means taking the average elapsed time to deliver a packet from source to destination. This metric includes all possible delays caused by queuing at the interface queue, propagation and transfer times and delays caused by control overhead [15].
- **Control Overhead**: this represents the total number of control packets transmitted during the simulation time. Overhead can be calculated by working the ratio of routing packets to the total number of packets generated by the source [15].
- **Jitter**: Average jitter is a performance characteristics used to measure deviation from true periodicity eventually of inactivity in packet across a specific network. When a network is stabilized with constant latency it will have no jitter. Packet jitter is expressed as an average of the deviation from the network main latency [16].

4. RESULTS DISCUSSION

The Random Way Point (RWM) [17] model is the commonly used mobility model in which every node randomly chooses a destination and moves towards it from a uniform distribution (0, Vmax) at any moment of time, where Vmax is the maximum allowable velocity for every node. Each node stops for a duration defined by the ‘pause time’ parameter when it reaches the destination. After the pause time it again chooses a random destination and repeats the whole process until the end of the simulation.

Network Overhead refers to metadata and network routing information sent by an application, which uses a portion of the available bandwidth of a communications protocol. This extra data, making up the protocol headers and application-specific information is referred to as overhead, since it does not contribute to the content of the message [16].

From Figure 3, Figure 4 and Figure 5 the variation in pause time and node speed gives considerable reduction, the lower overhead is better as the network resources will be utilised in data forwarding rather than distributing routing information via aggregating control packets. It is clear that ANTMANET denoted with blue bar has out perfumed all protocols this is due to the fact that ANTMANET is based on the ant colony optimisation algorithm that is referred to as distributed routing algorithm the nature of this algorithm guarantees lower overhead and higher throughputs every time.

The End to End Delay is a significant parameter for evaluating a protocol which must be low for good performance. Figure 6 and below shows that the variation in pause time and network speed gives significant impact in the performance of all protocols specially LANMAR as this protocol utilizes the land trade marks in order to perform packet forwarding, and the faster nodes moves it gets higher delay. This improves when the pause time doubles and triples. The best protocol performance is ANTMANET (denoted with blue bar), it show stability in the performance even when the nodes are super-fast also it improves when the pause time increases. And this is very important in such highly mobile environment because it offers the robustness factor to the network.

From Figure 9, Figure 10 and Figure 11, it is clear that the variation in pause time and node speed gives more or less the similar throughput up to the node speed 100 m/s then throughputs drops dramatically, this indicate that the bottleneck of all routing protocols exists after this speed. Again ANTMANET is clearly have the highest throughputs even after the bottleneck.

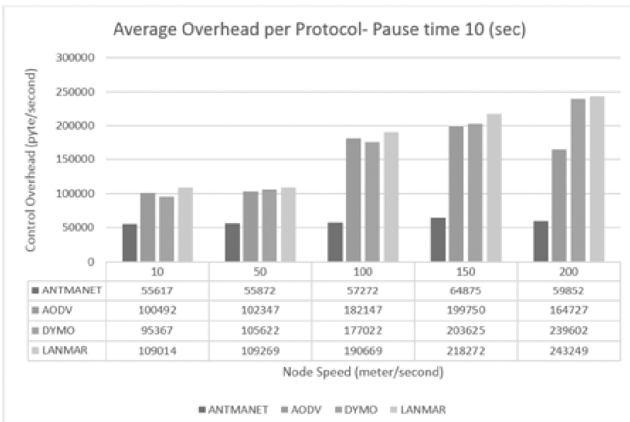

Figure 3: Overhead (bytes)-Pause time 10 sec

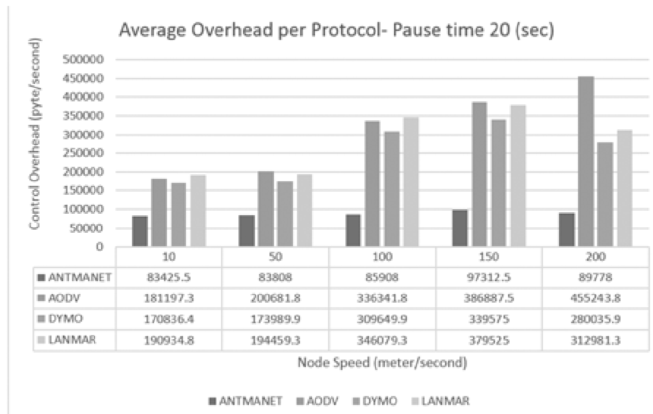

Figure 4: Overhead (bytes)-Pause time 20 sec

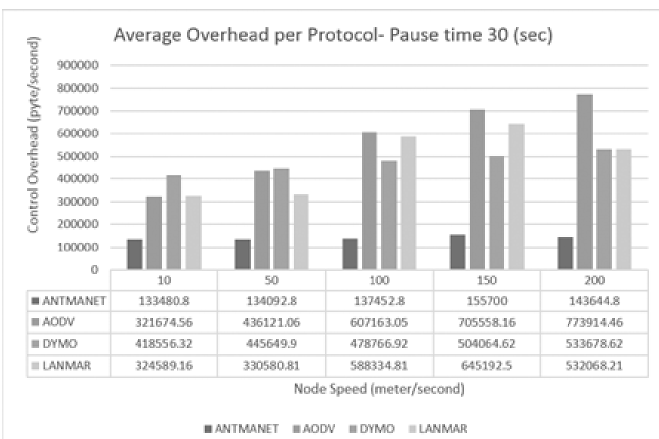

Figure 5: Overhead (bytes)-Pause time 30 sec

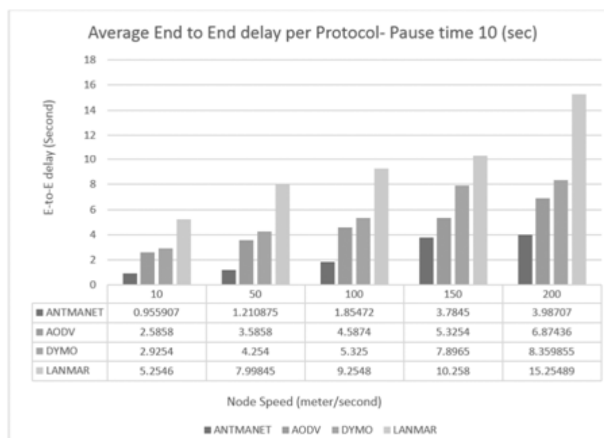

Figure 6: Average E-to-E delay-Pause time 10 sec

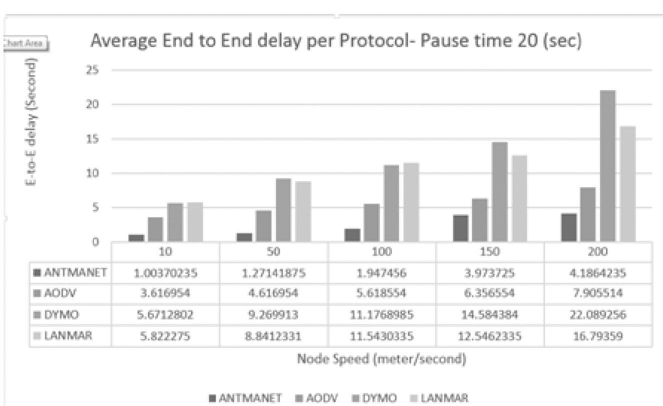

Figure 7: Average E-to-E Delay-Pause time 20 sec

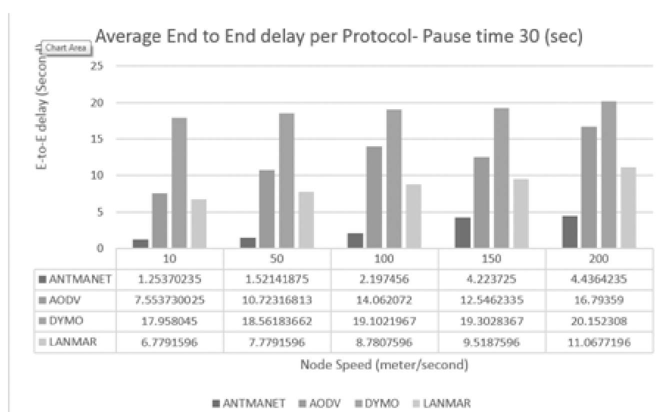

Figure 8: Average E-to-E Delay-Pause time 30 sec

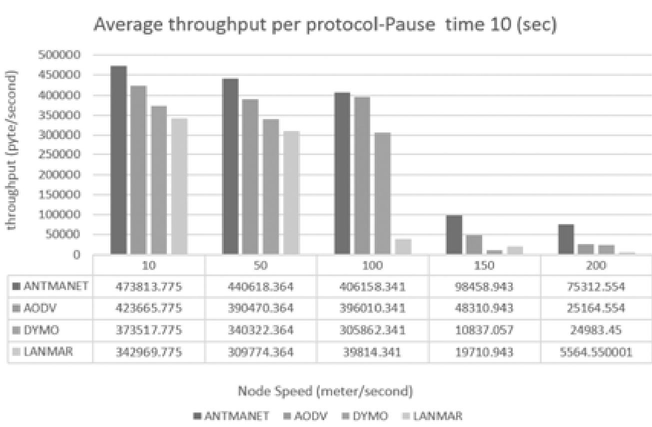

Figure 9: Throughputs-pause time 10 sec

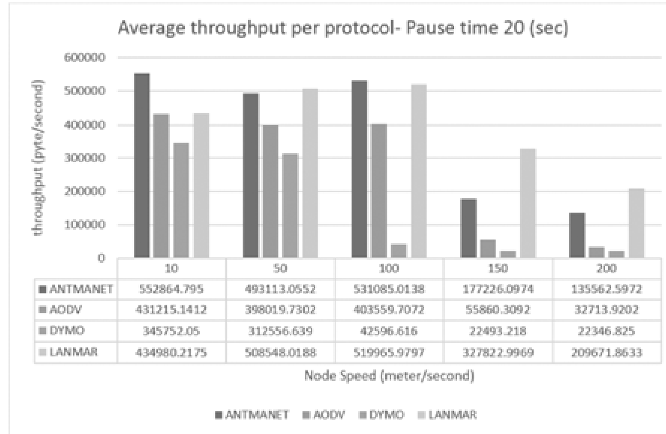

Figure 10: Throughputs-pause time 20 sec

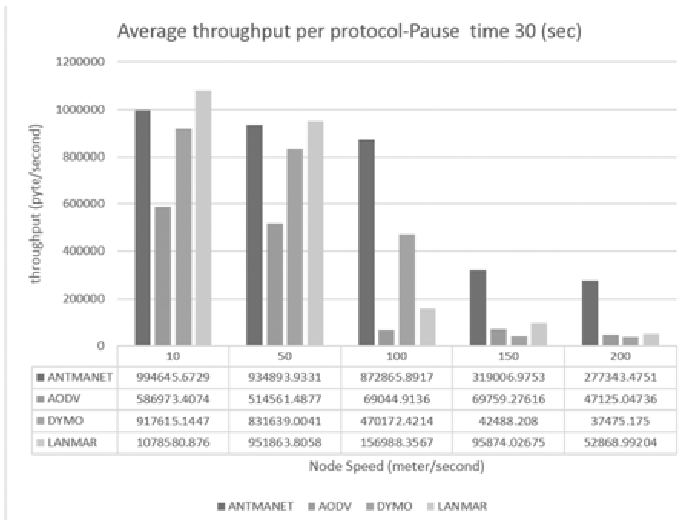

Figure 11: Throughputs-pause time 30 sec

5. CONCLUSION

The ANTMANET, AODV, DYMO and LANMAR protocols are compared in terms of the variation in pause time and node speed in CBR traffic under WSN high mobility network environment. Due to randomness in mobility, the mobility model and the traffic model are selected as scenario parameters.

The ANTMANET protocol is giving better performance than the AODV protocol for most of the performance parametric measures. The DYMO and LANMAR parameters are comparatively high for ANTMANET protocol which can be reduced by the reduction of control packets.

The future work of the research will focus on the reduction of the usage of control packets in routing.

Future work is focused towards modelling and evaluate the performance of ANTMANET with varanine more factors such as the packet size and network load. Also this work has forwarded our attention in to comparing ANTMANET to other ACO based protocols.

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