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Performance Evaluation of Reactive Routing Protocols Using IEEE 802.15.4 Application in Designed Wireless Sensor Network

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Abstract-Wireless Sensor Networks (WSN's) are decentralized type of networks used in sensing and processing physical data without any pre-existing infrastructure. WSN consists of sensing nodes that can interact among themselves and with the physical environment for sensing, measuring and controlling various parameters. For effective and efficient transmission of information in a seamless manner, the choice of routing protocol is still a major constraint in WSN design. In this paper, Reactive Routing protocols using IEEE 802.15.4 application have been evaluated on the designed network scenario. The parameters we have used are (i) Throughput (ii) AEED (iii) Number of Packets Forwarded (iv) Number of Packets Dropped as performance metrices in both Static and Mobile environment for 50, 75 and 100 nodes.

Keywords: Ad-hoc On-Demand Distance Vector (AODV), Dynamic MANET On-demand (DYMO), Dynamic Source Routing (DSR), Ad Hoc On-Demand Multipath Distance Vector (AOMDV)), Unipath Routing Protocols (URP)

I. INTRODUCTION

A Wireless Sensor Network (WSN) is a decentralized type of wireless network that does not require any pre-existing infrastructure. The recent advancements in mobile computing technologies and communication technologies have facilitated the design and development of WSNs. WSN consists of a large number of low-power smart sensor nodes that are randomly and densely deployed for sensing, measuring and controlling various parameters. WSNs find applications in military, logistics support, habitat monitoring, industrial control, environmental control, disaster relief and human centric applications [1].

There are a large number of challenges in the deployment of sensor networks like network topology design, hardware constraints, fault tolerance, production costs, scalability, survivability in aggressive environment and power consumption [2][3]. These challenges are equally complicated to those found in Wireless Ad hoc networks. Another major challenging task in design and deployment of WSNs is the selection of a routing protocol that provides a path between source and destination nodes for data transfer in an effective, efficient and scalable manner [4, 5].

In this paper, Section II provides a brief overview of various Routing protocols (RP) for WSNs followed by a literature Survey of the related work in Section III. Section IV illustrates designed network model, simulation based on selected parameters followed by results and discussion in Section V.

II. RP

The RP provides the mechanism of communication between the nodes and route selections between source and destinations while maintaining high QOS standards [6]. A comparative study of various RPs for heterogeneous WSN is given in [7]. The basic classification of RP's in WSN is shown in figure 1. These RP's can be classified in various categories such as URP and Multipath Routing Protocols (MRP's). These can be further classified as- Proactive, Reactive and Hybrid protocols.

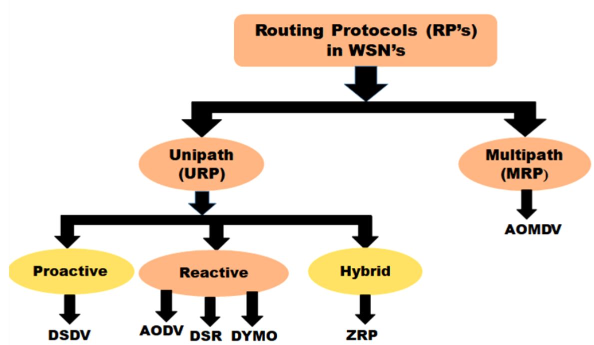


FIGURE 1: Classification of Routing Protocols in WSN's

URP.

These RP's establish only a single route between the originating and target node. Every route requires frequent route discovery process that increases the routing overheads. URP consists of route discovery procedure i.e. identifying a route between nodes, and route maintenance procedure or identifying an alternative route in case of link failure.

A.Proactive RP's (Table Driven Protocols):

In these protocols, the routes between various nodes are predefined. Data is usually transferred through these predefined routes. The data packets can be forwarded or delivered immediately as the routes are predefined. Each node stores the information about its immediate neighbors and they keep on updating information whenever there is change in network topology. Dynamic Destination-Sequenced Distance-Vector Routing Protocol (DSDV) is a proactive RP.

B.Reactive RP's (On Demand RP's):

In these protocols, each Node establishes their own routes on the on-demand process to send the data packets to the destination. Each Node sends all its data packets to all its neighbors or its intermediate nodes. This process is repeated until a route is established. The On-demand RP's perform two major tasks. (i) Route discovery from source node to destination node: While discovering route, the packet from source node carries the address of destination node as well the intermediate nodes in its path. (ii) Maintaining routes in case of route failures due to link breakage in multi-hop networks using acknowledgement mechanism. Whenever a route is requested, a delay is added to the network as time is consumed in route discovery process due to reactive nature of the protocols. AODV, DSR and DYMO are Reactive RP's.

- ***AODV.*** It creates routes based on demand and minimizes the number of broadcasts required. A transmitting node broadcasts a Route Request (RREQ) packet to all the neighboring nodes till the packet reaches its destination and a route table is prepared accordingly. The RREQ is acknowledged using the reverse path. Route discovery process is reinitiated whenever there is a link failure due to movement of nodes in the network. In order to notify any change in the link, AODV uses HELLO packets and link layer feedback mechanism. AODV provides low routing overhead and quick route discovery as the information regarding inactive nodes is not maintained.
- ***DSR.*** It follows the source route approach on demand basis in which the transmitting node keeps record of the destination as well as the intermediate nodes. It is a beaconless protocol designed for multi hop networks and does not require any HELLO messages for notifying its neighbors.

  When the desired route is not found in the cache of routing table, route discovery process is initiated by broadcasting a RREQ packet to all the near-by nodes. On receiving a RREQ packet, each node searches its cache for the desired destination. If no route is found in the cache, the node appends the RREQ packet and forwards it to the neighboring nodes. If the desired route is found, it acknowledges with a Route Reply (RREP) packet. If a broken link is found in the network, it uses a Route Error (RERR) packet for its maintenance.
- ***DYMO.*** This routing protocol is a successor of the AODV and DSR nowadays known as AODVv2. It simplifies the operation of AODV protocol, while retaining its basic mechanism. In this protocol, the nodes do not have routing information. They use a control packet for route discovery only when a node receives data packet from its neighboring nodes. DYMO involves two operations. (i) Route discovery: This process is initiated when the information regarding the destination is not present in the routing table of source node. Then routes are discovered on-demand by flooding a RREQ message to all the nodes in the network. If the desired route is found, acknowledgment is given by the RREP message containing the address of the discovered path. (ii) Route maintenance: This is performed in case of active route breakage to avoid dropping of packets. The node generates a RERR message on receiving a data packet for a destination with no predefined route. Other nodes are notified about the breaking of current route by RERR RM. The source on receiving the RERR reinitiates the route discovery if there are some packets remaining for delivery. Hello messages and Sequence numbers are used by the nodes for maintenance of routes and for avoidance of routing loops within the network.

C. Hybrid RP's.

These protocols like Zone RP (ZRP) make use of both proactive and On-demand RP's. These are non-uniform RP's which optimize the performance with adaptive and minimal overhead control and increases scalability by proactive route management using a route discovery mechanism.

This RP identifies various routes between the source node and the destination node and increases reliability as well as efficiency of the transmitted information. In this, the new routes are created only when all the existing routes failed. AOMDV is an example of MRP.

III. RELATED WORK

Periyasamy, P., and E. Karthikeyan [8] have presented the performance comparison of AODV and AOMDV in terms of variation in pause time and network load under RWM in CBR Traffic. Simulative result shows that AOMDV outperforms AODV. In [9], the authors have presented a performance comparison of AODV, DSR, OLSR and ZRP on the basis of several qualitative metrics. Simulative result shows that AODV performed better under different pause time and network speed conditions. While DSR provides better packet delivery ratio as compared to OLSR and ZRP but its performance degrades for average jitter and average end-to -end delay.

Prashant K. M. et al. [10] have presented a two-step performance comparison for ZRP, AODV, DYMO and DSR. Firstly, the scenario is analyzed for different pause times and for the second stage, maximum speed of the nodes is varied. It is concluded that ZRP has lower PDR and throughput than the AODV, DSR and DYMO. After performance evaluation in second stage, AODV outperforms DYMO and ZRP.

Waheb A. Jabbar et al. [11] evaluated the QoS and energy efficiency of RP's- OLSRv2, DYMO and MP-OLSR using three different applications (HTTP, VoIP and FTP) for traffic generation. The effect of the node mobility, network density and load traffic on these above stated protocols has been evaluated by considering precise performance metrics for each traffic application.

S. S. Naing et al. [12] used different mobility models to explore the performance metrics of two ad hoc RP's (AODV and DSR). The two mobility models: Random Way-point Mobility Model (RWMM) and Realistic Mobility Model are used in the same network conditions using NS2 Simulator. With RWMM for lower mobility, both AODV and DSR perform well. But AODV outperforms at high speeds for all parameters. In second mobility model, AODV and DSR perform equally but with slight decreased performance compared to RWMM.

In [13], the authors have presented a comparative analysis between mobility-based clustering (MBC) protocol and location aware fault tolerant clustering protocol (LFCP) on various qualitative metrics (i) stability period (ii) Network lifetime period (iii) Energy consumption. Simulative results show that LFCP-MWSN outperform MBC. In [14], the authors have compared the performance of AODV and DSR routing protocols over design network model on the basis of average End to End Delay, Throughput, Jitter and Total Packets Received using Qualnet simulator. Qualitative analysis shows that average jitter for DSR is 21.80 % greater than that of AODV whereas in terms of AEED, throughput and total packets received, AODV performs 5.67 %,0.83 and 0.85% better than DSR respectively. The earlier work reported in literature have used traffic applications for evaluating the performance of WSN in isolation either for static or mobile scenario. This present work focuses mainly on evaluation of reactive protocols in both static and mobile scenario using RWMM with a maximum speed of 10 m/s and a pause time of 30 sec using Zigbee application (IEEE 802.15.4) between nine pairs of source and destination nodes.

IV. SIMULATION DESIGN

We have designed a WSN with 50, 75 and 100 nodes in a terrain size of 1500 x1500 m^2 using QualNet. For traffic generation, we have used nine Zigbee applications (IEEE 802.15.4) between different source and destination nodes. In IEEE 802.15.4, at the physical layer we have used the default data rate of 250 kbps

A. Application used in Simulation.

Zigbee is a newly developed Wireless protocol with the purpose of building upper layers of the communication stack known as Open Systems Interconnection (OSI), using low-power, low data rate, and close proximity lower layers of Zigbee standard that are deliberate taking into consideration small cost and modest power factors. Physical Layer (PHY) and Medium Access Control (MAC) layer are the lower layers of Zigbee. Figure 2 shows the architecture of IEEE 802.15.4. The Zigbee architecture contains three layers: (i) physical layer (ii) MAC layer (media access control) (iii) upper layer (network layer, application layer).

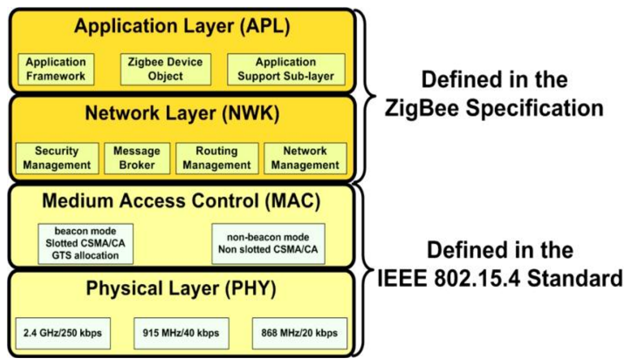


FIGURE 2: Architecture of IEEE 802.15.4

- *PHY.*

This fundamental layer specifies the hardware and channel requirements for communication purposes. In Zigbee, the main task of PHY is transmission and reception of data using IEEE 802.15.4 standard. Table 1 shows the defined frequency bands and number of channels used in PHY. Highest range 2.4 GHz frequency band is license free and universally used at the data rate of 250 kbps.

Table1. Frequency Bands of Physical Layer

Frequency Range	Band	Coverage	Data rate(kbps)	Channels
2.4GHz	ISM	Worldwide	250	11-26
902-928 MHz	ISM	America	40	1-10
868 MHz	-	Europe	20	0

- *MAC.*

This layer manages the RF data transactions between point-to-point neighboring devices. The MAC includes the Collision avoidance techniques (CSMA-CA).

- *Network Layer.*

This layer enables the accurate use of the MAC sub layer and acts an interface to upper layer. It allocates addresses and add/remove certain devices. The RP used by the network layer is AODV.

- *Application Layer.*

It is the topmost layer that provides an effective interface of the Zigbee system to its end users. It performs the function of sending messages between devices while managing group addresses and transporting data.

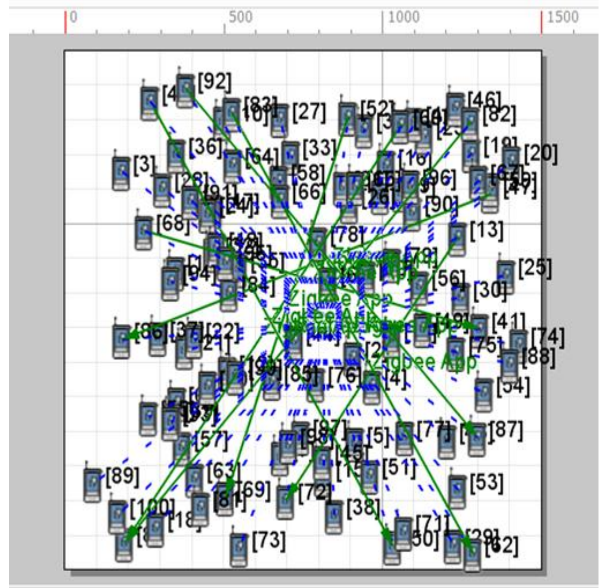
B. RWMM

In RWMM, each Mobile Node (MN) in the network is free to move randomly in different directions with different speeds independent of its neighboring nodes with variable pause time. RWMM is implemented widely due to its simplicity and availability for simulating the routing protocols. Each MN selects a random location along with a specific pause time t_p. After the completion of pause time duration, a new location is selected by the MN. The node propagation occurs across an area at a random speed uniformly distributed over a range of V_0 to V_{max} where V_0, V_{max} denote the minimum and maximum speeds respectively The process of selecting random location continues until the simulation finishes. The network is stable for small value of V_{max} and longer duration of t_p. For tp = 0, the design signifies a continuous mobility. Further, the existing RWMM was modified to allow MN propagates at a constant speed with zero pause time.

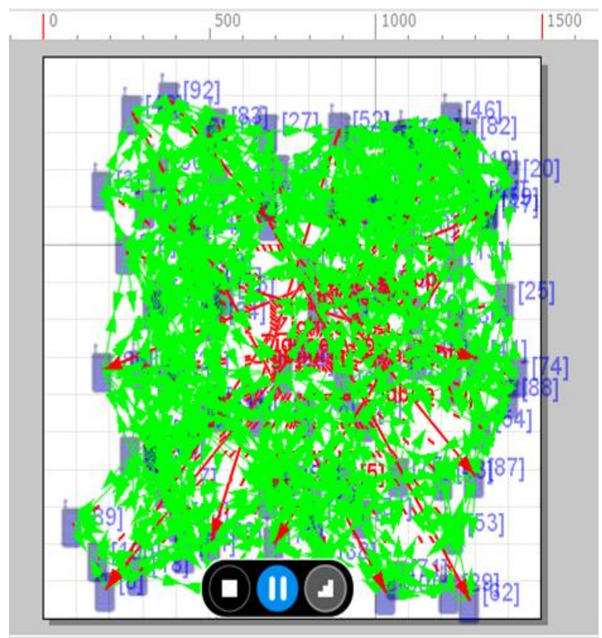
In the designed model, we have evaluated the performance of RP's in both static and mobile environment. The Node placement in designed Simulation framework is shown in figure 3 (a). For mobile scenario, we have taken RWMM with a maximum speed of 10 m/s and a pause time of 30 sec. We have used IPv4 as the Network Layer protocol with item size of 1024 bytes. Data rate is kept at 10 Mbps. The WSN running environment in shown in figure 3(b). The various parameters used for creation of simulative environment are given in table 2 below.

TABLE 2. Simulation Parameters

Simulation Parameters	
Simulator	Qualnet 7.3.1
Routing Protocols	AODV,DSR,DYMO
Transmission Terrain size	1500m x 1500m
Mobility	RWMM, max speed 0-10m/sec
Pause time	30sec
Simulation time	1100sec
Physical Layer model	IEEE 802.15.4
Network Layer Protocol	IPV4
Antenna Model	Omni directional
Application	Zigbee
Item Size	1024 bytes
Number of nodes	50,75,100
Zigbee Applications	For 100 nodes –{(42-50),(60-8),(83-62),(82-8),(92-87),(13-72),(68-41),(47-86),(52-69))}
Data Rate	10 Mbps



(a) WSN Node Placement



(b) WSN Running environment
FIGURE 3: Designed Simulation Framework

V. RESULTS AND DISCUSSION

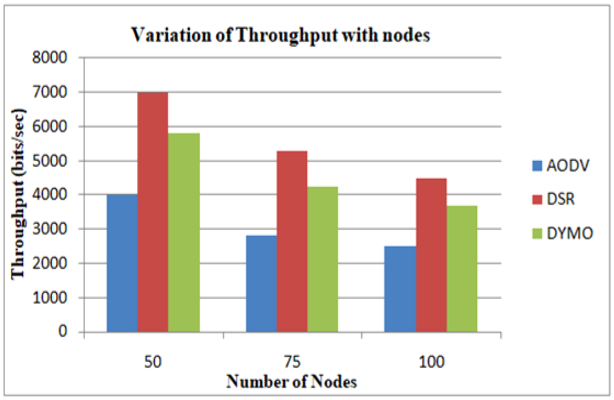
In the designed network, the performance of RP's for the internet-based IEEE 802.15.4 traffic application is evaluated by using **(i)Throughput (ii)AEED (iii) Number of Packets**

Forwarded (iv)Number of Packets Dropped as performance metrics.

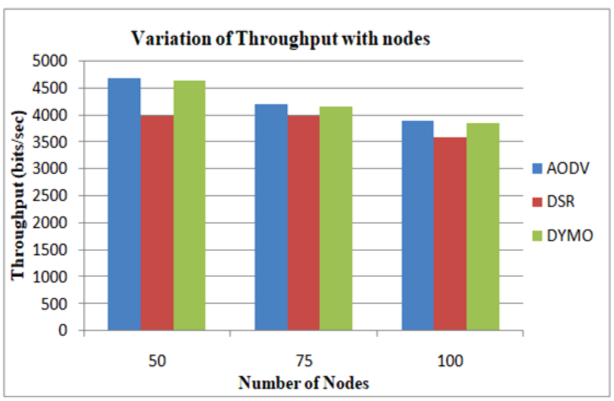
A. ***Throughput.***

The average rate of data successfully delivered over a communication channel expressed in bits/sec or packets/sec. For a better performance, higher throughput is always desirable. The variation of throughput with number of nodes with and without mobility is shown in figure 4.

From figure 4 (a) and 4 (b), it is evident that the throughput varies from 2500 to 7000 bits/sec and from 3600 to 4700 bits/sec in static and mobile scenario respectively.



(a) For Static Nodes



(b) For mobile nodes using RWMM

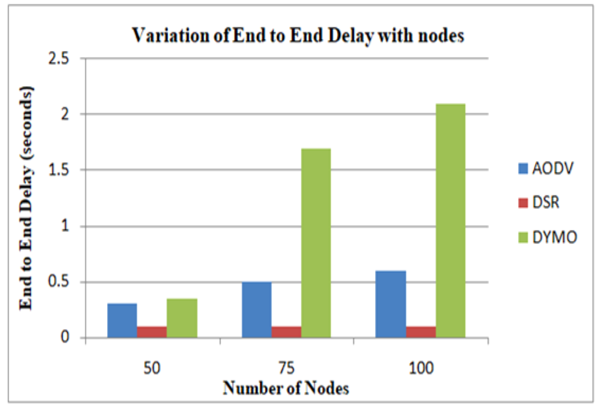
FIGURE 4: Throughput for AODV, DSR and DYMO

In both static and mobile scenarios, as the number of nodes increases, the throughput slightly decreases. In static scenario, the throughput of DSR is better than AODV and DYMO. However, in case of mobile scenario using RWMM, AODV and DYMO perform better than DSR.

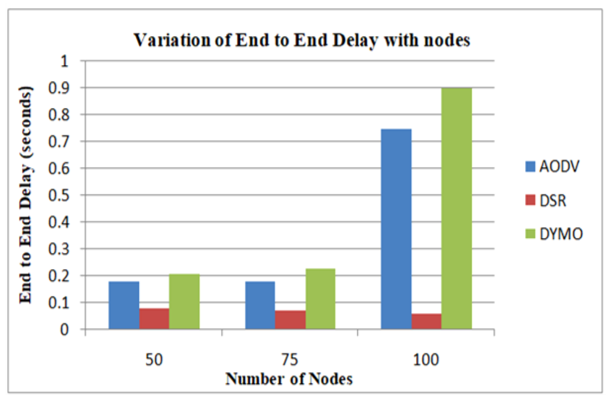
B. ***AEED.*** It is the time taken for a packet to travel across the network from origin to target. It is the average time interval due to buffering, propagation, retransmissions and queuing of all the surviving data packets that are transmitted. AEED is expressed as:

$$\text{AEED} = \frac{T_{total}}{NP} \qquad \dots (1)$$

Where T_{total} denotes the sum total delays occurring during transmission and NP represents the number of received packets. The better performance of the protocol is governed by lower value of AEED. The variation of AEED with number of nodes with and without mobility is shown in figure 5.



(a) For Static Nodes



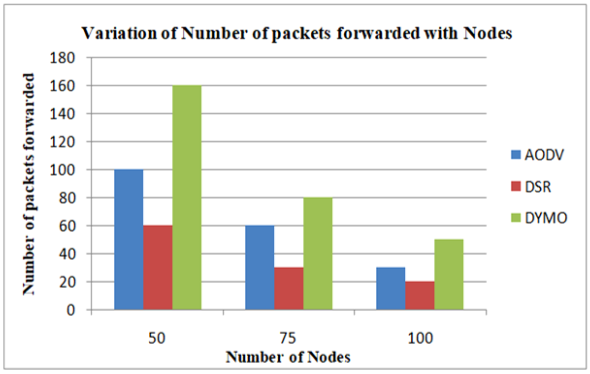
(b) For mobile nodes using RWMM

FIGURE 5: AEED for AODV, DSR and DYMO

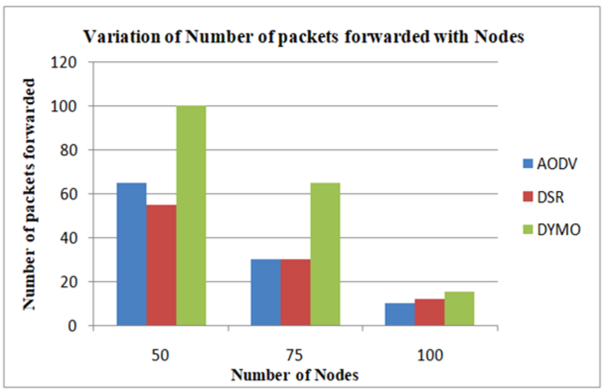
The AEED accrued by the protocols ranges between 0.1 to 2.1 seconds and 0.06 to 0.9 seconds for both static and mobile scenario respectively. For both scenarios, AEED increases with increase in number of nodes for AODV and DYMO. In static scenario, DSR performs better as compared to AODV and DYMO and provides minimum AEED. While in mobile scenario, the AEED for DSR decreases as the number of nodes increases. Hence, DSR performs better with lowest AEED.

C. Number of Packets Forwarded.

The variation of Number of packets forwarded with number of nodes with and without mobility is shown in figure 6.



(a) For Static Nodes



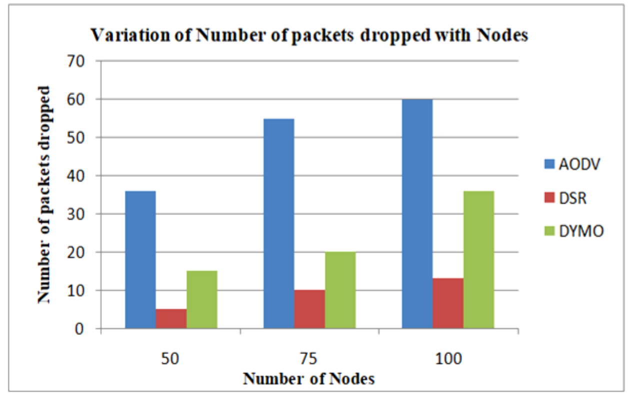
(b) For mobile nodes using RWMM

FIGURE 6: Packets forwarded for AODV, DSR and DYMO

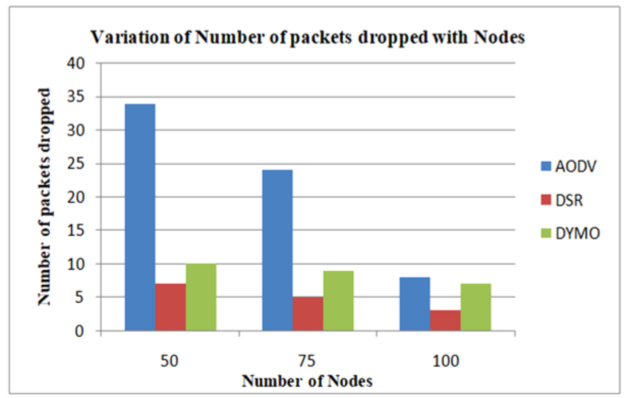
The number of packets forwarded varies from 20 to 160 for static scenario and 12 to 100 for mobile scenario. For both static and mobile scenario, DYMO outperforms both AODV and DSR protocol. As the number of nodes increases, the number of packets forwarded decreases due to increase in network congestion. In mobile scenario for 100 nodes though the packets forwarded with DSR are higher than AODV, still DYMO performs better for all node configurations.

D. Number of Packets Dropped.

The variation of Number of packets dropped with number of nodes with and without mobility is shown in figure 7.



(a) For Static Nodes



(b) For mobile nodes using RWMM

FIGURE 7: Packets dropped for AODV, DSR and DYMO

The number of packets dropped ranges between 5 to 60 for static scenario and 3 to 34 for mobile scenario using RWMM. For all node configurations in static scenario, the Number of packets dropped increases while in mobile scenario, the number of packets dropped decrease for AODV, DSR and DYMO. In both scenarios, DSR provides minimum packets dropped and hence outperforms both DYMO and AODV.

It has been observed that the performance of dynamic scenario is better than the static scenario when the density of nodes increases. The reason for that is the path distance between the sensor nodes decreases as the number of nodes increase in the given simulation area. Notwithstanding the gain due to decreasing path, the other propagation factors should also be taken into consideration which is not the scope of this paper.

V. CONCLUSIONS

In the present work, the performance of DSR, AODV and DYMO protocols for WSN using IEEE 802.15.4 (Zigbee) application is evaluated. We have compared the performance in both static and mobile environment for a designed network with 50, 75 and 100 nodes. From simulation results, it has been found that DSR performs better with lesser number of packets dropped in both static and mobile scenario. In terms of throughput, DSR and AODV perform better for static and mobile scenario respectively. DSR provides minimum AEED, and DYMO performs better in terms of number of packets forwarded in both static and mobile environments.

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