ENSC 427: Communication Networks

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Final Project

Performance of Mobile Ad-Hoc Network Routing Protocols

http://www.sfu.ca/~rtariq/proj.html

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Abstract

With the advent of cutting edge technological advancements in processor speed and wireless communications, advanced mobile wireless networks usage is growing by leaps and bounds. There are many such technologies and standards, and notable among them is Mobile Wireless Ad hoc network. Ad hoc is a Latin phrase meaning "for this". A Mobile Ad hoc network consists of a group of nodes equipped with wireless transceivers that can communicate with one another without using any fixed networking infrastructure. Communication is provisioned by the transmission of data packets over a common wireless channel. This kind of network facilitates wireless nodes to automatically find each other and self-configure to route IP packets among themselves.
In this project, we are going to use OPNET to simulate Mobile Wireless Ad hoc network with three different routing protocols: Ad Hoc On-Demand Distance Vector (AODV), Dynamic Source Routing (DSR) and Optimized Lint State Routing (OLSR). The three protocols are going to be evaluated in terms of performance metrics, which are Throughput Rate, Packet Overhead and Delay.

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1) Introduction:

Mobile Ad hoc is a decentralized wireless network in which any node in the network can act as a client or a server to share data directly among nodes. The peculiarity of this network is that it does not have any pre-existing infrastructure nor requires a centralized node. Furthermore, as a corollary, network also does not necessitate dedicated distribution nodes such as routers and switches. The wireless nodes by themselves can institute communication links. Wireless nodes automatically find each other and self-configure themselves to route data among themselves. Each node behaves and operates as a router, transmitting information to other node. Mobile Ad Hoc networks are self-organizing and adaptive. Since nodes may be in constant motion, Mobile Ad hoc networks also allow spontaneous formation and modification of mobile network topology. Mobile Ad hoc network have many advantages over traditional Wi-Fi network or wired networks. These are:

- Mobility
- Reduced installation time
- Long-term cost savings
- No Central Access Point

The transmission ranges of wireless network nodes are limited. Due to this, some nodes cannot communicate directly with each other. By necessity, multiple network hops are a requisite for a particular node to transmit data to a relatively far node. This implies routing is grounded on multi-hop routing from source to a destination node or nodes. Therefore, Mobile Ad hoc network is a multi-hop; perpetually changing wireless network as such traditional fixed routings protocols are not viable. Due to dynamic nature of ad hoc networks, several new routing protocols have been formulated and some of them will be discussed in the next section

2) Mobile Ad hoc Routing Protocols Design Issues:

Routing is a mechanism for determining the set of best paths for routing packets. The basic objective is to determine the lowest-cost path between any two nodes, where cost of a path equals the sum of all the cost of links that connect the nodes. Cost refers to desirability of sending traffic over a particular link. Typically, it is possible to attach a cost to a link connecting two nodes and this cost may be realized in form of link up/down, congestion, delay, throughput or other metrics. Routing is attained in most networks by running routing protocols among the nodes. These protocols deliver a distributed, dynamic solution to the problem of routing.

Routing protocols have the following major design requirements:

- **Responsiveness to changes**
  Network topology may change due to link or node failure. Hence a routing protocol should handle changes in topology seamlessly. It should also deal with bandwidth changes and congestion. Rapid convergence of routers to consistent set of routes is essential after an alteration in network

- **Optimality**
  Efficient resource utilization is expected
- **Robustness**
  The routing protocol should be able to work under high load, congestion, node failures and incorrect implementations
- **Implementation**
  The routing protocol algorithm should be simple and efficient to implement and should not excessively drain the underlying hardware.

There are various fixed Routing protocols such as RIP, OSPF and EIGRP that are currently in usage in wired and centralized network and do fulfill the above requirements. However, they cannot be directly implemented in the Mobile Ad hoc network as they are inadequate to tolerate various unique issues that are present in the network.
These issues are native to Mobile Ad hoc network due to decentralized and dynamic nature of the network.

The issues are as follows:
- **Exceedingly dynamic topology**
  The physical topology of the network is frequently changing due to mobility of nodes, which is rare in wired networks. Hence, a stringent routing protocol is needed to rapidly regenerate routing tables to tackle rapid and unpredictable topology changes. Although, fixed routing protocols do contain the capability to find a new route should a link or node fail, but they are relatively sluggish and consume relatively large time to converge.
  The need for fast converging protocol with much higher efficiency is paramount.

- **Bandwidth Limitations**
  Wireless has less bandwidth due to the limited radio frequency band. Moreover, routing protocols requires more bandwidth for transmitting updated network information when network changes occur due to frequent change in network topology. Since network topology change often changes, exchange of route information in terms of large overhead renders substantial bandwidth as waste in Ad-hoc network. In contrast, routing protocols in wired network require less bandwidth for exchanging routing updates and can rapidly populate routing tables.
  Hence, Bandwidth optimization and topology update algorithm with less overhead is essential

- **Channel Quality**
  As opposed to the stable link capacity of wired networks, wireless link capacity continually varies because of the impacts from transmission power, receiver sensitivity, noise, fading, and interference. In some cases, devices within a

network can have different transmission powers or receivers. It is highly desirable for a routing protocol to determine routes through better quality links.

- **Limited Resources**
  Wireless mobile networks have power restrictions. Devices like laptop, smart phones and tablets are run on battery and have low processing power and memory. Routing protocol is expected consume less processing power and memory for routing when devices change their position or devices exchange route information.

We conclude an ideal Mobile Ad hoc Routing Protocol should deal efficiently with above design issues.
To summarize, Mobile Ad hoc Routing Protocol should have the following desirable characteristics.

- Ability to function in wholly distributed and decentralized setting
- Adaptive to repeated topology deformation
- Convergence to optimal route rapidly
- Limited bandwidth utilization
- Sustain the whole network in case of any node failure and isolate the failed node
- Remote regions of the network should not be allowed to update topology information maintained by a particular node to conserve memory, process power and prevent congestion

3) Mobile Ad hoc Routing Protocols:

The need for new protocols for Mobile Ad hoc network has led to the emergence of numerous mobile routing protocols. They may be differentiated on the procedure followed by mobile nodes to acquire routing information and maintain routing tables. These classifications are proactive routing, reactive routing, and hybrid routing. We shall briefly describe them one by one:

- **Proactive or table-driven routing protocols**
  In proactive routing protocol, nodes in a wireless ad hoc network proactively maintain up to date routing paths in the routing table to all accessible nodes. A source node can get a routing path whenever it requires one.

- **Reactive routing protocols**
  Also called on-demand protocol, routes are only determined when required by a given source node. Source node starts route discovery and a path is establish once all the possible routes are examined and route to destination node is found.

- **Hybrid routing protocols**
  Combination protocols to derive the merits of both proactive and reactive routing protocols and overcome their shortcomings. Network is hieratically divided into zones. Proactive protocols are chosen for one zone while reactive is used for the other.

We are now ready to introduce and analyze ADOV, DSR, and OLSR mobile routing protocols which are frequently used in contemporary mobile wireless ad hoc networks.

3.1) Dynamic Source Routing (DSR):

Dynamic Source Routing utilizes source routing. Each individual packet has a list of nodes in orderly manner in its header to transverse the network and arrives at the destination node. It is an on-demand routing protocol which means that it only exchanges route information for finding path from source to destination when packets are required to be send to the destination node.

DSR is based on the mechanism of Source Routing protocol which means that routing information is updated only when source node or intermediate node changes their positions.

The DSR protocol is composed of two mechanisms, namely; Route Discovery and Route Maintenance

Route Discovery is the process by which a source node that desire to transmit a packet to a destination node procures a source route to that destination node. In this process, the source node floods a Route Request packet in the whole network and is responded by a Route Reply packet from either the destination node or another node that knows a route to the destination. A cache of source routes is maintained by each node which reduces the load of Route of discovery by limiting the frequency and transmission of Route Requests.

Route Maintenance is the process by which a source node detects if the network topology has been modified. Due to this change it can no longer use its route to the destination node because two nodes enlisted in the route have departed from the range of each other. A Route Error packet is generated and transmitted to the source node when a source route is fragmented. The source node can then either use any alternative route to D already in its cache or can utilize Route Discovery again to find a new route.

3.2) Ad Hoc On-Demand Distance Vector (AODV):

The AODV is an optimized distance vector routing protocol for Mobile Ad hoc wireless networks. It is an on demand or reactive protocol, as it finds routes only when required.

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AODV borrows the basic on-demand mechanism of Route Discovery and Route Maintenance from DSR, and adds use of hop-by-hop routing, sequence numbers, and periodic update.

A source node determines a route to a destination node, by flooding a Route Request packet to its neighbors, including the last known sequence number for that destination. The Route Request is forwarded via flooding in the network and eventually arrives at a particular node that has a route to the destination. Each node that forwarded the Route Request generates a reverse route back to the source node. As soon as the Route Request packet reaches a node with a route to the destination node, that node generates a Route Reply that has the number of hops necessary to reach the destination node and the most updated sequence number for the destination node perceived by the node generating the Reply. Each node that partakes in forwarding this Reply back toward source node forms a forward route to the destination node. Intermediary nodes remember only the next hop and not the entire route.

AODV demands that each node in an order time fashion transmit a Hello message, with a rate of once per second. Should three consecutive Hello messages fail to come from a neighbor, then that neighbor is assumed to be disconnected or out of range.

3.3)   Optimized Link State Routing (OLSR)

OLSR is a Table-driven (proactive) Mobile Ad hoc wireless routing protocol utilizes efficient link state routing algorithm. It exchanges topology information with other nodes of the network regularly. Each node selects a set of its neighbor nodes as "multipoint relays" (MPR). In OLSR, only MPRs, are responsible for forwarding control traffic to be distributed into the entire network. OLSR minimizes the overhead from flooding of control traffic by using only selected nodes, called MPRs, to retransmit control messages. For OLSR to provide shortest path routes to all destinations, MPR nodes declare link state information for their MPR selector nodes. Additional available link state information may be utilized for redundant paths.

The link state information is sent periodically in their control messages. A MPR node announces to the network that it has path to the nodes which have selected it as an MPR. In route calculation, the MPRs are used to form the route from a given node to any destination in the network. Furthermore, the protocol uses the MPRs to facilitate efficient flooding of control messages in the network In case of link failure the availability of the redundant route facilitates routing. The optimization is done by OLSR in two ways; one is by reducing control packets overhead which reduces control packets size and secondly only MPRs nodes in the networks forwards link state information rather than all nodes

4) Performance Metrics:

4.1) Throughput Rate:

Throughput rate is the rate of complete and successful packet delivery over a channel or node. Throughput rate is measured in frames or bits per second. To measure the throughput rate, we are going to use scenarios at which we are going to send the packets at a low and high traffic to measure max throughput rate in both networks.

4.2) Packet Overhead:

Network overhead is the header size that is essential for routing data over network. It does not contribute to useful data required for the application at a node and hence, consumes valuable bandwidth. Protocol overhead can be quantified as a ratio of header bytes to total number of bytes in the packet. Key issue in design is to minimize overhead but at the same time keeping routing efficient and robust

4.3) Delay:

Delay is lateness in packet delivery. To measure packets delay, we are going to alter two parameters; Node mobility and Traffic load. As the packet size increases or the distance between the sender and receiver increases, packet delay rises.

5) Simulation Software:

The software used for testing the performance of Mobile Ad Hoc Routing Protocols is OPNET 16.0A. OPNET is used over NS-2 because of the following reasons:

- OPNET is user friendly and easier to learn than NS-2
- OPNET has many deployment wizards that help in creating the network and altering its parameters.
- NS-2 require deep knowledge of TCL scripting
- OPNET can generate many graphs by checking a box and overlay them easily

6) Scenarios:

To test the performance of the Mobile Ad Hoc routing protocols AODV (reactive), DSR (reactive) and OLSR (proactive), we created a campus sub network with the dimensions of 1Km x 1Km. The bit rate used is 11Mbps and the MAC layer network standard is IEEE 802.11b. 10 nodes were used in the campus with two different mobility speeds in order to check routing protocol performance when nodes are under movement. In addition to altering mobility speeds, we altered the traffic load between high FTP load and low FTP load. FTP application is used because our intention is to test a simple file transfer

protocol and not a complex application or protocol. The following table summarizes the sub network parameters. And the final network topology is shown in figure 1.

Parameter	Value
Number of nodes	10
Size of sub network	1Km x 1Km
Network Standards	IEEE 802.11b
Power	5mW
Data bit rate	11Mbs
Traffic	FTP (Heavy , Low)
Node Mobility Speed	10m/s , 30 m/s

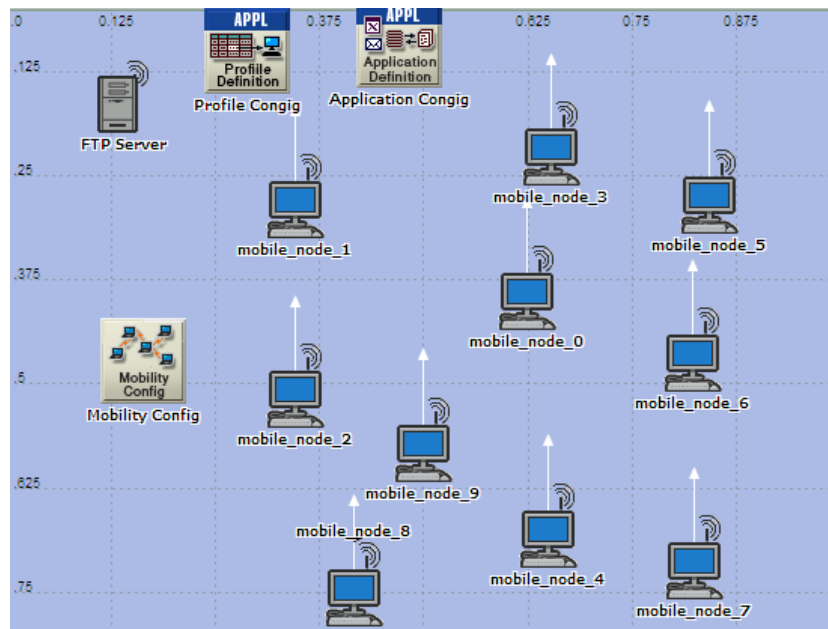**Table 1: Summary of network parameters**

Figure 1: Network Topology

As figre1 shows, the nodes are placed randomly in the 1km^2 campus. All nodes are mobile and are Ad hoc workstations. The only stationary node is the FTP server. Application Configurator is used to specify the application that going to be used in simulations and alter the traffic load. Profile Configurator helps in creating a profile for the FTP application. Mobility Configurator is used to create node movement and specify a movement speed and direction. We are testing three Mobile Ad hoc routing protocols with altering mobility speed and traffic load, which generates 12 different scenarios. The following table summarizes the 12 scenarios.

Protocol\ Parameter	Traffic	Mobility Speed
AODV	Low	10m/s
AODV	Low	30m/s
AODV	High	10m/s
AODV	High	30m/s
DSR	Low	10m/s
DSR	Low	30m/s
DSR	High	10m/s
DSR	High	30m/s
OLSR	Low	10m/s
OLSR	Low	30m/s
OLSR	High	10m/s
OLSR	High	30m/s

Table 3: Summary of 12 scenarios used in simulations

7) Results and Discussion:

For each scenario, three performance metrics were recorded. Each scenario ran for 30 minutes. The graphs were grouped up by similarity in parameters. e.g. AODV graph with low FTP traffic and mobility speed of 10m/s was combine with DSR and OLSR graphs with equivalent parameters. The result is 4 graphs for each performance metric. Each graph has three lines. Each line represents a scenario. The following four graphs are the

Routing Overhead in 12 different scenarios. **For all graphs Blue line is AODV, Red line is DSR and Green line is OLSR.**

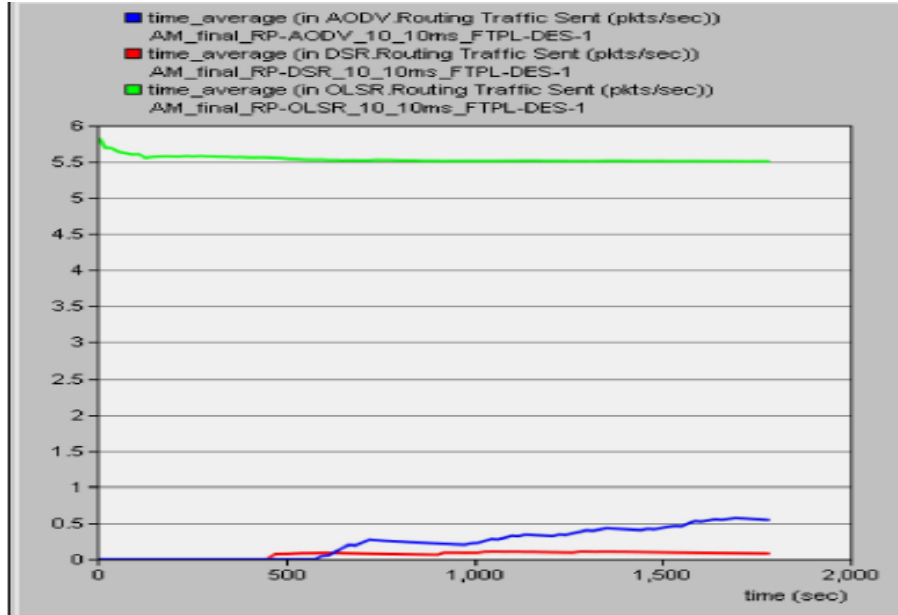## 7.1)   Packet Overhead Results:

Figure 2: Routing overhead of Ad Hoc routing protocols with low FTP traffic and 10m/s mobility
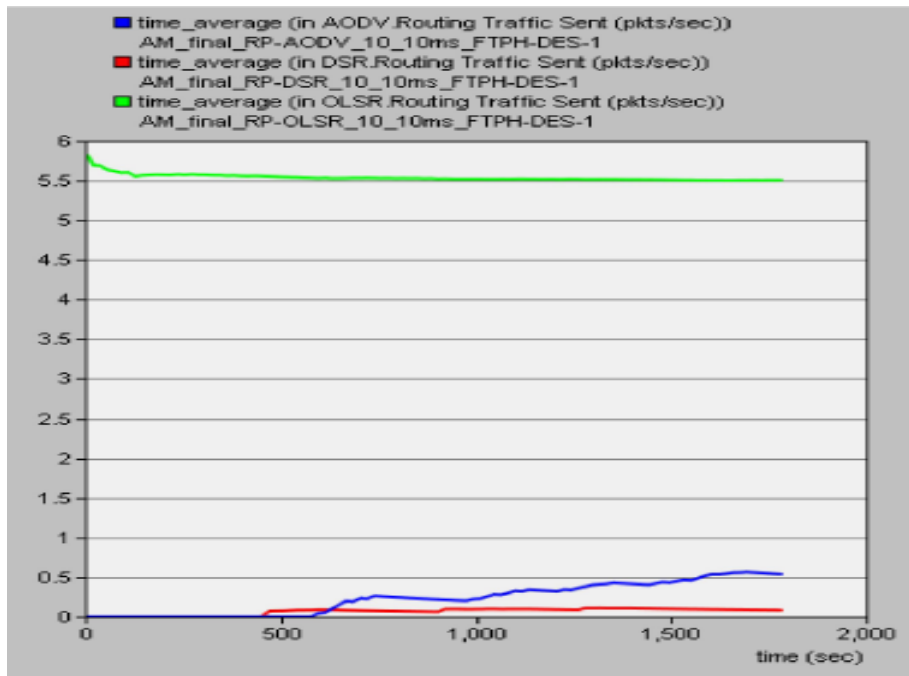

Figure 3: Routing overhead of Ad Hoc routing protocols with High FTP traffic and 10m/s mobility
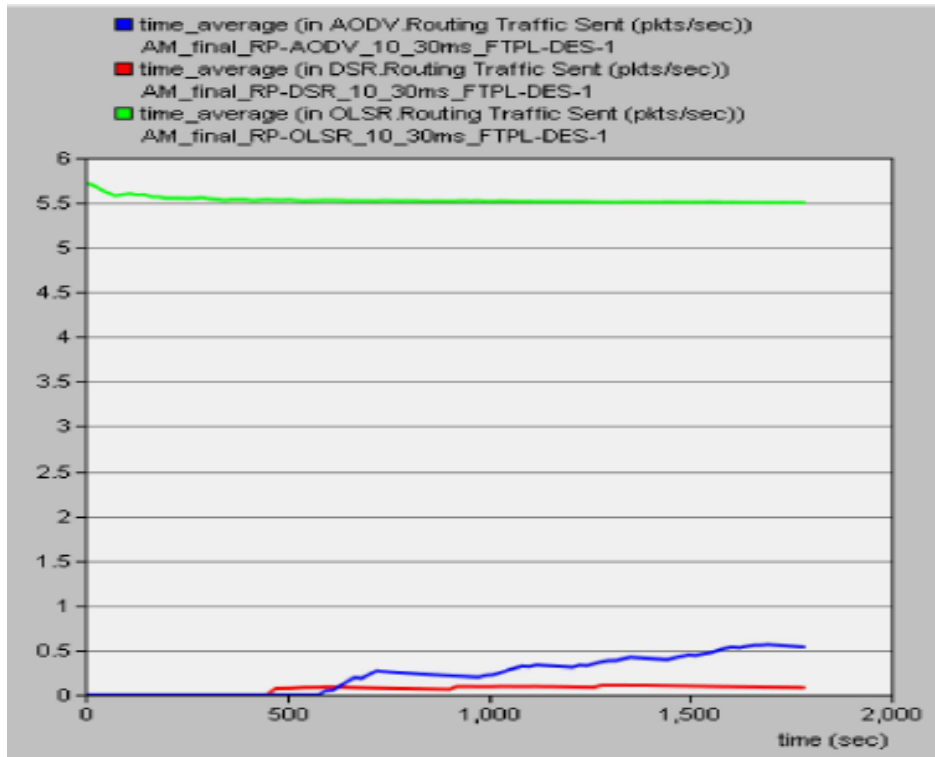
Figure 4: Routing overhead of Ad Hoc routing protocols with low FTP traffic and 30m/s mobility
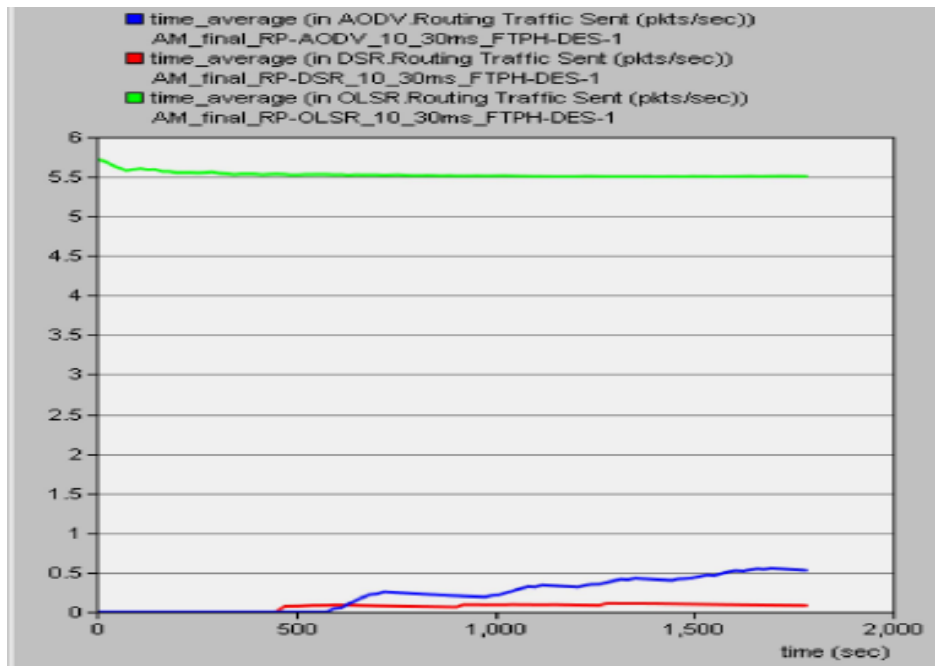

Figure 5: Routing overhead of Ad Hoc routing protocols with high FTP traffic and 30m/s mobility

As the graphs show, OLSR (green) has a constant routing overhead rate in all cases. In addition to the constant routing overhead, OLSR has the highest routing overhead compared to AODV (blue) and DSR (red). The reason behind the big

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overhead rate is that OLSR includes some of the FTP data in the header. On the other hand, DSR has a constant-low overhead rate in all scenarios. In DSR, the packets traversing the network include the IP address of every node in their route. However, since the network capacity is low, the overhead in DSR is almost constant and does not change with altering the mobility and traffic. In the AODV case, the overhead rate is increasing with time with a higher rate than DSR but less than OLSR. The following table summarizes the results of the routing overhead rate in all graphs. The numbers 1, 2 and 3 means best, second best and worst respectively.

Scenario/Routing Protocol	AODV	DSR	OLSR
10m/s – Low FTP Traffic	2	1	3
10m/s – High FTP Traffic	2	1	3
30m/s – Low FTP Traffic	2	1	3
30m/s – High FTP Traffic	2	1	3

Table 3: Summary of the graphs of routing overhead of Ad Hoc routing protocol
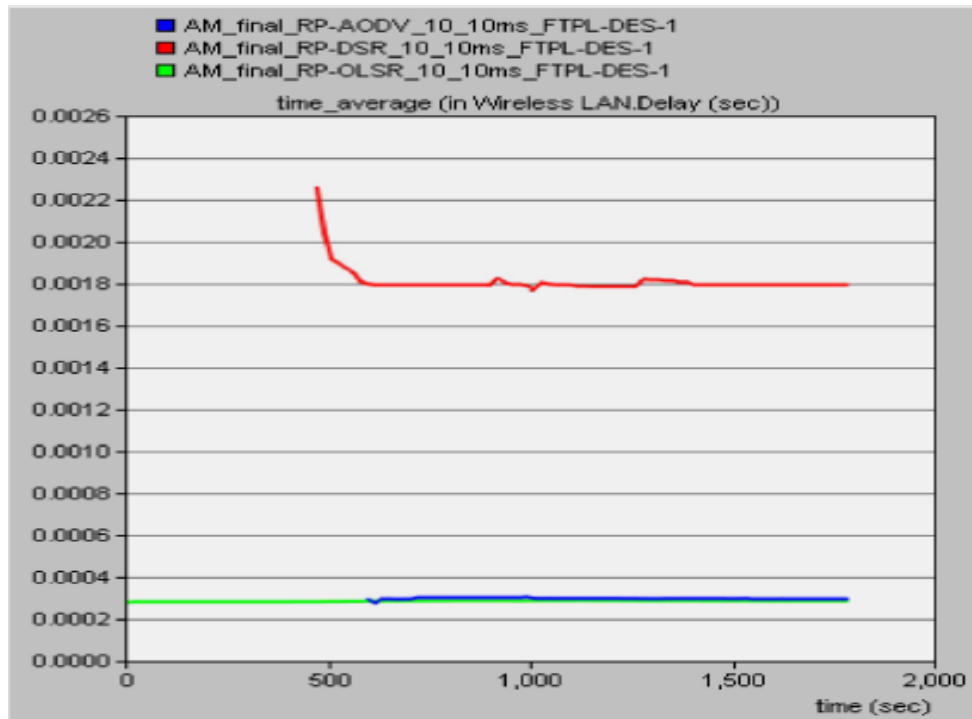
7.2)   End-To-End Delay Results:

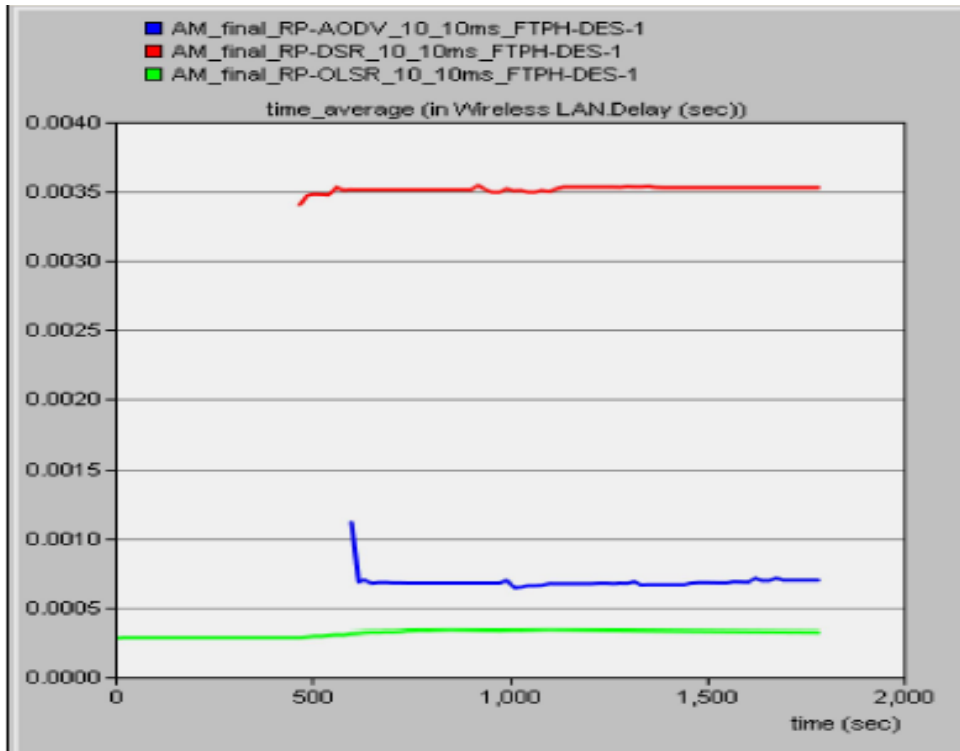Figure 6: End-To-End Delay of Ad Hoc routing protocols with low FTP traffic and 10m/s mobility

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Figure 7: End-To-End Delay of Ad Hoc routing protocols with high FTP traffic and 10m/s mobility
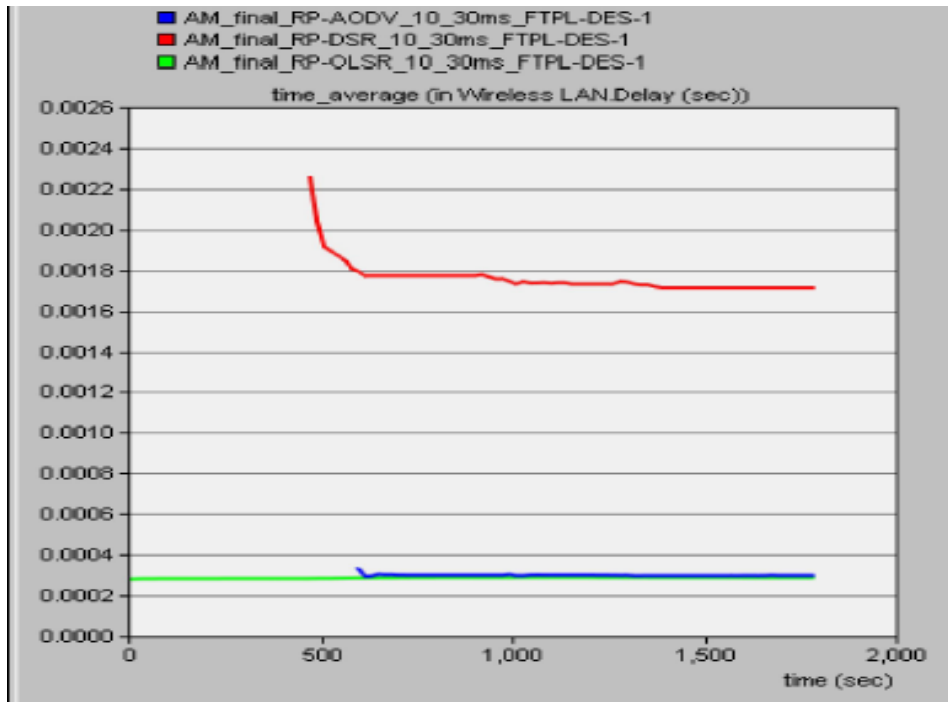

Figure 8: End-To-End Delay of Ad Hoc routing protocols with low FTP traffic and 30m/s mobility
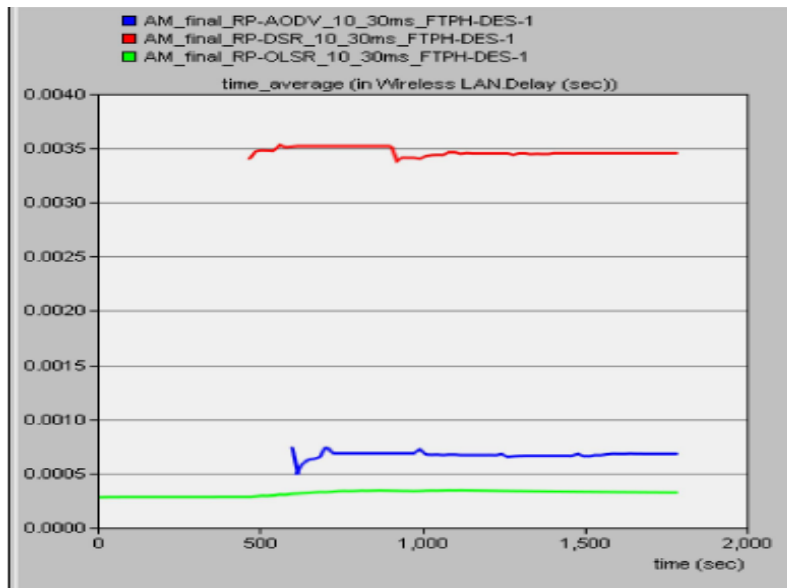
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Figure 9: End-To-End Delay of Ad Hoc routing protocols with high FTP traffic and 30m/s mobility

As the graphs show, DSR (red) has the highest end-to-end delay in all scenarios. For the (10 m/s - low FTP traffic) and (30 m/s - low FTP traffic) scenarios, DSR has a delay around 2.3 msec. Then the delay drops to 1.8 msec and stays constant all the way to the end of the simulation. Since the packets traversing the network in DSR include the IP address of every node in their overhead, delay drops after few seconds since the traversing packets have a record of the IP address of all nodes in the network. On the other hand, OLSR (green) has a constant-low delay at 0.3 msec in all scenarios since OLSR is a proactive protocol and has a table of all routes leading to other nodes in the network. For the AODV (blue) protocol scenarios, mobility doesn't have an effect on the delay performance; however, traffic load has. As the traffic load increases, AODV's delay increases from 0.3 msec to 0.7 msec. The following table summarizes the results of the end-to-end delay in all graphs. The numbers 1, 2 and 3 means best, second best and worst respectively.

Scenario/Routing Protocol	AODV	DSR	OLSR
10m/s – Low FTP Traffic	1	3	1
10m/s – High FTP Traffic	2	3	1
30m/s – Low FTP Traffic	1	3	1
30m/s – High FTP Traffic	2	3	1

Table 4: Summary of the graphs of end-to-end delay of Ad Hoc routing protocol
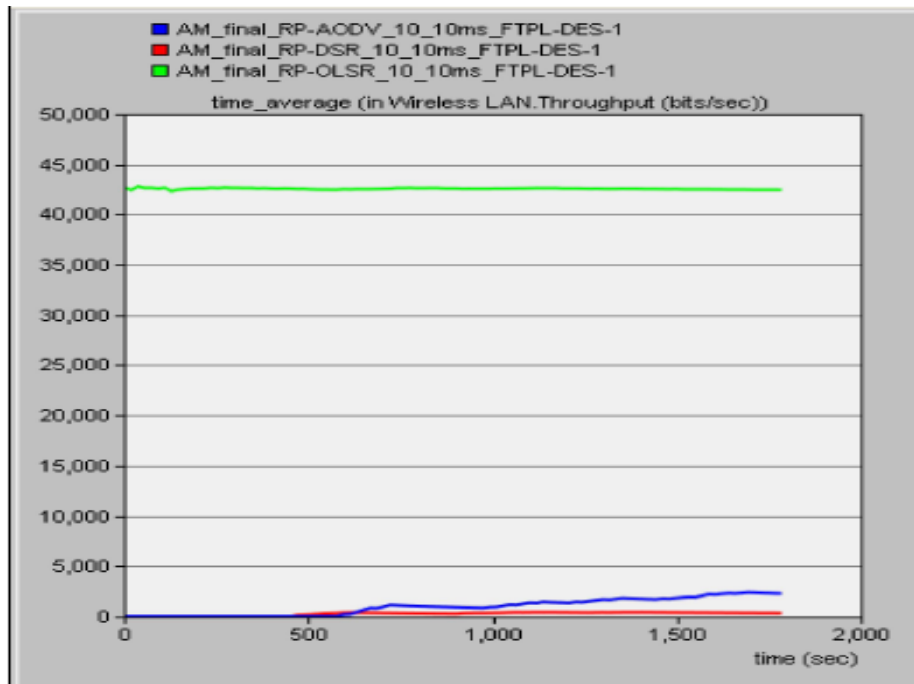
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7.3)   Throughput Rate Results:

Figure 10: Throughput rate of Ad Hoc routing protocols with low FTP traffic and 10m/s mobility
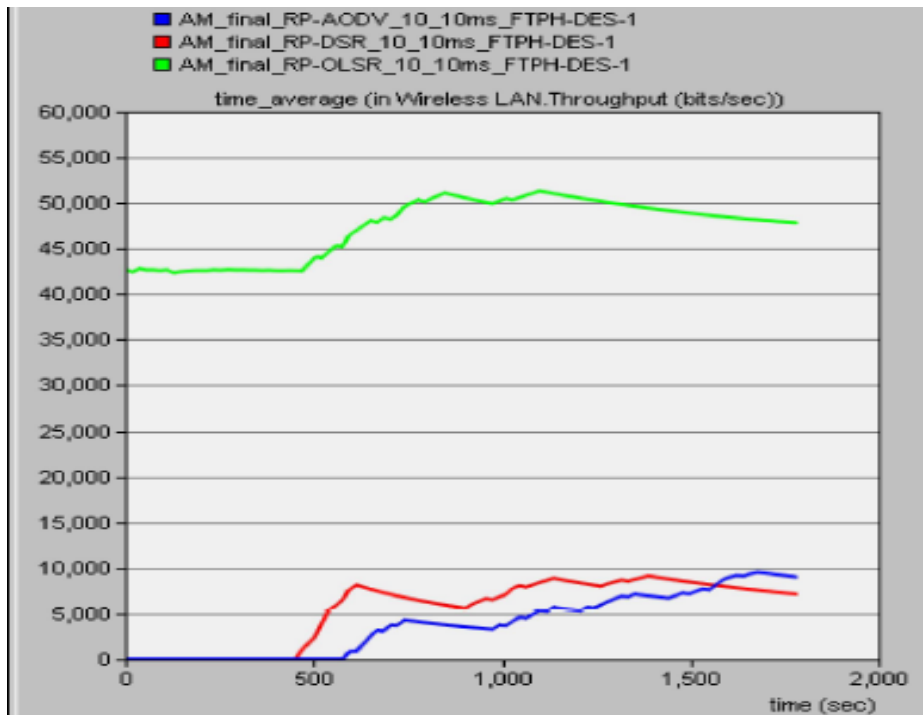

Figure 11: Throughput rate of Ad Hoc routing protocols with high FTP traffic and 10m/s mobility
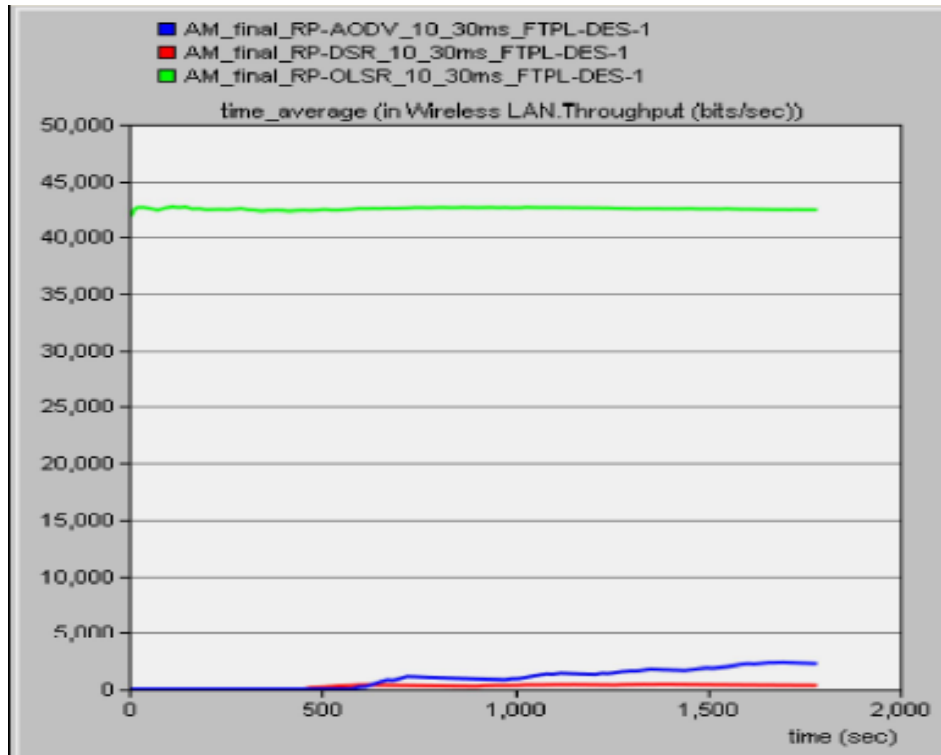
Figure 12: Throughput rate of Ad Hoc routing protocols with low FTP traffic and 30m/s mobility
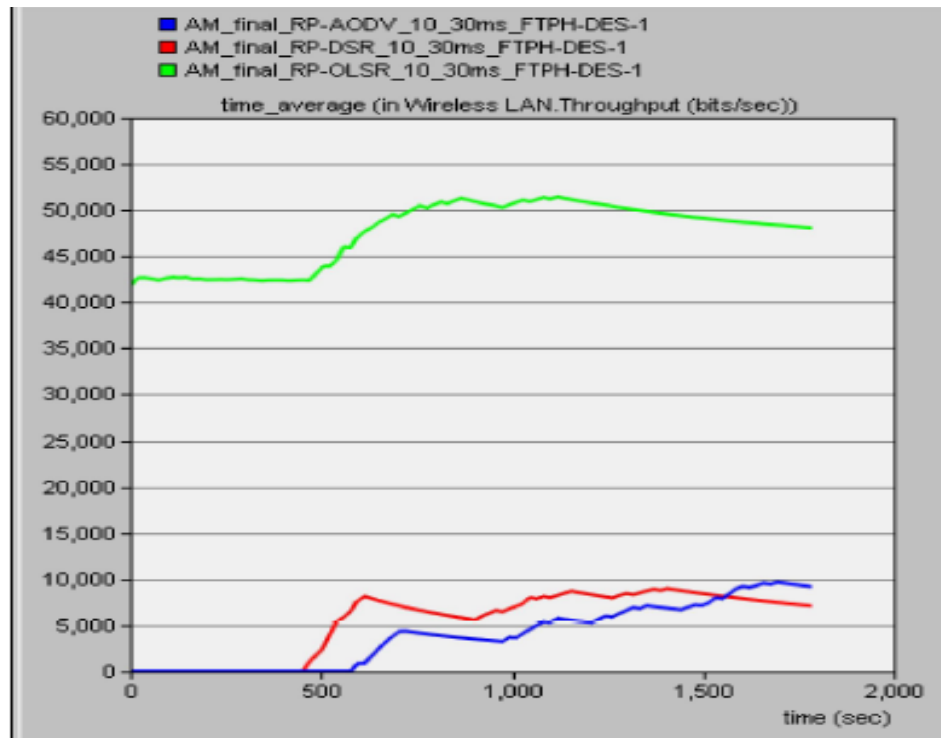

Figure 13: Throughput rate of Ad Hoc routing protocols with high FTP traffic and 30m/s mobility

As the graphs show, OLSR (green) has the highest throughput rate compared to AODV (blue) and DSR (red). The OLSR throughput rate is constant at 43kbits/sec for the scenarios (10 m/s - low FTP traffic) and (30 m/s - low FTP traffic). OLSR throughput rate starts rising gradually to approximately 50kbits/sec at 500 sec with high FTP traffic load. In the case of AODV (blue), throughput rate doesn't change with mobility; throughput rate is equivalent for the scenarios of 10 m/s and 30 m/s. The same case applies for DSR (red) scenarios; throughput rate doesn't change with altering mobility. On the other hand raising the traffic load affects both DSR and AODV. DSR outperforms AODV in high traffic. But both DSR and AODV are outperformed by OLSR in all scenarios. The following table summarizes the results of the throughput rate in all graphs. The numbers 1, 2 and 3 means best, second best and worst respectively.

Scenario/Routing Protocol	AODV	DSR	OLSR
10m/s – Low FTP Traffic	2	3	1
10m/s – High FTP Traffic	3	2	1
30m/s – Low FTP Traffic	2	3	1
30m/s – High FTP Traffic	3	2	1

Table 5: Summary of the graphs of throughput rate of Ad Hoc routing protocol

7.4) General Comments on Results:

In all graphs, since DSR and AODV are reactive routing protocols, they both need to send route traverse packets. Consequently, all DSR and AODV graphs start a bit late. On the other hand, OLSR graphs start from 0 sec since OLSR is a proactive protocol or table-driven protocol.

8) Conclusion:

By observing the simulation results of Mobile Ad Hoc routing protocols AODV, OLSR and DSR, we can state that OLSR has the best throughput rate and end-to-end delay, but the worst routing overhead rate for all traffic and node mobility speeds. On the other hand, DSR is superior in overhead rate but has the worst throughput rate and end-to-end delay. Also, AODV has a better delay in low traffic and low mobility speeds. In

conclusion, Routing protocol superiority depends on scenarios and applications. Each protocol is suitable for a certain applications. OLSR is the best in high capacity networks since it has the best performance in throughput rate and end-to-end delay. In contrast, DSR is the best in low capacity networks since it has a constant-low overhead rate. Moreover, network load has a significant effect on network performance, whereas node speed did not have a big impact on the results. Finally, we can make a generalization with caution, since we need more testing to prove it, that Proactive protocols behave better in high capacity networks and Reactive protocols are better in low capacity networks.

9) References:

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