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Comparison of OLSR & DYMO Routing Protocols on the Basis of Different Performance Metrics in Mobile Ad-Hoc Networks

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Abstract

Mobile ad-hoc network (MANET) is a collection of self-configuring wireless mobile routers dynamically forming a temporary infrastructure-less network. Nodes are moving randomly thus changing organization and topology of the wireless network. Major challenges that make the design of adequate routing protocols are multihop, mobility, scalability, bandwidth, and battery power constraints. Dozens of routing protocols have been developed for MANETs over the past few years. Routing protocol is a standard that controls selection of the route for routing packets between nodes in MANET. This research presents the investigation of two routing protocols namely OLSR (Optimized Link State Routing) and DYMO (Dynamic MANET Ondemand) on the basis of different performance metrics like throughput, optimal hop count and average network delay. Performance metrics were examined on the basis of four different parameters namely number of nodes, mobility speed, pause time, and topological area. Simulation was performed using Network Simulator-2 (NS-2) under Random Waypoint mobility model. Results show that DYMO outperforms OLSR in terms of throughput. Increasing area and speed decreases throughput whereas increasing pause time and number of nodes improve throughput of both protocols. With respect to optimal hop count, OLSR outperforms DYMO. Increasing area, number of nodes, and pause time increase hop count whereas increasing speed decreases hop count of both protocols. Average network delay of both protocols increases with increase in area, number of nodes, and speed. Increasing pause time improves delay of both protocols. Fluctuation in delay of both protocols increases for area above 500 x 300 m^2 and speed above 5 m/s for all number of nodes.

Keywords: Ad hoc networks, wireless networks, adhoc on-demand distance vector, optimized link state routing protocol, ad hoc network routing protocols.

1. Introduction

Mobile ad-hoc network (MANET) is a collection of wireless mobile nodes dynamically forming a temporary infrastructure-less network. Nodes are moving randomly thus changing organization and topology of the wireless network. MANET may operate in a stand-alone fashion, or may be connected to the Internet. Multihop, mobility, heterogeneous scalability, bandwidth, and battery power constraints make the design of adequate routing protocols a major challenge. Routing protocol is necessary in such an environment in order to exchange packets between two hosts which are not directly connected (Sarkar *et al.* 2007).

Mobile users like group of researchers, students, or firefighters having laptops equipped with powerful CPUs, large hard disk drives, and good sound and image capabilities can communicate with each other by forming a temporary wireless network without any established infrastructure or centralized administration. Such networks are quite popular in commercial and military applications because they are formed on the fly without any base station or central controller (Sarkar *et al.* 2007).

The primary focus of MANET group within IETF is to develop and evolve MANET specifications. The goal is to form scalable MANETs and solve challenges like limited wireless transmission range, hidden terminal problems, packet losses due to transmission errors, mobility-induced route changes, and battery constraints etc. MANETs could enhance the service area of access networks and provide wireless connectivity into areas with poor or previously no coverage. The multihop property of an ad-hoc network needs to be linked by a gateway to the wired backbone. User mobility enables users to switch between devices, migrate sessions, and still get the same tailored services. Host mobility facilitates the user's devices to move around the networks and retain connectivity and reachability (Sarkar *et al.* 2007).

1.1. Routing Protocols

Many routing protocols are developed for MANETs over the past few years. Routing protocol is a standard that controls selection of the route for routing packets between nodes in MANET. All nodes are mobile and can be connected dynamically in an arbitrary manner. Nodes act like routers and take part in discovery and maintenance of routes to other nodes. The addition of more nodes complicates the situation. Routing protocol is responsible for discovering the network topology, selecting the best path between the nodes, minimizing the bandwidth overhead, and providing rapid coverage after the topology changes (Jayakumar and Gopinath 2008). Proactive, reactive, and hybrid routing are different techniques used in MANET routing protocols. In proactive (table-driven) routing protocol, nodes continuously assess routes to all reachable nodes and attempt to keep reliable and latest routing information. Therefore, in case of need, the source node can get a routing path immediately. In reactive (on-demand) routing protocol, routing paths are searched only when needed. A route discovery operation invokes a route-determination procedure. The discovery procedure terminates when either a route has been found or no route is available after examination for all route permutation. Hybrid routing protocols, merge the virtues of both proactive and reactive routing protocols and surmount their drawbacks. Normally, hybrid routing protocols exploit hierarchical network architectures (Sarkar *et al.* 2007). This research analyzed the performance of OLSR and DYMO routing protocol in MANETs.

1.1.1. Dynamic MANET on-Demand Routing Protocol (DYMO)

Dynamic MANET On-demand (DYMO) routing protocol enables reactive, multihop unicast routing between participating DYMO routers. DYMO is an enhanced version of AODV. DYMO operation is split into route discovery and route maintenance. Routes are discovered on-demand when the originator initiates hop-by-hop distribution of a RREQ (rout request) message throughout the network to find a route to the target, currently not in its routing table. This RREQ message is flooded in the network using broadcast and the packet reaches its target. The target then sent a RREP (route reply) to the originator. Upon receiving the RREP massage by the originator, routes have been established between the two nodes. For maintenance of routs which are in use, routers lengthen 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. 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 RERR (route error) massage. Upon receiving the RERR massage, the source deletes that route. In future, it will need to perform route discovery again, if it receives a packet for forwarding to the same destination. DYMO uses sequence numbers to ensure loop freedom and enable them to determine the order of DYMO route discovery messages, thus avoiding use of obsolete routing information (Chakeres and Perkins 2006).

1.1.2. Optimized Link State Routing (OLSR) Protocol

Optimized Link State Routing (OLSR) is a proactive MANET routing protocol. Unlike DSDV and AODV, OLSR reduces the number of retransmissions by providing optimal routes in terms of number of hops. For this purpose, the protocol uses MPRs (Multipoint Relays) to efficiently flood its control messages by declaring the links of neighbors within its MPRs instead of all links. Only the MPRs of a node retransmit its broadcast messages, hence no extra control traffic is generated in response to link failures. OLSR is particularly suitable for large and dense networks. The path from source to destination consists of a sequence of hops through the MPRs. In OLSR, a HELLO message is broadcasted to all of its neighbors containing information about its neighbors and their link status and received by the nodes which are one hop away but they are not passed on to further nodes. In response of HELLO messages, each node would construct its MPR Selector table. MPRs of a given node are declared in the subsequent HELLO messages transmitted by this node. OLSR is designed to work in a completely distributed manner and does not require reliable transmission of control messages. Control messages contain a sequence number which is incremented for each message. Thus the recipient of a control message can easily identify which information is up-to-date - even if the received messages are not in order (Clausen and Jacquet 2003).

2. Previous Research

Mobile Adhoc network is a quite new field for researchers and many researchers have done research work in this new area. A number of wireless routing protocols are designed to provide communication in wireless environment. Few of these protocols are AODV, OLSR, DSDV, DSR, TORA, ZRP, LAR, LANMAR, STAR, and DYMO etc. Performance comparison among some set of routing protocols is already performed by the researchers, however, the comparison between OLSR and DYMO is rare. Review of some the papers which have been published regarding this field is given below.

Rahman and Zukarnain (2009) worked on the simulation based performance comparison of AODV, DSDV and I-DSDV MANETs protocols using NS-2 with respect to metrics like packet delivery fraction(PDF), end to end (E2E) delay and routing overhead in term of pause time, number of nodes and node speed. Simulation results indicate that the performance of I-DSDV is better than

DSDV. It is also observed that the performance increases with increase in number of nodes but above 30 nodes the performance of I-DSDV and DSDV deteriorate due to a lot of control packets are generated. It is also observed that I-DSDV is even better than AODV protocol in PDF but lower than AODV in E2E delay and routing overhead. I-DSDV consume more computation overhead than DSDV in the presence of mobility, performing better when compared to AODV. I-DSDV improved the PDF and E2E delay when the node is high but still has lower performance than AODV.

Aziz *et al*. (2009) evaluated AODV, DSR and DYMO routing protocols in MANET in terms of routing overhead, throughput and average end to end delay using network simulation 2 for varying number of nodes, area size, and pause time. Simulation results show that for packet delivery ratio, all routing protocols are quite similar. DSR has low and consistent routing overhead as compared to AODV and DYMO for the nodes equal to 10 and 30. Meanwhile for nodes equal to 50, DSR and AODV have low and consistent routing overhead than DYMO. DYMO routing protocol outperforms AODV and DSR in terms of throughput. For average end to end delay, DYMO is better than AODV and DSR for the 10 nodes. For 30 and 50 nodes, AODV outperforms DSR and DYMO routing protocol in term of stable and low average end to end delay.

Malany *et al.* (2009) compared the performance of AODV, Fisheye, DYMO, STAR, RIP, LANMAR, and LAR routing protocols for MANETs in terms of throughput and delay. Simulation results show that at node densities of 2, 10, 50 and 100, STAR and RIP routing protocols showed lower throughput values whereas other routing protocols are consistent. As the node density is increased further, the LANMAR has a higher throughput. RIP, STAR, Fisheye and LANMAR protocols showed a dip at a node density of 50. AODV, DYMO and LANMAR protocols are having higher end to end delays than others. Whereas LANMAR and RIP shows considerable amount of delay in scaled up environment.

Rahman *et al.* (2009) compared the performance of DSDV, DSR, and AODV routing protocols in MANETs for varying network load, mobility, and network size. From simulation results they concluded that AODV and DSR perform better than DSDV protocol. Packet dropping rate for DSR is very less than DSDV and AODV. DSR generates less routing load than AODV. Both AODV and DSR perform better under high mobility than DSDV.DSR performs higher than the DSDV and AODV in term of packet delivery fraction and delay.

Saad and Zukarnain (2009) evaluated the throughput, and routing overhead of AODV routing protocol with Random Waypoint (RWP), Random Walk (RW), and Random Direction (RD) models for various speeds and number of nodes using OMNET++ simulator. Results show that the routing overhead of all mobility models increase with increase in number of nodes. Routing overhead is highest in RD model and lowest in RWP model. All models are less consistent but RWP Model outperforms both RW and RD models with respect to throughput. The effect on the routing overhead is less with RWP model as compared to RW and RD. The routing overhead is increasing with average increase in speed. Throughput for RWP model is better and consistent as compared to RW and RD models with varying speed. In RW and RD models, throughput increases for average increase in speed.

Kumar *et al.* (2008) evaluated the performances of AODV, DSDV, DSR and OLSR routing protocols for MANET using NS-2. Results show that AODV and DSR perform better than DSDV and OLSR in high mobility scenarios. DSDV and OLSR fail to respond fast enough to changing topology. Routing overhead in DSDV and OLSR remain almost constant and OLSR being winner irrespective of mobility while in AODV, it increases with increase in mobility. DSR however generates lower overhead than AODV while OLSR and DSDV generate almost constant overhead due proactive nature. Poor performance of DSR in respect of average delay can be accounted to aggressive use of caching and inability to delete old route. But it seems that caching helps DSR to maintain low overhead.

Azad *et al.* (2008) analyzed the performance of AODV, DSR, OLSR and ZRP routing protocols in Mobile WiMAX environment using different mobility scenarios. Simulation results show that on the average ZRP and AODV perform better than DSR and OLSR. DSR has less routing overhead, but average end to end delay is higher. However in case of OLSR, it has higher routing overhead, but average end to end delay is less. For packet delivery ration and throughput, DSR and OLSR have poor performance as compared to other protocols.

Bali *et al.* (2007) evaluated the, the effects of multi-hop, data rate, and scalability on routing performance of AODV, DSR, and OLSR through simulation using a joint PHY/MAC architecture for 802.15.4a-like UWB ad hoc networks combined with a realistic path-loss model. Simulation results show that AODV outperforms DSR in network scenario. Moreover AODV outperforms OLSR in small networks with low data rates (less than almost 1Kb/s). OLSR outperforms AODV when data rate increases (greater than 1Kb/s) for the same network size. However, the performance of OLSR degrades as network size increases and AODV again outperforms it.

Muktadir (2007) compared the energy consumption and throughput of OLSR and DYMO routing protocols in MANET using NS-2 under Manhattan Grid Mobility Model for varying node velocity, data send rate and transmission range. Simulation results show that OLSR is more energy efficient than DYMO but DYMO performs better than OLSR protocol in terms of Throughput. DYMO is more speed-sensitive then OLSR. Data send rate does not affect Throughput is less affected by varying data send for both protocols. Power consumption and Throughput deceases due increase in transmission range for both protocols.

Al-Maashri and Ould-Khaoua (2006) evaluated the performance of DSR, AODV and OLSR routing protocols for MANETs using NS-2 on the basis of delivery ratio with nodes moving at speeds ranging from 0 to 20 m/s in the presence of the bursty self-similar traffic. Simulation results indicate that The DSR routing protocol has exhibited superior performance in terms of data packet delivery ratio.

Reddy and Reddy (2006) analyzed DSDV, AODV, TORA, and DSR routing protocols using ns2 simulator with identical traffic load and mobility patterns and considering TCP as transport protocol and FTP as traffic generator. Results indicate that the performance of proactive routing protocol DSDV is far better than remaining protocols for TCP based traffic. DSR which uses source routing is the best among reactive routing protocols. Traffic performance of reactive routing protocols is better than proactive routing protocols for UDP.

3. Simulation Framework

This is simulation based study and to compare DYMO and OLSR protocols for mobile adhoc networks, we choose the Network Simulator-2 as simulation environment. Source code of both DYMO and OLSR were accordingly installed. Different scenarios for mobility (RWP) and traffic (CBR) models were set using “setdest” and “cbrgen” tools. After that, DYMO and OLSR routing protocols were simulated on the basis of four different parameters i.e. number of nodes, mobility speed, pause time, and topological area, which produced trace files. Then AWK language was used to extract values for five different performance metrics i.e. throughput, optimal hop count, and average network delay from those trace files. In the last those values were manipulated using MS-Excel program to get results in graphical form.

Simulation has been performed using Network Simulator-2 (NS-2). NS-2 is a discrete event, object oriented, simulator developed by a research group in VINT project at University of California, Berkeley. NS-2 designed for the simulation of unicast and multicast routing protocols for both wired and wireless architectures.

AWK is a programming language was created at Bell Labs in the 1970s. It is used for processing text-based data, either in files or data streams. The name AWK is derived from the first word of its author’s names — Aho, Weinberger, and Kernighan (Aho *et al.*1988).

The simulation of DYMO and OLSR was conducted using different parameters. Detail of these traffic and mobility parameters is given in table 1.

Table 1: Traffic and Mobility parameters for OLSR and DYMO

Parameter	Short Description	Value/Type
Topological Area	Represents topology or arrangement of mobile nodes. Determined in x & y axis. Also known as network size or dimensional area. Measured in meters.	500 x 300 m^2, 800 x 400 m^2, 1000 x 500 m^2
No. of nodes	Nodes are communication devices or routers.	20, 30, 40
Pause time	The maximum amount of time, a node stays before a new direction and speed is selected.	0, 10, 20, 40, 80, 120, 160, 200
Max. speed	Maximum mobility speed of a node. Measured in meter/second.	5 m/s, 20 m/s, 40 m/s, 60 m/s
Transmission range	Radio transmission range allows a mobile node to send & receive radio signals. Measured in meters.	250 m
Mobility pattern	Define movement of nodes, which is characterized by speed, direction, and rate of change.	Random way point
Application	Denote the traffic type to be used i.e. CBR or TCP. CBR stands for constant bit rate. Used for real time traffic like video & audio applications.	CBR
PHY	PHY stands for physical layer. 802.11b is basically IEEE wireless standard.	802.11b
Packet size	Node sends & receives data in the form of packet. Measured in kilobytes.	512 kB
Packet transmission rate	Every traffic source sends a packet at specific rate that is measured in packet/second.	2 packets/second
Simulation time	Total duration for which simulation runs.	400 s
No. of CBR connections	Total number of CBR connections that can be established among different mobile nodes for communication. Also denoted as "mc".	20

3.1. Performance Metrics

The following five performance metrics were used to compare DYMO and OLSR protocols.

3.1.1. Throughput

Throughput is defined as total number of packets received by the destination. It is a measure of effectiveness of a routing protocol (Reddy and Reddy 2006). Throughput is determined as the ratio of the total data received to required propagation time. The throughput (messages/second) is the total number of delivered data packets divided by the total duration of simulation time (Al-Maashri and Ould-Khaoua, 2006).

3.1.2. Optimal Hop Count

Hop count is the number of hops a packet took to reach its destination (Jorg 2003).

3.1.3. Average Network Delay

Average network delay indicates how long it took for a packet to travel from the CBR source to the application layer of the destination. It represents the average data delay an application or a user experiences when transmitting data (Jorg 2003). It is calculated by subtracting "time at which first packet was transmitted by source" from "time at which first data packet arrived to destination" which includes all possible delays caused by buffering during route discovery latency, queuing at the interface queue, retransmission delays at the MAC, propagation and transfer times (Aziz *et al* 2009).

4. Experiments

The main focus of this section is to presents the results of simulations in graphical form. These results are categorized on the basis of five different performance metrics namely throughput, optimal hop count, average network delay, normalized routing load, and packet delivery ratio. Performance metrics are examined on the basis of four different parameters namely number of nodes, mobility speed, pause time, and topological area.

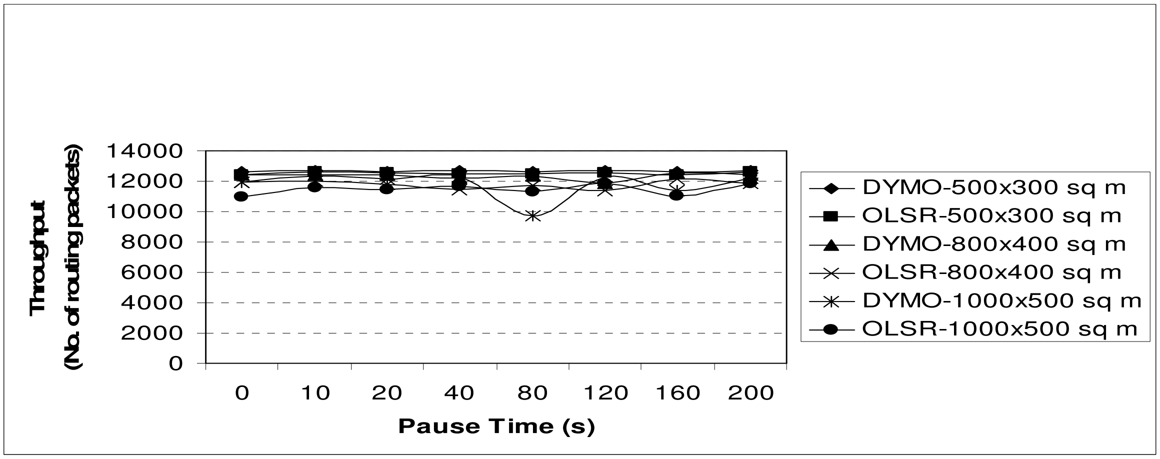
4.1. Throughput

The simulation analysis of OLSR and DYMO in figures 4.1 to 4.12 shows the throughput of both protocols for different number of nodes (20, 30, 40), speeds (5 m/s, 20 m/s, 40 m/s, 60 m/s), pause time (0, 10, 20, 40, 80, 120, 160, 200), and topological areas (500 x 300 m^2, 800 x 400 m^2, 1000 x 500 m^2).

The following figures show that DYMO performs well than OLSR in terms of throughput. Increasing topological area and mobility speed decreases throughput whereas increasing pause time and number of nodes improves throughput of both protocols. For small area and number of nodes, Pause time have a minor effect, however throughput of both protocols increases with increase in pause time for large mobility speed and area. Throughput of DYMO fluctuates as pause time increases beyond 80 seconds. Throughput of both protocols increases slightly with increase in number of nodes because increasing number of nodes allows more data traffic within a specified simulation time. Throughput of both protocols is most affected for 60 m/s node speed and 1000 x 500 m^2 area but improve as pause time increases thus increasing the mobility speed and area have negative effects on throughput. Change in pause time has more effects on the performance of OLSR than DYMO due to its proactive nature. The graphs show that when area is 500 x 300 m^2 and nodes are 20, both DYMO and OLSR have high throughput. But when area increases to 800 x 400 m^2, there is a drop in throughput of both these protocols due to scatter nodes. However, when number of nodes is increased OLSR shows good throughput, but as speed increases there is a fluctuations in the throughput.

The reason that DYMO outperforms OLSR is that more routing packets are generated and delivered by DYMO than OLSR. Generally, reactive protocols have more throughput than proactive protocols due to good packet delivery ratio and least packet drop at high mobility speed. This is due to fact that DYMO finds less routes, so the number of “out of order packets” sent by DYMO is less than OLSR.

Figure 4.1: Throughput verses Pause Time for DYMO & OLSR (Number of Nodes=20, Mobility Speed=5 m/s, Area=500x300, 800x400, & 1000x500 m^2, mc=20).



In Figure 4.1, throughput of DYMO is better than OLSR especially for small area. Throughput is high for both protocols when speed is low but decreases with increase in area. There is a little improvement in throughput with increase in pause time. In Figure 4.2 throughput further decreases with increase in mobility speed especially for large area and low pause time, although it increases with increase in pause time even for large area. DYMO shows good results than OLSR.

Figure 4.2: Throughput verses Pause Time for DYMO & OLSR (Number of Nodes=20, Mobility Speed=20 m/s, Area=500x300, 800x400, & 1000x500 m^2, mc=20).

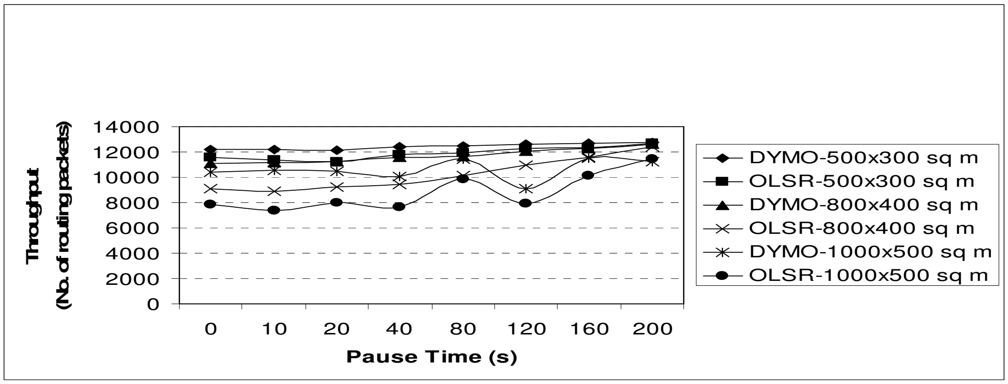
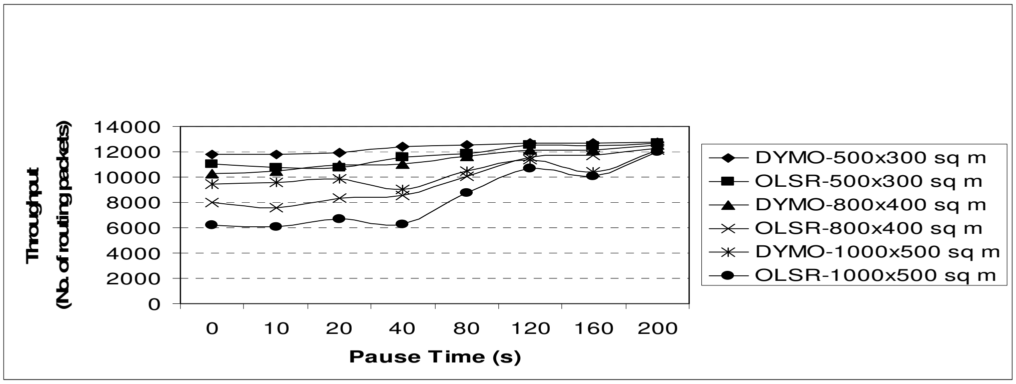


Figure 4.3: Throughput verses Pause Time for DYMO & OLSR (Number of Nodes=20, Mobility Speed=40 m/s, Area=500x300, 800x400, & 1000x500 m^2, mc=20).



In Figure 4.3, Increase in area has more effects on OLSR than DYMO especially for large area. Increase in pause time improves throughput of both protocols. But in Figure 4.4, Increase in speed further decreases throughput of both protocols especially OLSR when area in large. Pause time shows positive effects on throughput of both protocols.

Figure 4.4: Throughput verses Pause Time for DYMO & OLSR (Number of Nodes=20, Mobility Speed=60 m/s, Area=500x300, 800x400, & 1000x500 m^2, mc=20).

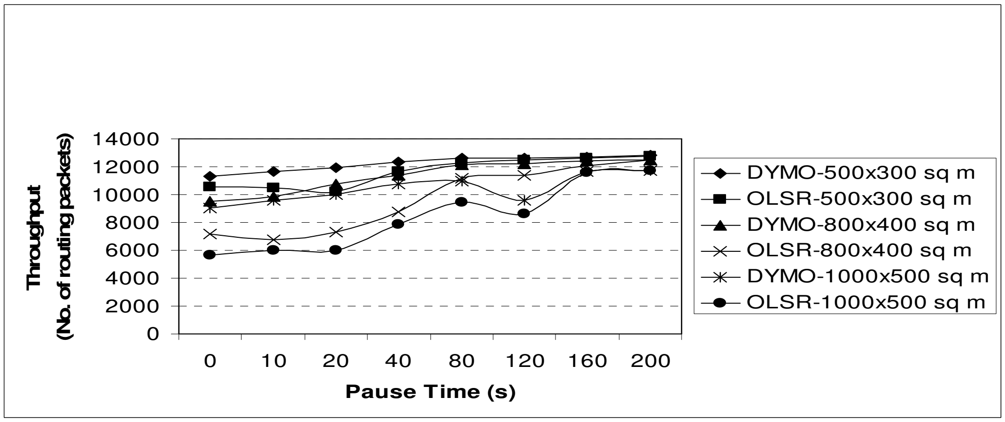
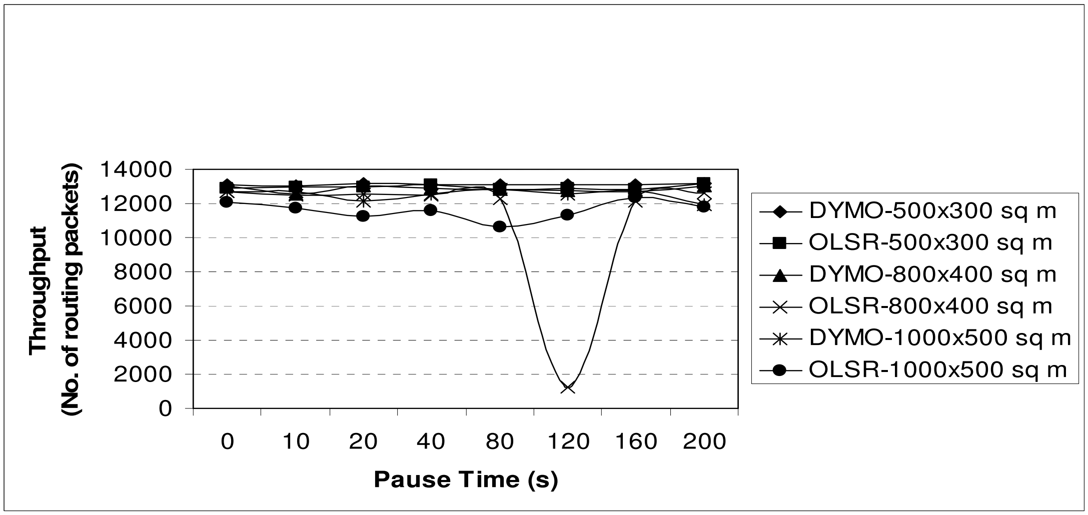


Figure 4.5: Throughput verses Pause Time for DYMO & OLSR (Number of Nodes=30, Mobility Speed=5 m/s, Area=500x300, 800x400, & 1000x500 m^2, mc=20).



Throughput of both protocols in Figure 4.5 increases slightly when number of nodes reach 30. DYMO performs better than OLSR especially for 500x300 m^2 area. Throughput is high for both protocols for low speed but decreases when area is large. Pause time has somehow positive effect on throughput.

In Figure 4.6, 4.7 and Figure 4.8, throughput further decreases when speed is increased to 20 m/s especially for areas above 500x300 m^2 and low pause time. Increasing pause time to 200 s greatly improve throughput of both protocols. Large speed and area have more effects on the throughput of OLSR than DYMO. Increase in pause time improves throughput of both protocols. Mobility speed of 60 m/s greatly effect throughput of OLSR than DYMO, for areas above 500x300 m^2. For 200 s pause time, through of both protocols improve largely.

Figure 4.6: Throughput verses Pause Time for DYMO & OLSR (Number of Nodes=30, Mobility Speed=20 m/s, Area=500x300, 800x400, & 1000x500 m^2, mc=20).

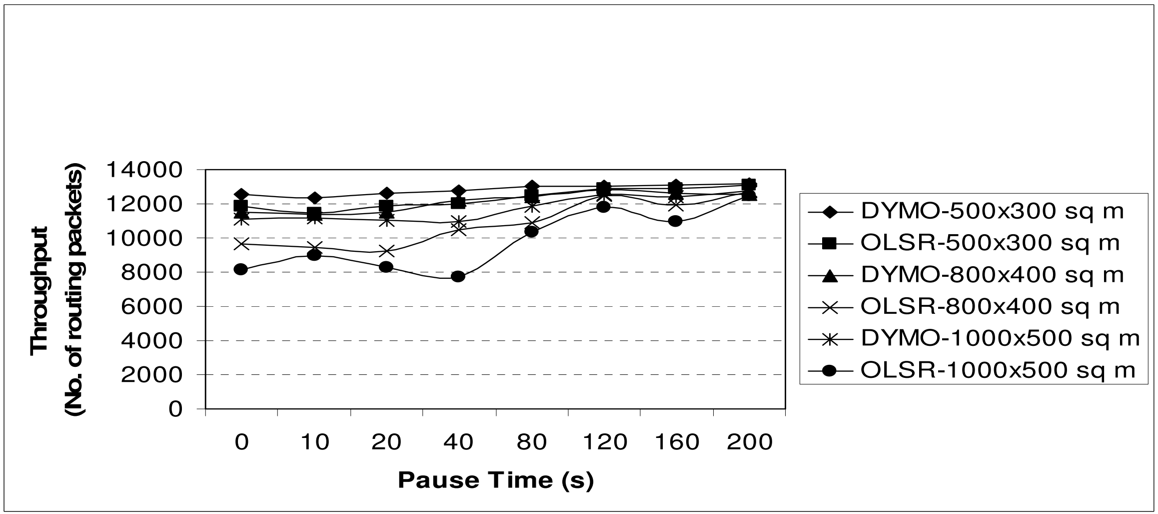


Figure 4.7: Throughput verses Pause Time for DYMO & OLSR (Number of Nodes=30, Mobility Speed=40 m/s, Area=500x300, 800x400, & 1000x500 m^2, mc=20).

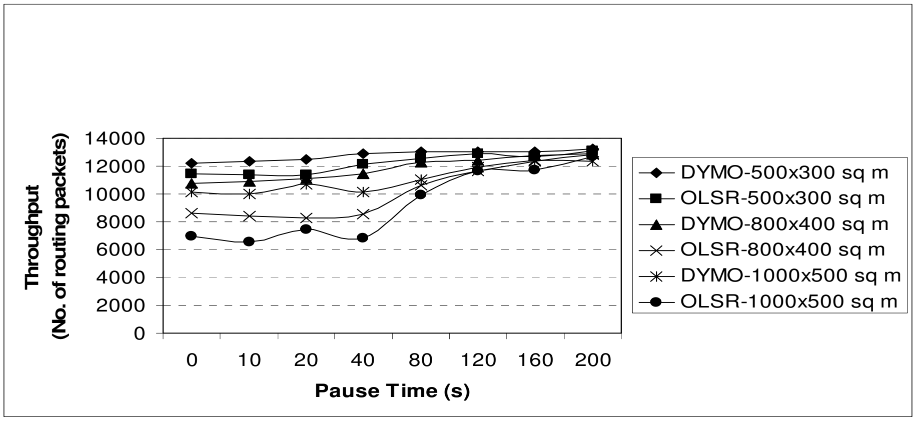


Figure 4.8: Throughput verses Pause Time for DYMO & OLSR (Number of Nodes=30, Mobility Speed=60 m/s, Area=500x300, 800x400, & 1000x500 m^2, mc=20).

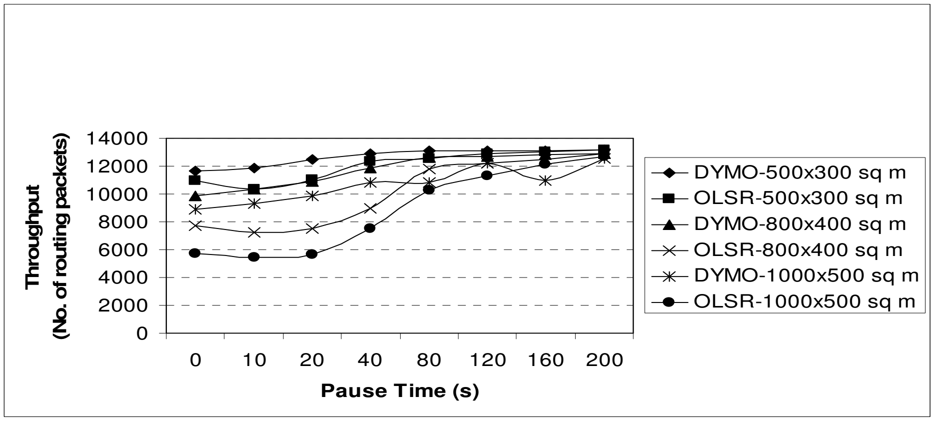
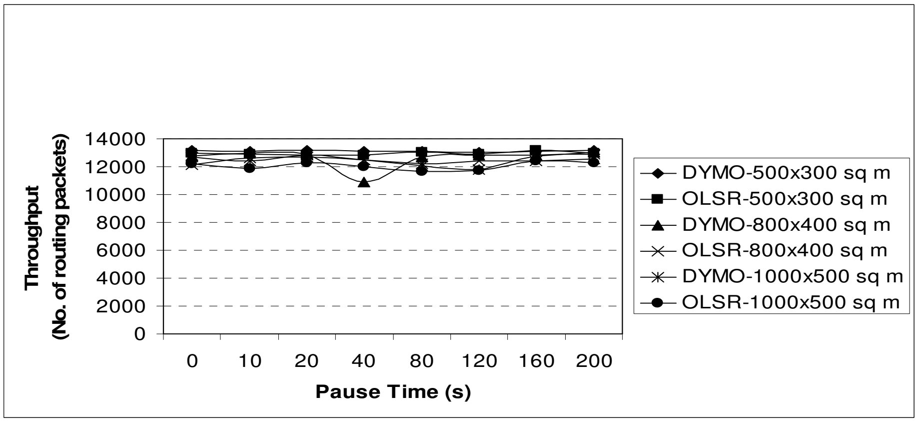


Figure 4.9: Throughput verses Pause Time for DYMO & OLSR (Number of Nodes=40, Mobility Speed=5 m/s, Area=500x300, 800x400, & 1000x500 m^2, mc=20).



Increase in node density to 40 slightly in Figure 4.9, increase throughput of both protocols. DYMO performs better than OLSR especially for 500x300 m^2 area. Graph shows good throughput for both protocols for low speed but throughput decreases when area is large. But in Figure 4.10, throughput further decreases when speed is increased to 20 m/s especially for areas above 500x300 m^2 and low pause time. Increasing pause time to 200 s greatly improve throughput of both protocols.

Figure 4.10: Throughput verses Pause Time for DYMO & OLSR (Number of Nodes=40, Mobility Speed=20 m/s, Area=500x300, 800x400, & 1000x500 m^2, mc=20).

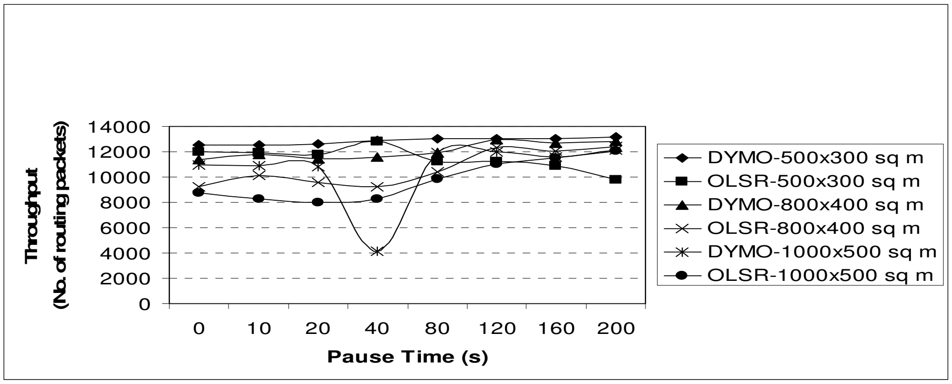
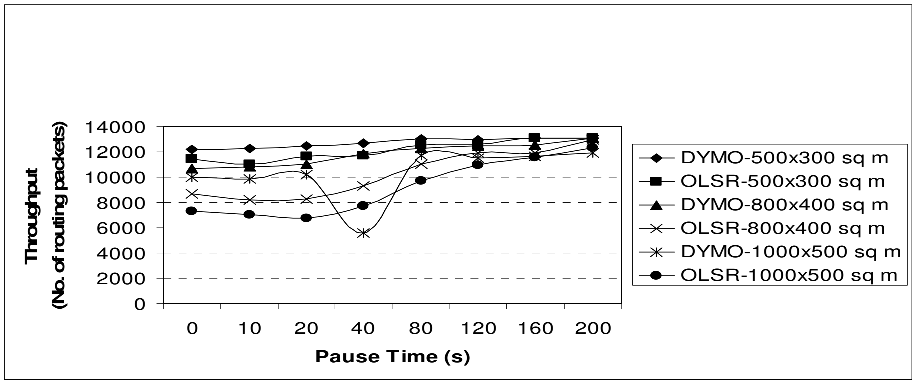
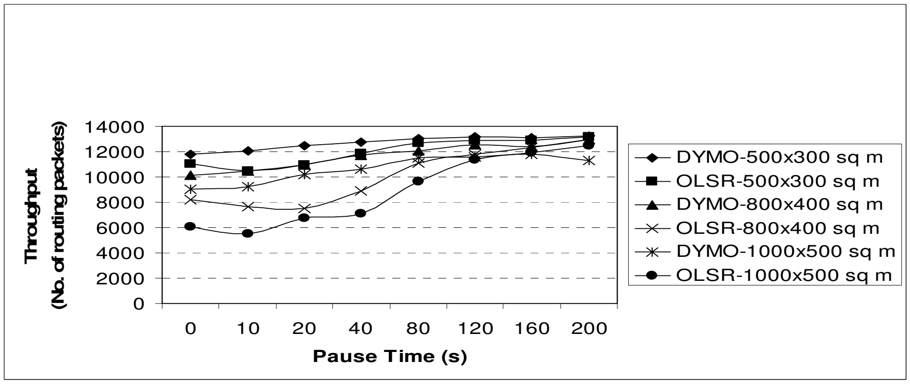


Figure 4.21: Throughput verses Pause Time for DYMO & OLSR (Number of Nodes=40, Mobility Speed=40 m/s, Area=500x300, 800x400, & 1000x500 m^2, mc=20).



In Figure 4.11 & 4.12, large speed and area have more effects on the throughput of OLSR than DYMO. Increase in pause time improves throughput of both protocols. Node speed of 60 m/s greatly effect throughput of OLSR than DYMO, for areas above 500x300 m^2, however throughput of both improve when pause time reaches 200 s.

Figure 4.32: Throughput verses Pause Time for DYMO & OLSR (Number of Nodes=40, Mobility Speed=60 m/s, Area=500x300, 800x400, & 1000x500 m^2, mc=20).



4.2. Optimal Hop Count

The simulation analysis of OLSR and DYMO in figures 5-16 to 5- 30 shows the optimal hop count of both protocols for different number of nodes (20, 30, 40), speeds (5 m/s, 20 m/s, 40 m/s, 60 m/s), pause time (0, 10, 20, 40, 80, 120, 160, 200), and topological areas (500 x 300 m^2, 800 x 400 m^2, 1000 x 500 m^2).

The following figures show that OLSR outperforms DYMO in terms of optimal hop count. Increasing area and number of nodes also increases hop count of both protocols. Increasing pause time slightly increases hop count, whereas increasing speed slightly decreases hop count of both protocols. For example for 500 x 300 m^2 area and 20 nodes, the optimal hop count for DYMO and OLSR is nearly about 1 hop. But when area increases to 800 x 400 m^2 for the same number of nodes, the optimal hop count for both protocols is raised to 1.5 to 2 hops. In case of using 1000 x 500 m^2 area, the optimal hop count for DYMO and OLSR is reached to 2 hops, which shows that both protocols take the longest path from source to destination due to sparse network topology. The optimal hop count of DYMO is slightly higher for the mobility speed of above 5 m/s but optimal hop count of OLSR is less affected due to variations in mobility speed. For 30 and 40 nodes, the optimal hop count of DYMO is between 1.5 to 2 hops for all the three topological areas, having a slightly higher value than OLSR. On the other hand, for low and moderate mobility speed with respect to pause time, same effect is observed except at mobility speed of 40 and 60 m/s. The optimal hop count for DYMO and OLSR is nearly reduced to 1.5 or at 1 hop due to the frequent change in the node's positions. But as pause time increases above 20 s, hop count also increases especially for area of 1000 x 500 m^2.

The reason that optimal hop count is less for OLSR than DYMO is that proactive protocols like OLSR are less affected due to frequent change in mobility and increased pause time due to stable routes and periodic updates. In OLSR, shortest possible hops are selected and long stable routing paths are used thus minimizing the overall optimal hop count value. DYMO on the other hand, uses multipath that allows considering more routing paths than OLSR resulting in greater hop count value.

Figure 4.13: Optimal Hop Count verses Pause Time for DYMO & OLSR (Number of Nodes=20, Mobility Speed=5 m/s, Area=500x300, 800x400, & 1000x500 m^2, mc=20).

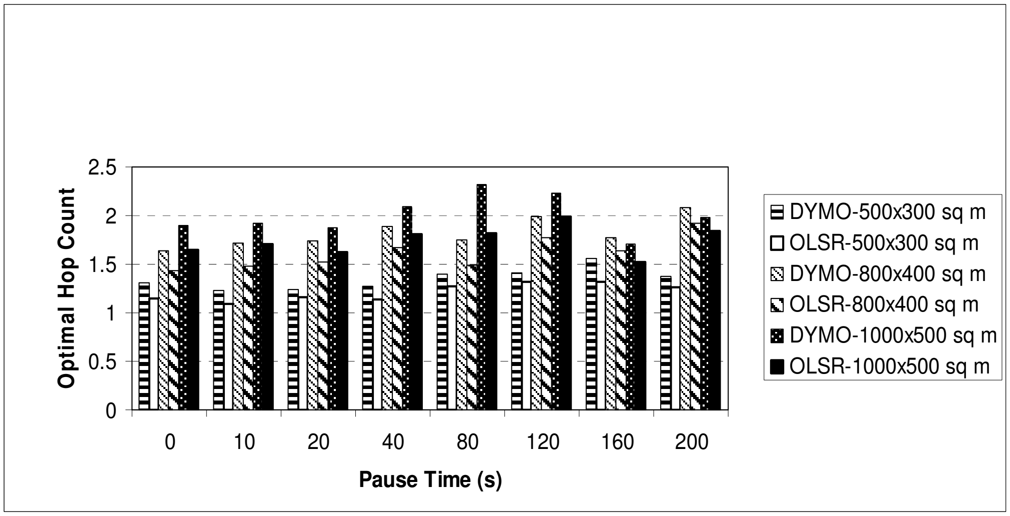
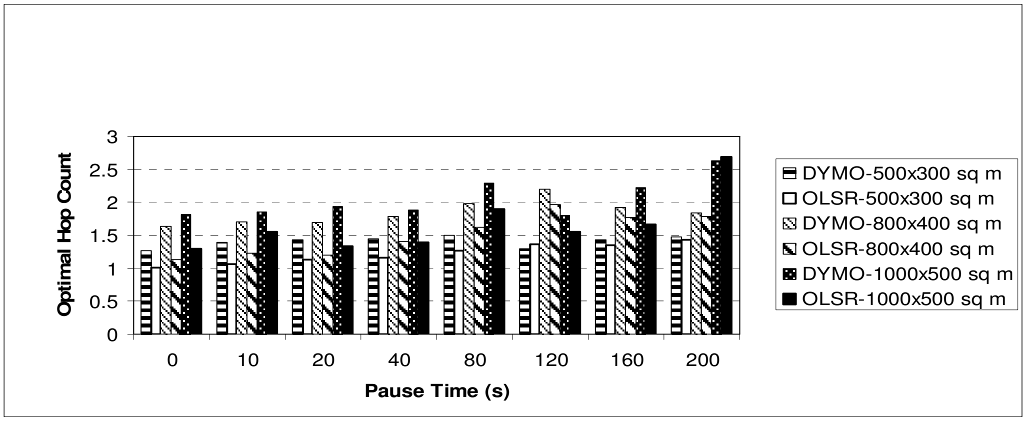


Figure 4.13 shows that hop count of OLSR is less than DYMO. Moreover hop count increases with increase in pause time and area.

Figure 4.14: Optimal Hop Count verses Pause Time for DYMO & OLSR (Number of Nodes=20, Mobility Speed=20 m/s, Area=500x300, 800x400, & 1000x500 m^2, mc=20).



In Figure 4.14, increasing speed to 20 m/s further decrease hop count of both protocols especially OLSR thus reducing the effect of increase in pause time and area. But in Figure 4.15, shows that increase in speed to 40 m/s greatly reduces hop count of both protocols despite increase in pause time and area although OLSR performs well than DYMO.

Figure 4.15: Optimal Hop Count verses Pause Time for DYMO & OLSR (Number of Nodes=20, Mobility Speed=40 m/s, Area=500x300, 800x400, & 1000x500 m^2, mc=20).

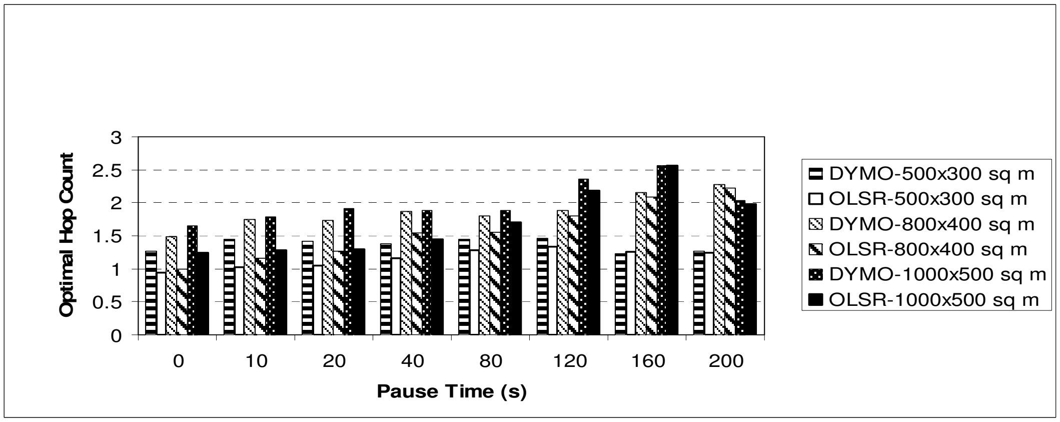
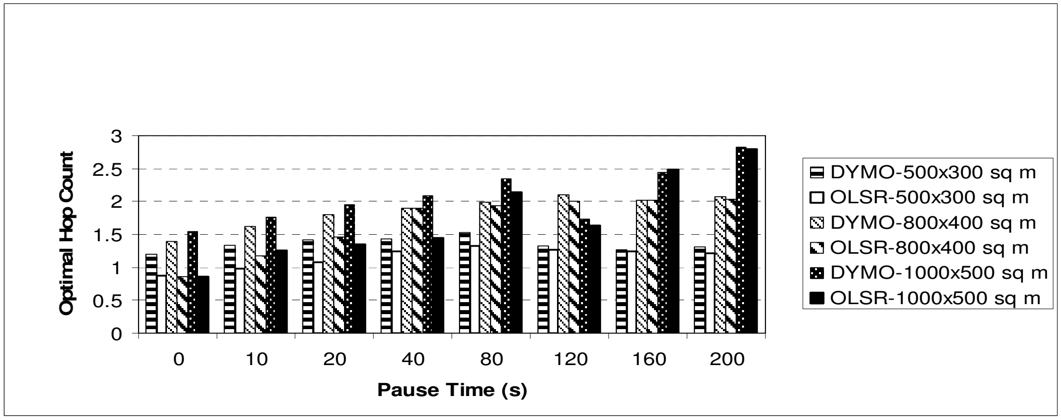


Figure 4.16: Optimal Hop Count verses Pause Time for DYMO & OLSR (Number of Nodes=20, Mobility Speed=60 m/s, Area=500x300, 800x400, & 1000x500 m^2, mc=20).



In Figure 4.16, hop count of OLSR is less than 1 as compared to DYMO which is greater than 1 for 60 m/s speed, 0 s pause time, and 500x300 m^2 of area. Graph shows that in most cases hop count reduces to 2 except for 1000x500 m^2 area and pause time above 80. In Figure 4.17, Increase in node density also decreases hop count of both protocols. For small speed, the difference in hop count of both protocols is very small. Hop count increases with increase in pause time and area.

Figure 4.17: Optimal Hop Count verses Pause Time for DYMO & OLSR (Number of Nodes=30, Mobility Speed=5 m/s, Area=500x300, 800x400, & 1000x500 m^2, mc=20).

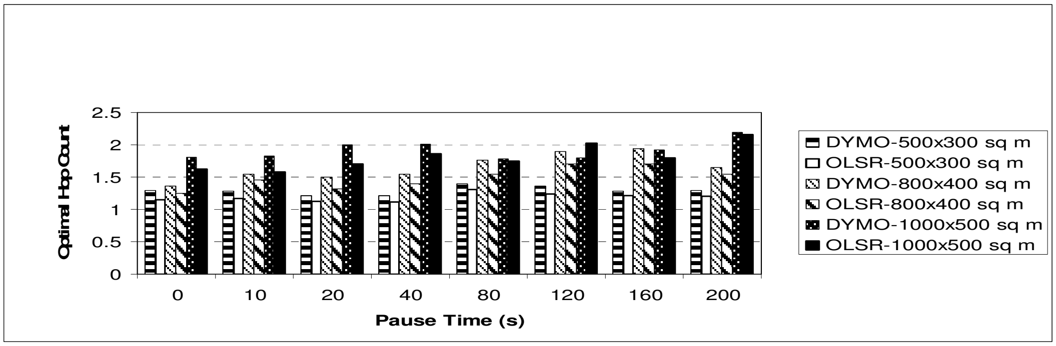
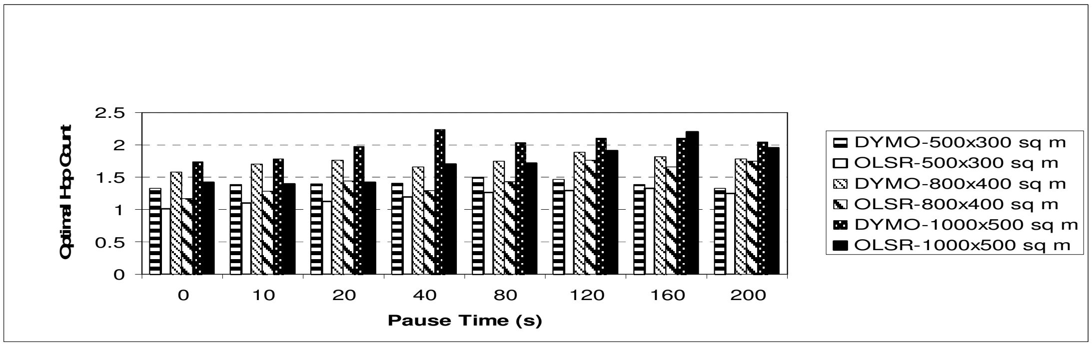


Figure 4.18: Optimal Hop Count verses Pause Time for DYMO & OLSR (Number of Nodes=30, Mobility Speed=20 m/s, Area=500x300, 800x400, & 1000x500 m^2, mc=20).



In Figure 4.18, for 20 m/s speed and 30 nodes, hop count of both protocols further reduces despite increase in pause time and area. In Figure 4.19, Increase in speed and number of nodes slightly reduces hop count of both protocols while increase in pause time and area increase hop count.

Figure 4.19: Optimal Hop Count verses Pause Time for DYMO & OLSR (Number of Nodes=30, Mobility Speed=40 m/s, Area=500x300, 800x400, & 1000x500 m^2, mc=20).

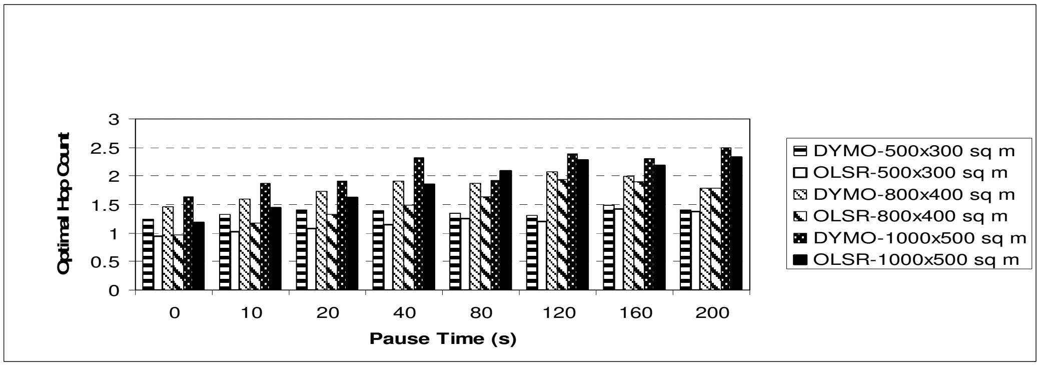


Figure 4.20: Optimal Hop Count verses Pause Time for DYMO & OLSR (Number of Nodes=30, Mobility Speed=60 m/s, Area=500x300, 800x400, & 1000x500 m^2, mc=20).

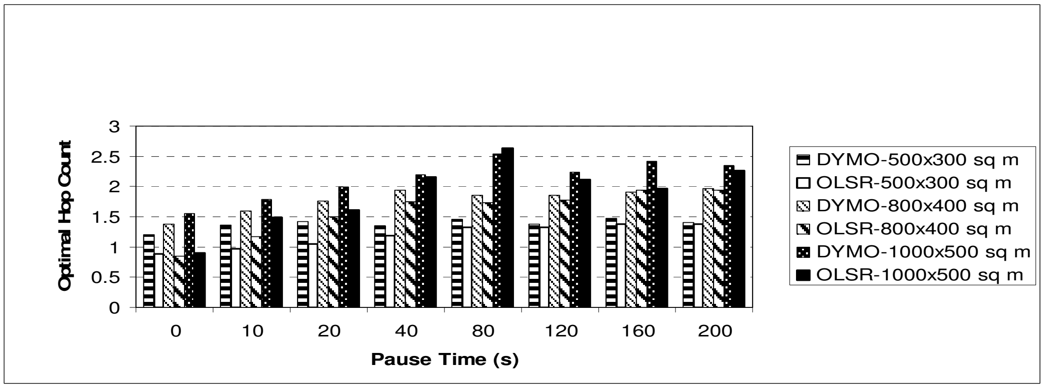
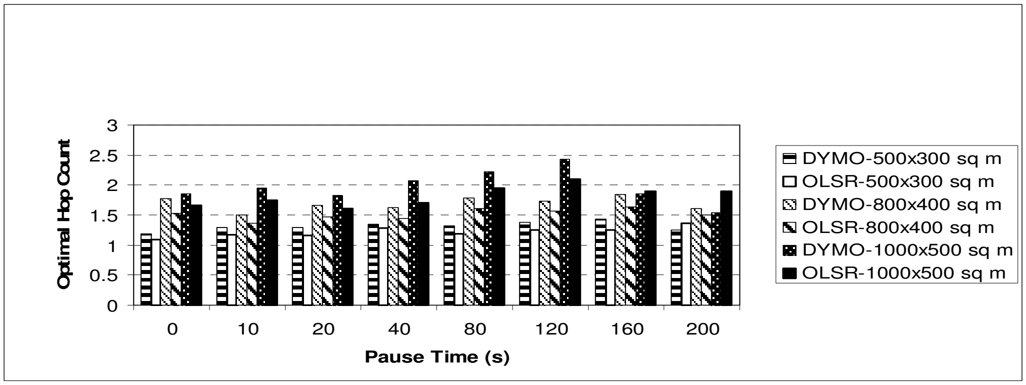


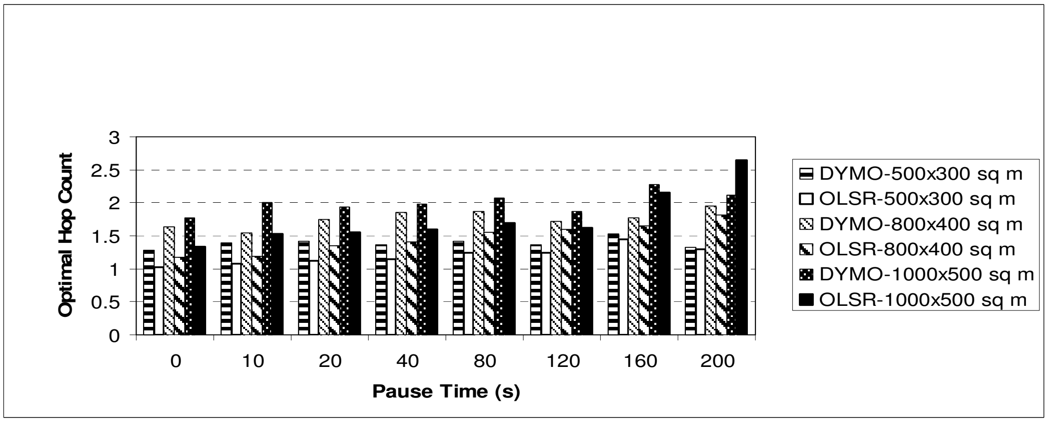
Figure 4.20 shows that further increase in speed reduces hop count even less than 1 for 500x300 m^2 area and 0 s pause time. In most cases, hop count is in between 1.5 and 2.

Figure 2.21: Optimal Hop Count verses Pause Time for DYMO & OLSR (Number of Nodes=40, Mobility Speed=5 m/s, Area=500x300, 800x400, & 1000x500 m^2, mc=20).



In Figure 2.21, Increase in node density decreases hop count of both protocols even at low mobility speed. For 500x300 m^2 area and hop count of both protocols is in between 1 and 1.5 and in most cases it is less than 2.

Figure 4.22: Optimal Hop Count verses Pause Time for DYMO & OLSR (Number of Nodes=40, Mobility Speed=20 m/s, Area=500x300, 800x400, & 1000x500 m^2, mc=20).



In Figure 4.22, with high node density and mobility speed, the effect of pause time and area is reduced thus hop count is mostly limited to 2. For small area and low pause time hop count of OLSR is equal to 1 which is less than DYMO. In Figure 4.23, Increase in speed and number of nodes further reduces hop count of both protocols especially OLSR while increase in pause time and area increase hop count yet in most cases it is less than 2. For small area and low pause time, hop cont of OLSR is even less than 1.

Figure 4.23: Optimal Hop Count verses Pause Time for DYMO & OLSR (Number of Nodes=40, Mobility Speed=40 m/s, Area=500x300, 800x400, & 1000x500 m^2, mc=20).

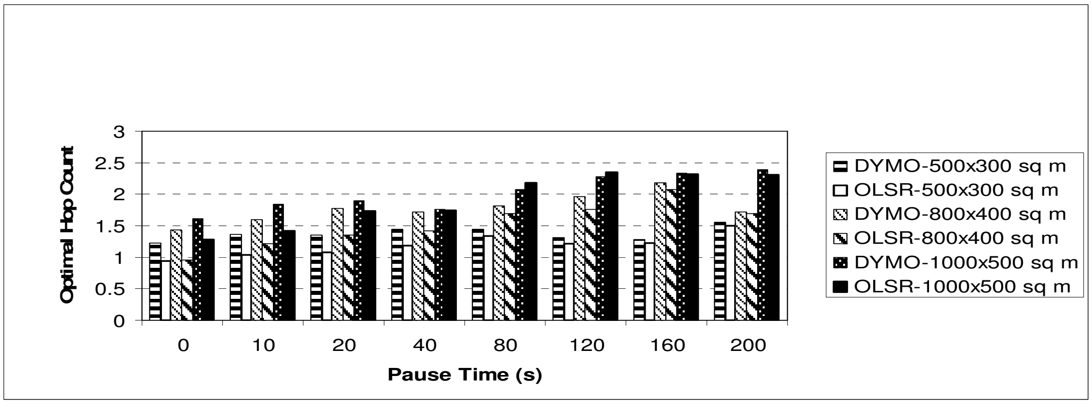
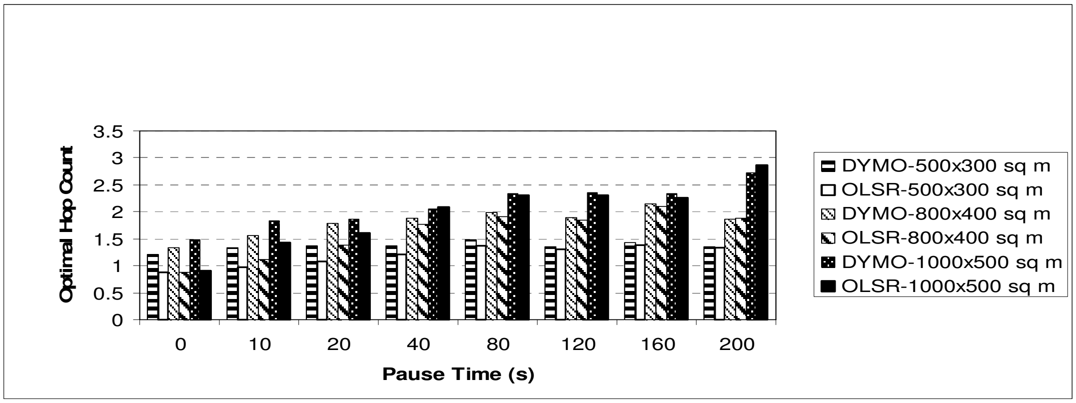


Figure 4.24: Optimal Hop Count verses Pause Time for DYMO & OLSR (Number of Nodes=40, Mobility Speed=60 m/s, Area=500x300, 800x400, & 1000x500 m^2, mc=20).



In Figure 4.24, with 40 nodes and 60 m/s speed, the hop count of OLSR is reduced considerably as compared to DYMO. Graph shows that hop count of OLSR is less than 1 for all areas at 0 s pause time.

4.3. Average Network Delay

The simulation analysis of OLSR and DYMO in figures 5-31 to 5- 45 shows the average network delay of both protocols for different number of nodes (20, 30, 40), speeds (5 m/s, 20 m/s, 40 m/s, 60 m/s) , pause time (0, 10, 20, 40, 80, 120, 160, 200), and topological areas (500 x 300 m^2, 800 x 400 m^2, 1000 x 500 m^2).

Graphs show that average network delay of both protocols increases with increase in area, number of nodes, and speed. Increasing pause time slightly improves delay of both protocols. Fluctuation in delay of both protocols increases for area above 500 x 300 m^2 and speed above 5 m/s for all number of nodes. For 20 nodes and 5 m/s speed, the average network delay is small and consistent when area is 500 x 300 m^2, however delay increases and fluctuates when area increases to 800 x 400 m^2 and 1000 x 500 m^2 for both protocols. The average network delay of DYMO is slightly smaller than OLSR, however increasing the area to 800 x 400 m^2 and 1000 x 500 m^2, increases the average network delay of DYMO due to more average time a packet takes to reach the destination. As the mobility speed increases above 5 m/s, a large variation and increase can be observed in average network delay for both protocols at 800 x 400 m^2 and 1000 x 500 m^2, however DYMO have consistent and small average network delay when area is restricted to 500 x 300 m^2. For the pause time of 160 s and 200 s, a little stability in average delay can be seen for DYMO especially for 500 x 300 m^2 and 800 x 400 m^2 of area. OLSR also suffers when mobility speed is high and pause time is low. Average network delay of both protocols fluctuates greatly due to increase in number of nodes above 20, especially for area above 500 x 300 m^2 and mobility speed above 20 m/s.

Frequent route discovery due to link breakages and movement of nodes, queuing and MAC delay at the intermediate nodes before a packet reaches the destination causing increase in the overall average end to end delay. As routes break, nodes discover new routes using route discovery process, which lead to longer end to end delays. On the other hand, OLSR has stable and low end to end delay due to its stable routing tables and entries. Slight changes in mobility speed or link breakage requires a slight change in routing entries, thus maintains a low and stable end to end delay for OLSR. However OLSR have increased average end to end delay at higher mobility speed, due to frequent link breakages and change in topology.

Figure 4.25: Average Network Delay verses Pause Time for DYMO & OLSR (Number of Nodes=20, Mobility Speed=5 m/s, Area=500x300, 800x400, & 1000x500 m^2, mc=20).

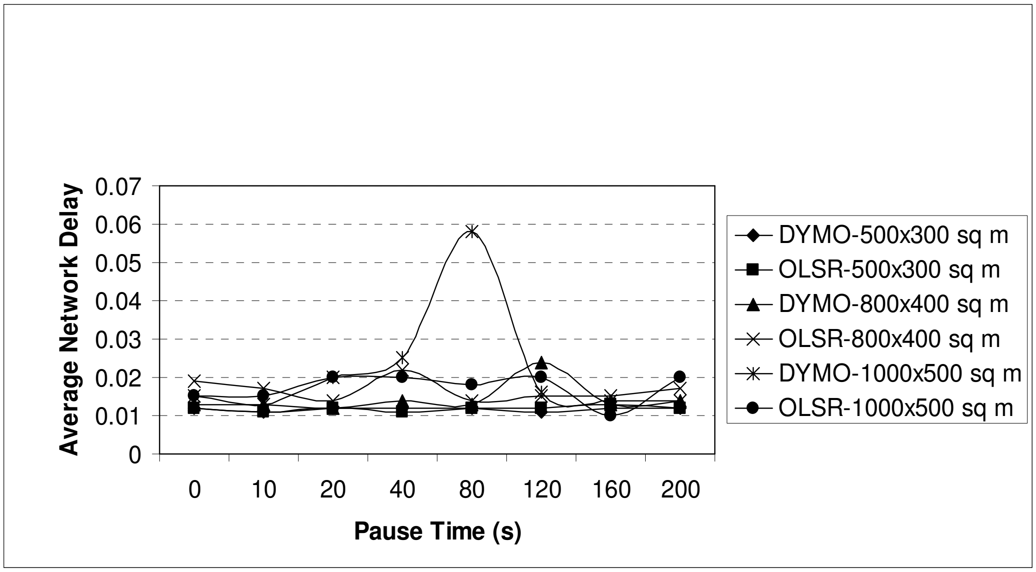


Figure 4.25 shows that for low speed and small area, delay of both protocols is small and consistent, however it increases and fluctuates for large area especially 1000x500 m^2. Increase in pause time reduces delay of both protocols.

In Figure 4.26 delay of both protocols increases and fluctuates with increase in speed and area. Small area and high pause time still shows good results for both protocols. At 1000x500 m^2, delay of DYMO is very high and variable even at 200 s pause time.

Figure 4.26: Average Network Delay verses Pause Time for DYMO & OLSR (Number of Nodes=20, Mobility Speed=20 m/s, Area=500x300, 800x400, & 1000x500 m^2, mc=20).

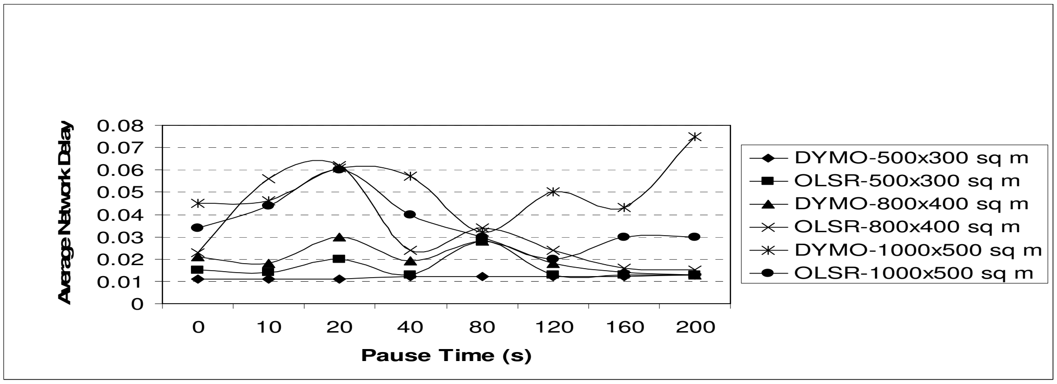
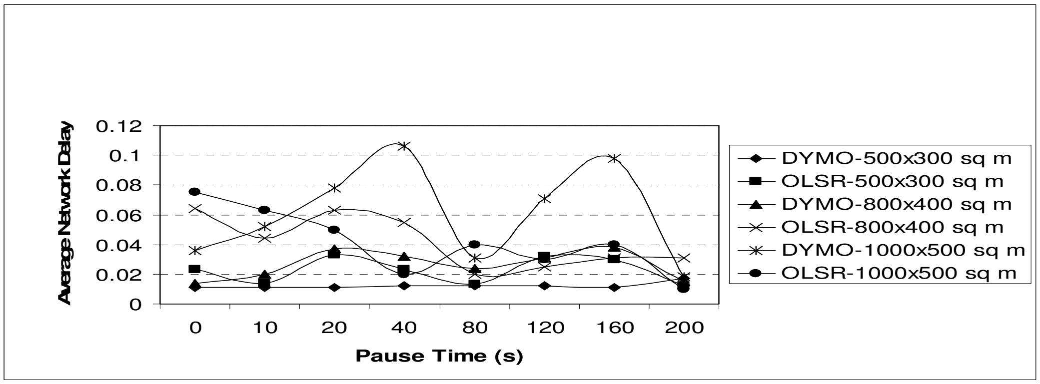
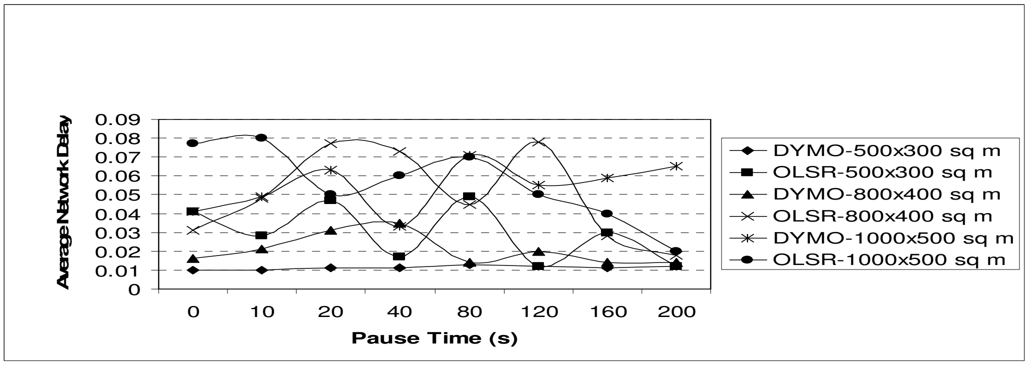


Figure 4.27: Average Network Delay verses Pause Time for DYMO & OLSR (Number of Nodes=20, Mobility Speed=40 m/s, Area=500x300, 800x400, & 1000x500 m^2, mc=20).



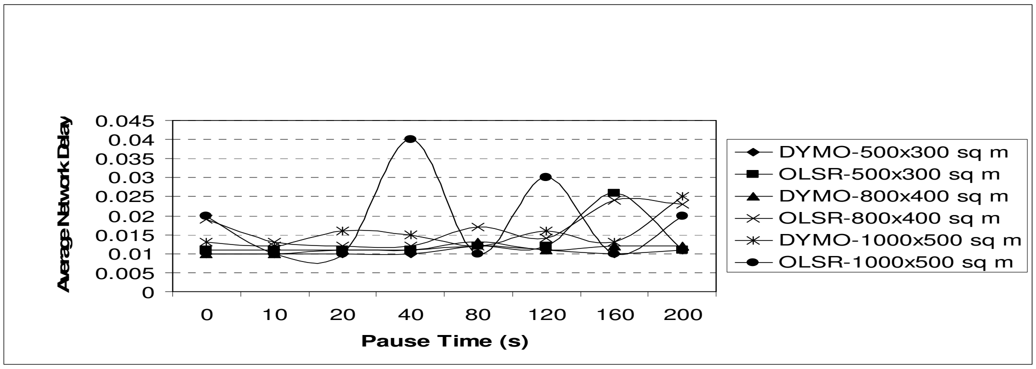
In Figure 4.27, further increase in speed makes the situation worst as delay of OLSR also increases even for small area. However delay of both protocols decreases at 200 s pause time.

Figure 4.28: Average Network Delay verses Pause Time for DYMO & OLSR (Number of Nodes=20, Mobility Speed=60 m/s, Area=500x300, 800x400, & 1000x500 m^2, mc=20).



In Figure 4.28, At 60 m/s speed, only DYMO has small and consistent delay for 500x300 m^2 area. Delay in all other cases increases and fluctuates for both protocols. At high pause time however delay decreases considerably.

Figure 4.29: Average Network Delay verses Pause Time for DYMO & OLSR (Number of Nodes=30, Mobility Speed=5 m/s, Area=500x300, 800x400, & 1000x500 m^2, mc=20).



Increase in node density in Figure 4.29, also increase delay of both protocols for large area even for low mobility speed. However delay of both protocols remains small for small area. But in Figure 4.30, for 20 m/s speed, delay of both protocols increases and fluctuates. Small area and high pause time still shows low delay for both protocols. At 1000x500 m^2, delay of OLSR is very high and variable even at 200 s pause time.

Figure 4.30: Average Network Delay verses Pause Time for DYMO & OLSR (Number of Nodes=30, Mobility Speed=20 m/s, Area=500x300, 800x400, & 1000x500 m^2, mc=20).

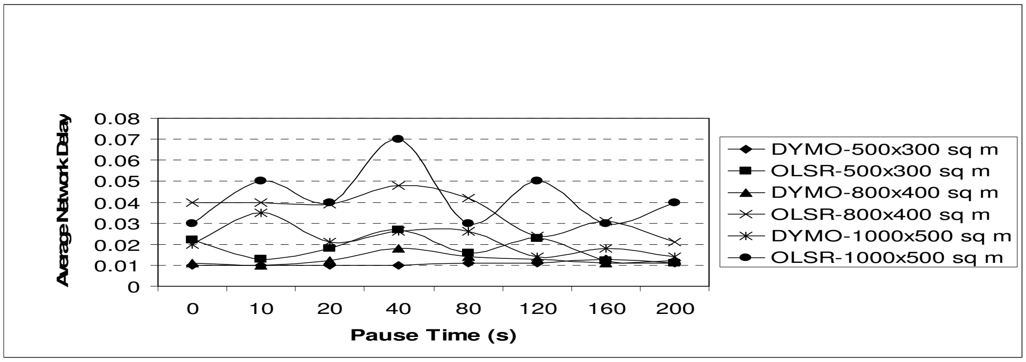


Figure 4.31: Average Network Delay verses Pause Time for DYMO & OLSR (Number of Nodes=30, Mobility Speed=40 m/s, Area=500x300, 800x400, & 1000x500 m^2, mc=20).

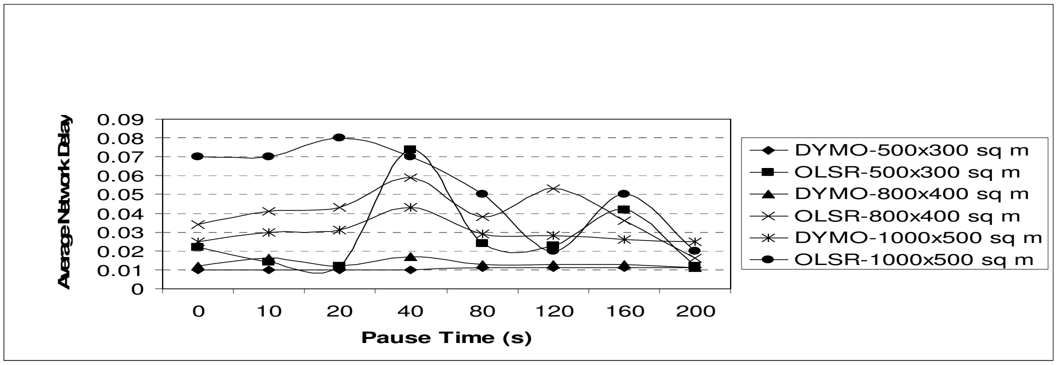


Figure 4.31, shows a high increase in delay of OLSR as compared to DYMO at low pause time and increased speed. However this effect is considerably reduced with increase in pause time. For small area, DYMO shows low and consistent delay as compared to OLSR.

Figure 4.32: Average Network Delay verses Pause Time for DYMO & OLSR (Number of Nodes=30, Mobility Speed=60 m/s, Area=500x300, 800x400, & 1000x500 m^2, mc=20).

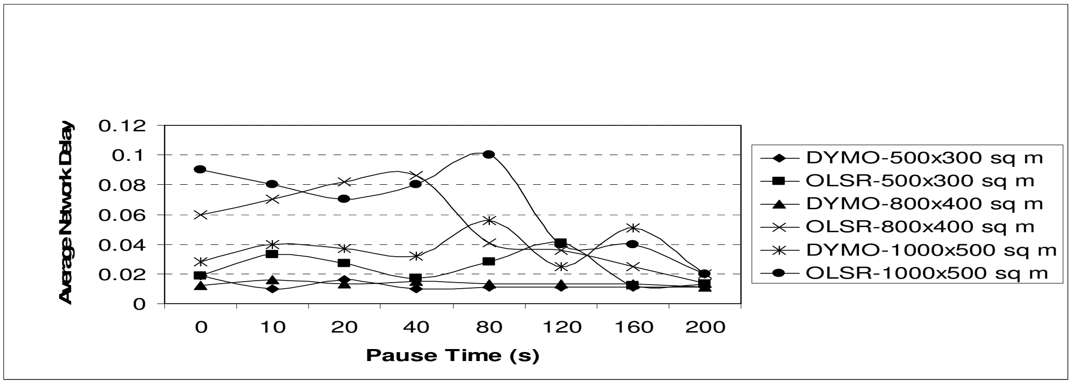


Figure 4.32, shows a high increase in delay of both protocols at low pause time, high node density, and increased speed. Delay however decreases with increase in pause time especially at 200 s. DYMO has low and consistent delay as compared to OLSR for small area.

Figure 4.33: Average Network Delay verses Pause Time for DYMO & OLSR (Number of Nodes=40, Mobility Speed=5 m/s, Area=500x300, 800x400, & 1000x500 m^2, mc=20).

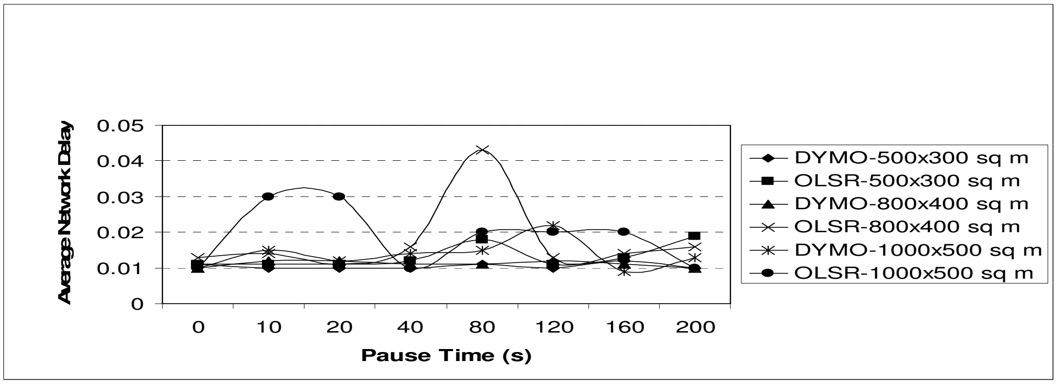


Figure 4.33, shows that delay increases with increased node density even at low speed. DYMO shows good results as compared to OLSR. Delay of both protocols is low for small area.

Figure 4.34: Average Network Delay verses Pause Time for DYMO & OLSR (Number of Nodes=40, Mobility Speed=20 m/s, Area=500x300, 800x400, & 1000x500 m^2, mc=20).

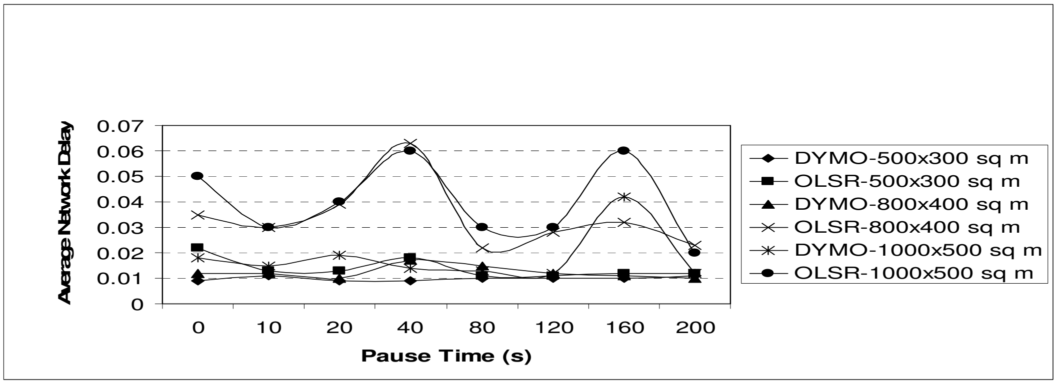


Figure 4.34, shows a large increase and variations in delay for OLSR protocol for 800x400 m^2 and 1000x500 m^2 areas. DYMO is comparably good even for large area. Delay of both protocols is low for small area and low pause time.

In Figure 4.35, with further increase in mobility speed, delay increases further and fluctuates in OLSR protocol for 800x400 m^2 and 1000x500 m^2 areas. DYMO is comparably good even for large area. Delay of both protocols is low for small area and low pause time.

Figure 4.35: Average Network Delay verses Pause Time for DYMO & OLSR (Number of Nodes=40, Mobility Speed=40 m/s, Area=500x300, 800x400, & 1000x500 m^2, mc=20).

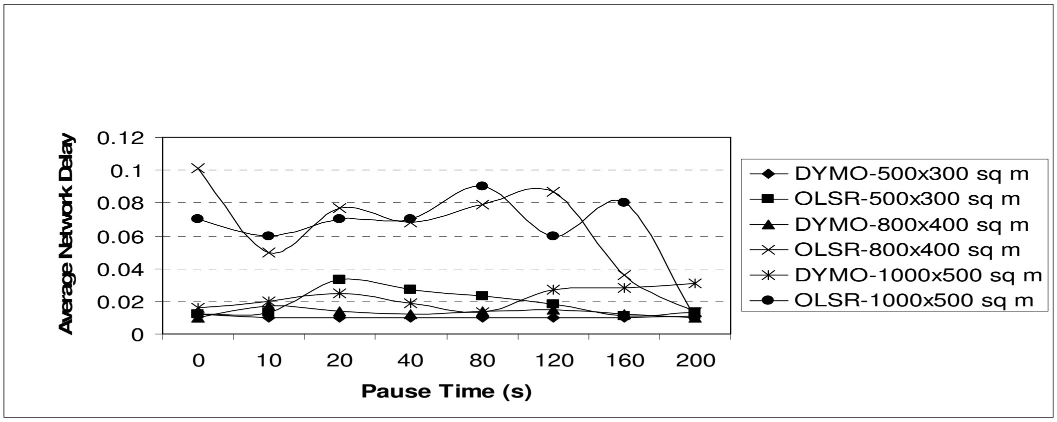
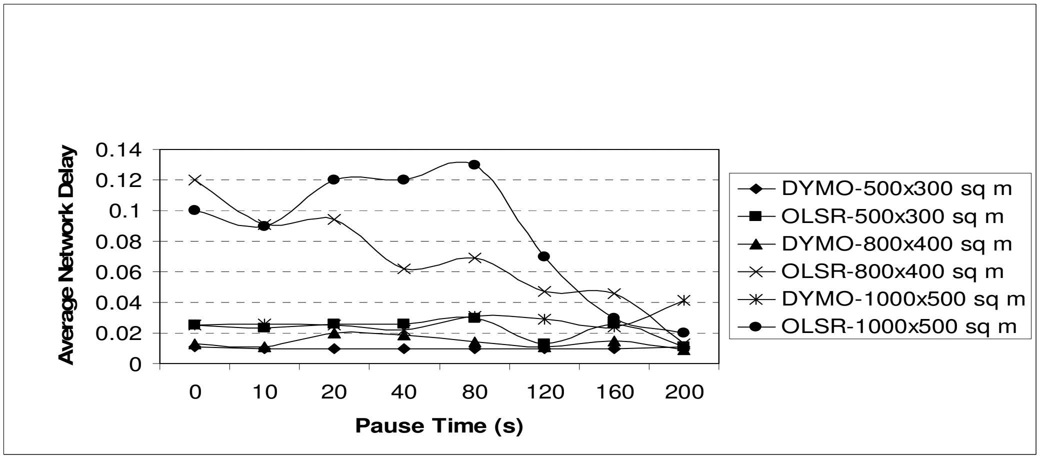


Figure 4.36: Average Network Delay verses Pause Time for DYMO & OLSR (Number of Nodes=40, Mobility Speed=60 m/s, Area=500x300, 800x400, & 1000x500 m^2, mc=20).



In Figure 4.36, delay of OLSR protocol touches its maximum limit and fluctuates for large area. Delay of DYMO is comparably small even at large area. For small area and low pause time, both protocols have small delay.

4.4. Screenshots for OLSR and DYMO

The screenshots for DYMO and OLSR are given in figure 5.75 and 5.76. These screenshots are created in NS2 using a program called Network Animator (NAM), which is used to show the visual aspect of the network in terms of node movement, packets send/receive, number of nodes and arrangement of nodes within the topology.

Figure 4.37: Screenshot created by NAM in NS2 for DYMO protocol for 20 Nodes, 5 m/s Max. Speed, 0 s Pause time, 800 x 400 m^2 Area, & 20 CBR Connections

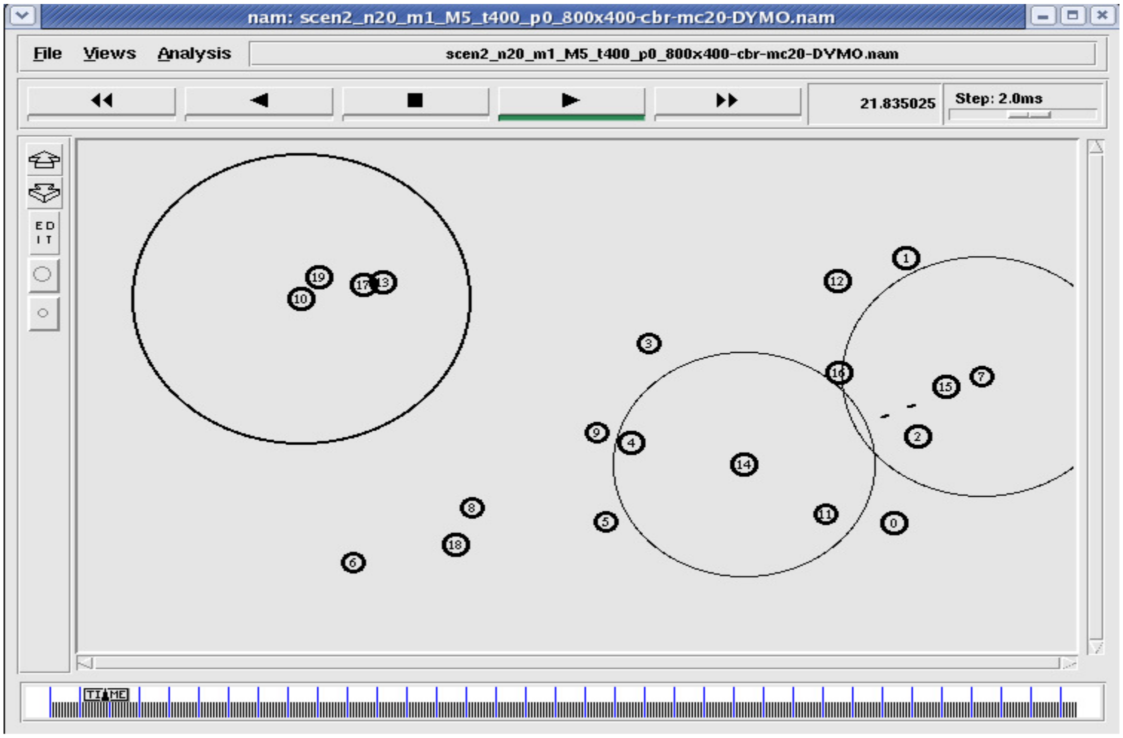
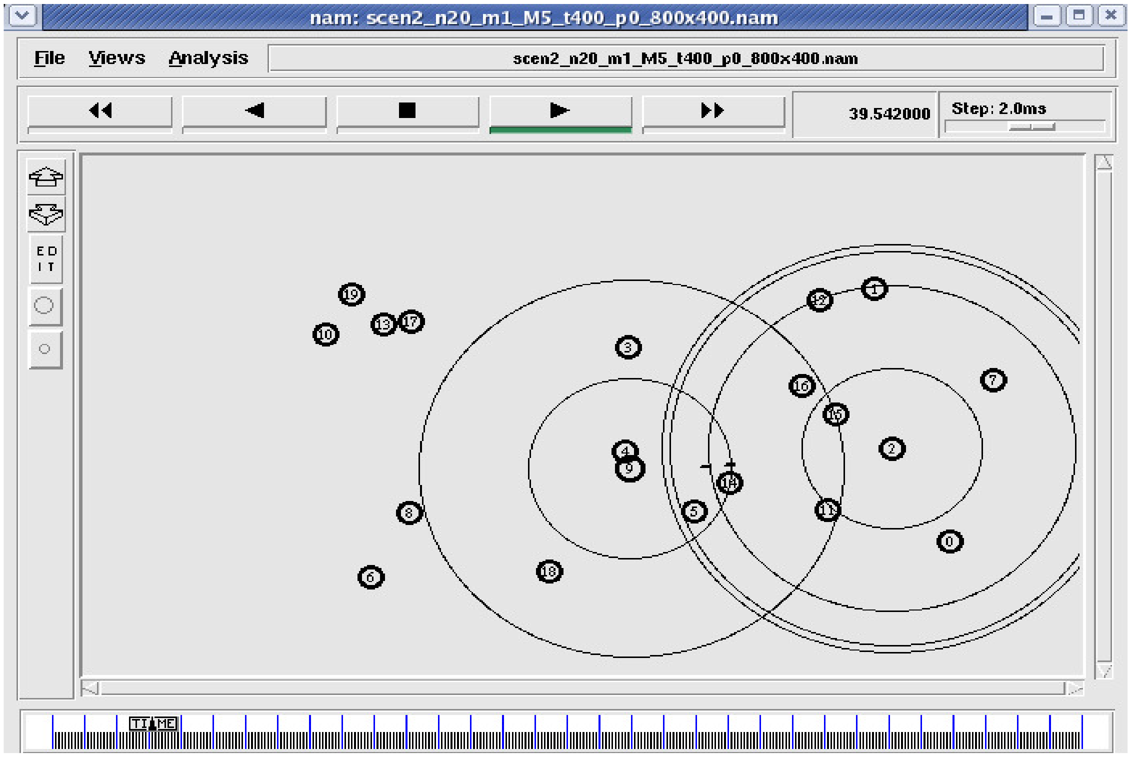


Figure 4.38: Screenshot created by NAM in NS2 for OLSR protocol for 20 Nodes, 5 m/s Max. Speed, 0 s Pause time, 800 x 400 m2 Area, & 20 CBR Connections



5. Summary, Conclusion and Future Work

This research work presents the investigation of OLSR and DYMO routing protocols in MANETs. DYMO routing protocol enables reactive, multihop unicast routing between participating DYMO routers. DYMO operation is split into route discovery and route maintenance. Routes are discovered on-demand using RREQ and RREP massages. For maintenance of routs which are in use, routers lengthen 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. RERR massage is used in case of broken, missing or unknown route. OLSR is a proactive routing protocol. OLSR uses MPRs in order to reduce the number of retransmissions by providing optimal routes in terms of number of hops. Only the MPRs of a node retransmit its broadcast messages. In OLSR, a HELLO and TC messages are broadcasted to all of its neighbors so each node would construct its MPR Selector table. MPRs of a given node are declared in the subsequent HELLO messages transmitted by this node.

Analysis of DYMO and OLSR were carried out on the basis of throughput, optimal hop count, and average network delay. Simulations were performed using NS-2 under Random Waypoint mobility model by changing the number of nodes, mobility speed, pause time, and topological area.

Simulation results show that DYMO performs well than OLSR in terms of throughput. Increasing area and speed decreases throughput whereas increasing pause time and number of nodes improves throughput of both protocols. The reason that DYMO outperforms OLSR is that more routing packets are generated and delivered by DYMO than OLSR. Generally, reactive protocols have more throughput than proactive protocols due to good packet delivery ratio and least packet drop at high mobility speed. This is due to fact that DYMO finds less routes, so the number of “out of order packets” sent by DYMO is less than OLSR.

With respect to optimal hop count, OLSR outperforms DYMO. Increasing area and number of nodes also increases hop count of both protocols. Increasing pause time slightly increases hop count, whereas increasing speed slightly decreases hop count of both protocols. The reason that optimal hop count is less for OLSR than DYMO is that proactive protocols like OLSR are less affected due to frequent change in mobility and increased pause time due to stable routes and periodic updates. In OLSR, shortest possible hops are selected and long stable routing paths are used thus minimizing the overall optimal hop count value. DYMO on the other hand, uses multipath that allows considering more routing paths than OLSR resulting in greater hop count value.

Average network delay of both protocols increases with increase in area, number of nodes, and speed. Increasing pause time slightly improves delay of both protocols. Fluctuation in delay of both protocols increases for area above 500 x 300 m^2 and speed above 5 m/s for all number of nodes. Frequent route discovery due to link breakages and movement of nodes, queuing and MAC delays at the intermediate nodes before a packet reaches the destination causing increase in the overall average end to end delay. As routes break, nodes discover new routes using route discovery process, which lead to longer end to end delays. On the other hand, OLSR has stable and low end to end delay due to its stable routing tables and entries. Slight changes in mobility speed or link breakage requires a slight change in routing entries, thus maintains a low and stable end to end delay for OLSR. However OLSR have increased average end to end delay at higher mobility speed, due to frequent link breakages and change in topology.

There are many future directions that can be considered for further enhancement. Some of the guidelines are as follows:

Changing the performance metrics for evaluating routing protocols such as performing energy comparison of OLSR and DYMO because mobile nodes often have very limited battery energy and battery drain often causes route break. MANETs are often deployed in various environments with different mobility patterns. Different mobility models are used which better suit the situation. Mobility model used in this dissertation can thus be replaced with some other mobility model. Choosing different network simulator such as Qualnet, GlomoSim, Mannasim, Omnet, and Opnet etc can also be used to improve the simulation results. Instead of CBR traffic type which is used in this research work, other traffic types such as TCP or VBR (variable bit rate) can also be used in the simulation of routing protocols.

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