Journal of Multidisciplinary Engineering Science and Technology (JMEST)
ISSN: 2458-9403
Vol. 9 Issue 1, January - 2022

Performance Comparison of different routing protocols for Wireless Mesh Networks

Md. Palash Tai
Lecturer, Dept. of CSE, Pundra University of Science & Technology, Bogura, Bangladesh
e-mail: polashice999@gmail.com

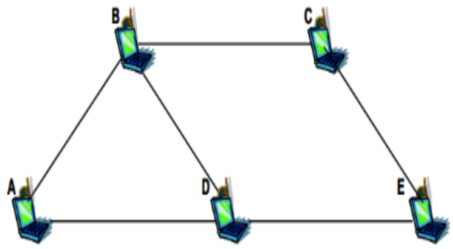
Abstract*—Wireless Mesh Network is a new emerging and promising technology in the wireless network world. It could completely change the way its next generation wireless network using capability. Wireless mesh networks are the next step in the evolution of wireless architecture, delivering wireless services for a large variety of applications in personal, local, campus, and metropolitan area. A wireless ad-hoc network represent a system of wireless mobile nodes that can freely and dynamically self-organize into arbitrary and temporary network topologies. Ad hoc wireless networks are increasingly gaining importance due to their advantages such as low cost and ease of deployment. In this paper, we present a detailed simulation study of the performance of different routing algorithms like Ad-hoc On demand Distance Vector Routing(AODV),Destination Sequenced Distance Vectored routing, Dynamic Source routing, Temporally Ordered Routing Algorithm (TORA) in ad hoc and wireless mesh networks using ns2(Network simulator) environment. We also implement hardware configuration of the mesh routers.

***Keywords*—Wireless Mesh Network; AODV; DSR; DSDV; TORA**

I. INTRODUCTION

An Ad hoc network is a collection of mobile nodes, which forms a temporary network without the aid of centralized administration or standard support devices regularly available as conventional networks. These nodes generally have a limited transmission range and, so, each node seeks the assistance of its neighboring nodes in forwarding packets and hence the nodes in an Ad hoc network can act as both routers and hosts. Thus a node may forward packets between other nodes as well as run user applications. By nature these types of networks are suitable for situations where either no fixed infrastructure exists or deploying network is not possible. Ad hoc mobile networks have found many applications in various fields like military, emergency, conferencing and sensor networks. Each of these application areas has their specific requirements for routing protocols. Since the network nodes are mobile, an Ad hoc network will typically have a dynamic topology, which will have profound effects on network characteristics. The distributed nature of wireless ad-hoc networks makes them suitable for a variety of applications where central nodes can't be relied on and may improve the scalability of networks compared to wireless managed networks, though theoretical and practical limits to the overall capacity of such networks have been identified. Wireless ad-hoc networks can be further classified by their application:

- mobile ad hoc networks (MANET)A mobile ad hoc network (MANET) is a continuously self-configuring, infrastructure-less network of mobile devices connected without wires.
- Vehicular Ad hoc Networks (VANETs)are used for communication between vehicles and roadside equipment. Intelligent vehicular ad hoc networks (InVANETs) are a kind of artificial intelligence that helps vehicles to behave in intelligent manners during vehicle-to-vehicle collisions, accidents.
- Smart Phone Ad hoc Networks (SPANs)leverage the existing hardware (primarily Bluetooth and Wi-Fi) in commercially available smart phones to create peer-to-peer networks without relying on cellular carrier networks, wireless access points, or traditional network infrastructure.
- Internet based mobile ad hoc networks (iMANETs)are ad hoc networks that link mobile nodes and fixed Internet-gateway nodes. One implementation of this is Persistent System's CloudRelay.
- Military / Tactical MANETs are used by military units with emphasis on security, range, and integration with existing systems.



Example of an Ad Hoc Network

Fig.1: depicts a peer-to-peer multi-hop ad hoc network.

Mobile node A communicates directly with B (single hop) when a channel is available. If Channel is not available, then multi-hop communication is necessary e.g. A->D->B. For multi-hop communication to work, the intermediate nodes should route the packet i.e. they should act as a router. For example communication between A-C, B, or D & E, should act as route.

A wireless mesh network (WMN) is a communications network made up of radio nodes organized in a mesh topology. It is also a form of wireless ad hoc network. Wireless mesh networks often consist of mesh clients, mesh routers and gateways. The mesh clients are often laptops, cell phones and other wireless devices while the mesh routers forward traffic to and from the gateways which may, but need not, connect to the Internet. The coverage area of the radio nodes working as a single network is sometimes called a mesh cloud. Access to this mesh cloud is dependent on the radio nodes working in synchronization with each other to create a radio network. A mesh network is reliable and offers redundancy. Wireless mesh networks can be implemented with various wireless technology including 802.11, 802.15, 802.16, cellular technologies or combinations of more than one type. Mesh networks may involve either fixed or mobile devices. Some current applications:

- U.S. military forces are now using wireless mesh networking to connect their computers, mainly ruggedized laptops, in field operations.
- Electric meters now being deployed on residences transfer their readings from one to another and eventually to the central office for billing without the need for human meter readers or the need to connect the meters with cables.
- The laptops in the One Laptop per Child program use wireless mesh networking to enable students to exchange files and get on the Internet even though they lack wired or cell phone or other physical connections in their area.
- The 66-satellite Iridium constellation operates as a mesh network, with wireless links between adjacent satellites. Calls between two satellite phones are routed through the mesh, from one satellite to another across the constellation, without having to go through an earth station. This makes for a smaller travel distance for the signal, reducing latency, and also allows for the constellation to operate with far fewer earth stations than would be required for 66 traditional communications satellites.

Multi-radio mesh refers to a unique pair of dedicated radios on each end of the link. This means there is a unique frequency used for each wireless hop and thus a dedicated CSMA collision_domain. This is a true mesh link where you can achieve maximum performance without bandwidth degradation in the mesh and without adding latency. Thus voice and video applications work just as they would on a wired Ethernet network. In true 802.11 networks, there is no concept of a mesh. There are only Access Points (AP's) and Stations. A multi-radio wireless mesh node will dedicate one of the radios to act as a station, and connect to a neighbor node AP radio.

II. Routing Protocols

The goal of wireless mesh network is to establish a correct and efficient route between the nodes and to ensure correct delivery of packets. Routing protocols are used whenever a packet needs to be transmitted to the destination through number of nodes. These protocols find the route and deliver the packet to the proper destination. Routing is used to select the best suitable path for the transmission of packets from one place to another

II.I Current Routing Protocols

The current routing protocols implemented by ns2 are:

- **DSDV**- Destination-Sequenced Distance Vector routing
- **DSR**- Dynamic Source Routing
- **TORA/IMPE**- Temporally ordered routing algorithm
- **AODV**- Ad hoc On-Demand Distance Vector Routing

II.II Destination-Sequenced Distance Vector routing

Destination-Sequenced Distance-Vector Routing (DSDV) is a table-driven routing scheme for ad hoc mobile networks based on the Bellman–Ford algorithm. It was developed by C. Perkins and P. Bhagwat in 1994. The main contribution of the algorithm was to solve the routing loop problem. Each entry in the routing table contains a sequence number, the sequence numbers are generally even if a link is present; else, an odd number is used. The number is generated by the destination, and the emitter needs to send out the next update with this number.

II.II.I Advantages and disadvantages

The availability of paths to all destinations in network always shows that less delay is required in the path set up process. The method of incremental update with sequence number labels, marks the existing wired network protocols adaptable to Ad-hoc wireless networks. Therefore, all available wired network protocol can be useful to ad hoc wireless networks with less modification. DSDV requires a regular update of its routing tables, which uses up battery power and a small amount of bandwidth even when the network is idle. Whenever the topology of the network changes, a new sequence number is necessary before the network re-converges; thus, DSDV is not suitable for highly dynamic or large scale networks. (As in all distance-vector protocols, this does not perturb traffic in regions of the network that are not concerned by the topology change.)

II.III Dynamic Source Routing

Dynamic Source Routing (**DSR**) is a routing protocol for wireless mesh networks. It is similar to AODV in that it forms a route on-demand when a transmitting node request one. However, it uses source routing instead of relying on the routing table at each intermediate device. Determining source routes requires accumulating the address of each device between the source and destination during route discovery. The accumulated path information is cached by nodes processing the route discovery packets. The learned paths are used to route packets. To accomplish source routing, the routed packets contain the address of each device the packet will traverse. This may result in high overhead for long paths or large addresses, like IPv6. To avoid using source routing, DSR optionally defines a flow id option that allows packets to be forwarded on a hop-by-hop basis.

II.III.I Advantages and disadvantages

This protocol uses a reactive approach which eliminates the need to periodically flood the network with table update messages which are required in a table-driven approach. In a reactive (on-demand) approach such as this, a route is established only when it is required and hence the need to find routes to all other nodes in the network as required by the table-driven approach is eliminated. The intermediate nodes also utilize the route cache information efficiently to reduce the control overhead. The disadvantage of this protocol is that the route maintenance mechanism does not locally repair a broken link. Stale route cache information could also result in inconsistencies during the route reconstruction phase. The connection setup delay is higher than in table-driven protocols. Even though the protocol performs well in static and low-mobility environments, the performance degrades rapidly with increasing mobility. Also, considerable routing overhead is involved due to the source-routing mechanism employed in DSR. This routing overhead is directly proportional to the path length.

II.IV TEMPORALLY ORDERED ROUTING ALGORITHM

The TORA attempts to achieve a high degree of scalability using a "flat", non-hierarchical routing algorithm. In its operation the algorithm attempts to suppress, to the greatest extent possible, the generation of far-reaching control message propagation. In order to achieve this, the TORA does not use a shortest path solution, an approach which is unusual for routing algorithms of this type. TORA builds and maintains a Directed Acyclic Graph (DAG) rooted at a destination. No two nodes may have the same height. Information may flow from nodes with higher heights to nodes with lower heights.

The protocol performs three basic functions:

- Route creation
- Route maintenance
- Route erasure

II.V Ad hoc On-Demand Distance Vector Routing

The AODV (Ad-Hoc On-Demand Distance Vector) routing protocol is a reactive routing protocol that uses some characteristics of proactive routing protocols. Routes are established on-demand, as they are needed. However, once established a route is maintained as long as it is needed. Reactive (or on-demand) routing protocols find a path between the source and the destination only when the path is needed (i.e., if there are data to be exchanged between the source and the destination). An advantage of this approach is that the routing overhead is greatly reduced. A disadvantage is a possible large delay from the moment the route is needed (a packet is ready to be sent) until the time the route is actually acquired. In AODV, the network is silent until a connection is needed. At that point the network node that needs a connection broadcasts a request for connection. Other AODV nodes forward this message, and record the node that they heard it from, creating an explosion of temporary routes back to the needy node. When a node receives such a message and already has a route to the desired node, it sends a message backwards through a temporary route to the requesting node. The needy node then begins using the route that has the least number of hops through other nodes. Unused entries in the routing tables are recycled after a time.

II.V.I Advantages and disadvantages

The main advantage of this protocol is having routes established on demand and that destination sequence numbers are applied to find the latest route to the destination. The connection setup delay is lower. One disadvantage of this protocol is that intermediate nodes can lead to inconsistent routes if the source sequence number is very old and the intermediate nodes have a higher but not the latest destination sequence number, thereby having stale entries. Also, multiple Route Reply packets in response to a single Route Request packet can lead to heavy control overhead. Another disadvantage of AODV is unnecessary bandwidth consumption due to periodic beaconing

iii. General Concept of NS2

NS-2 is the acronym of network simulator-2.NS2 source code is copyrighted but freely distributed and discrete event simulator which works on packet scenario of networking projects for both wired and wireless network. NS-2 was developed at LBNL (Lawrence Berkeley National Laboratory) under VINT project (Virtual Internet Test bed) by LBL. NS-2 is a portable tool that works on all UNIX, Linux and windows operating systems. NS-2 has many built in libraries and functions which support many routing protocols, network topologies like bus, ring, hybrid, star topologies to design both wired and wireless network with the help of simulation scripts. Main advantage of NS-2 is that we can easily calculate total throughput, error rate, end to end delay, total number of packet send and received by destination with custom scripts AWK. NS-2 support both transport layer protocols TCP and UDP to transmit data in the form of packets from source to destination and NS2 support mainly four type of traffic generators to generate data in the form of packets and send packets over transport layer protocols. CBR (Constant Bit Rate), exponential traffic (poison traffic), Pareto traffic (poo traffic) and FTP are traffic generators.
To run the TCL script NS2 use the NAM (network animator) which is a visualization tool which show the nodes and flow of packet written in the TCL script. In this paper we worked on wired network and try to compare TCP and UDP protocols by calculating their total throughput and packet flow analysis and packet drop rate.

III.I Background on the ns Simulator

NS simulator is based on two language: an object oriented simulator ,written in c++ and a oTcl (an object oriented extension of Tcl) interpreter, used to execute users command scripts. NS has a rich library of network and protocol objects. There are two class hierarchies:
The compiled C++ hierarchy and the interpreted Otcl one ,with one to one corresponds between them.
The compiler C++ hierarchy allows us to achieve efficiency in the simulator and faster execute times. This is in particular useful for the detailed definition and operation of protocols. This allows one to reduce packet and event processing time. NS is a discrete event simulator, where the advance of the time depends on the timing of events which are maintained by a scheduler. An event is an object in the C++ horary with an unique ID, a scheduled time and a pointer to an object that handle the event. The scheduler keeps an ordered data structure with the events to be executed and fires them one by one, involving the handler the event.

III.II Tcl and Otcl programming

Tcl(Tool Command Language) is used for millions of people in the world. It is a language with a very simple sintaxis and it allows a very easy integration with other languages. Tcl was created by Jhon Ousterhout.

The characteristics of this language are:

- It allows a fast development
- It provide a graphique interface
- It is compatible with many platforms
- It is flexible for integration
- It is easy to use
- It is free

III.IV Featurs of NS2

NS2 (Network Simulator version2): NS2 is a discrete event simulator targeted at networking research. It provides support for simulation of TCP, routing, and multicast protocols over all networks wireless.NS2 can be employed in most UNIX systems and windows (XP, VESTA and 7), and in this paper windows XP is used. Most procedure processes of the NS2 code are written in C++. It uses TCL as its scripting language, Otcl adds object orientation to TCL.NS (version 2) is an object oriented, discrete event driven network

III.V Application of NS2

In order to solve the realistic problems in the teaching and experiment of computer network courses, a NS2-based demonstration and experiment system for computer network courses has been constructed. This system is made up of two parts, one of which is the demonstration system for teachers to demonstrate in class, and the other is the experiment system for students to do experiment in the laboratory or after school. This system has achieved some beneficial effect in the education practice. The future work is focused on the improvement of the experiment database.

III.VI Experimental setup

Main NS2 Simulation Steps

The followings show the three key step guide line in defining a simulation scenario in a NS2:

Step 1: Simulation Design

The first step in simulating a network is to design the simulation. In this step, the users should determine the simulation purposes, network configuration and
assumptions, the performance measures, and the type of expected results.

Step 2: Configuring and Running Simulation

This step implements the design in the first step. It consists of two phases:

• Network configuration phase: In this phase network components (node, TCP and UDP) are created and configured according to the simulation design. Also, the events such as data transfer are scheduled to start at a certain time.

• *Simulation Phase*: This phase starts the simulation which was configured in the Network Configuration Phase. It maintains the simulation clock and executes events chronologically. This phase usually runs until the simulation clock reached a threshold value specified in the Network Configuration Phase.

In most cases, it is convenient to define a simulation scenario in a Tcl scripting file (e.g., <file>) and feed the file as an input argument of an NS2 invocation (e.g., executing “ns <file>”).

Step 3: Post Simulation Processing

The main tasks in this steps include verifying the integrity of the program and evaluating the performance of the simulated network. While the first task is referred to as *debugging*, the second one is achieved by properly collecting and compiling simulation results .

Model parameters

Here, we specified the model state variables used to describe the abstracted environment in the NS2.

These are:

a) Bandwidth

In this study, it is believed that the bandwidth will be allocated sufficiently to meet the required transmission capacity. In networking, the transmission capacity of a computer or a communication channel is measured in megabits per second (Mbps)

Bandwidth = Packet size / time interval (1)

b) Throughput

This is a measure of the data-transfer rate through a complex communication or networking scheme. Throughput is considered as an indication of the overall performance of the system. In communications, throughput is usually measured as the number of bits or packets processed each second. For the purpose of this work, we used number of packets.

Throughput= Packet (Mb) / time (s) (2)

Dropped Packets:

The data packets that fail to reach sink due to congestion during transmission are dropped packets. The number of dropped packets, with respect to the change in sensor reporting interval and the average of dropped packets at all nodes are considered in this work. In a better congestion control algorithm the count of dropped packets is significantly low.

End to End Delay (E2E) :

EED is the cumulative delay that might come about as a result of buffering during discovery of routes over sensor network, queuing at interfaces of the sensor nodes, delays in retransmission at the MAC, and the time taken for propagation and transfer over the sensor field. where -the time that data packet n was sent -the time that data packet n was received and - the total number of data packets received

IV. Simulation Tools

The simulation were performed using Network simulator 2 (NS-2.34), particularly popular in the field of networking community. The traffic sources are FTP (File Transfer Protocol). The source-destination pair are spread randomly over the network. The model parameters that have been used in the project are listed below.

Simulation Parameter	Value
Simulator	NS2
Simulation Time	150 Seconds
Simulation Area	350m x 350m
Examined routing protocol	DSDV, DSR, TORA, AODV
Number of Mesh Routers	256
Number of source	252
Number of destination	4
Pause time	10s
Mac Type	Mac/802_11
Traffic control protocol	TCP
Channel type	Wireless Channel

Table 1: Simulation parameter and values

This process repeats throughout the simulation, causes continuous changes in the topology of the underlying network. Different network scenario for different number of nodes and packet size to find the changes is parameters.

V. Result and Discussion

The below figure 2, shows the packet transmission from the source node to the destination node. Here all nodes are connected using wireless connection.

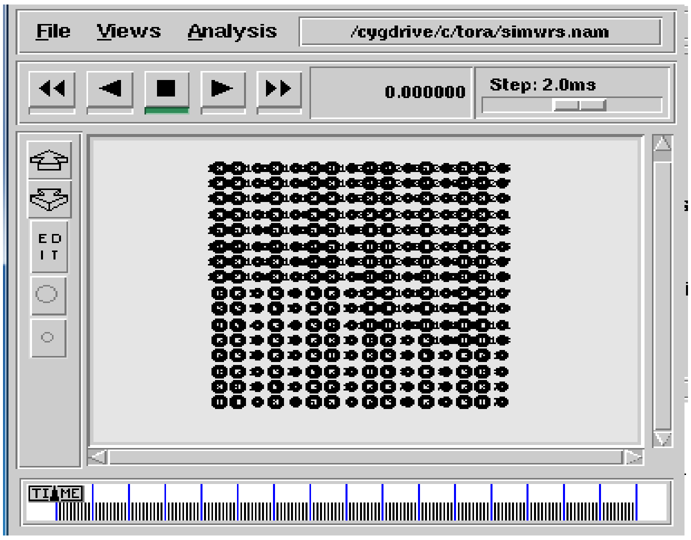


Fig.2: packet transmission from the source node to the destination node

Here in Figure 3. we show the Throughputs versus Number of nodes where DSDV gives high throughput at higher loads and TORA gives low throughputs. DSDV and DSR gives moderate throughput.

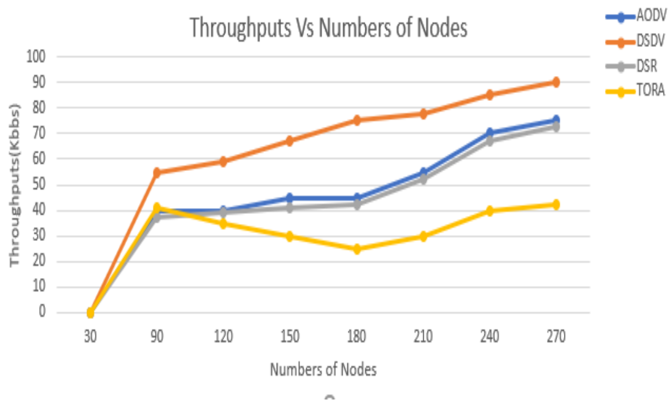


Fig.3: Throughputs Vs Number of Nodes

Here in Figure 4. we show the Average End to End Delay versus Number of nodes at High load conditions where AODV gives low End to End Delay at higher load conditions and TORA and DSDV gives high End to End Delay respectively.

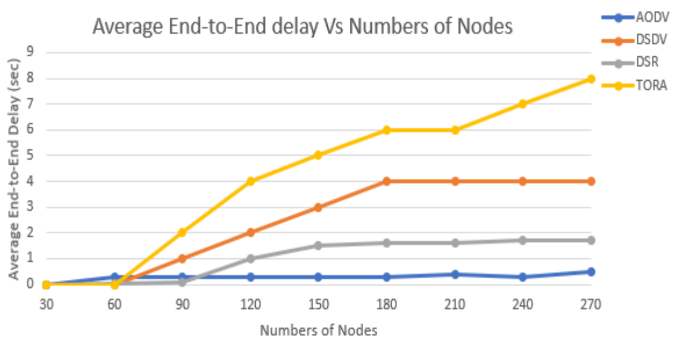


Fig.4: Average End to End Delay Vs Number of Nodes at High load conditions

Here in Figure 5. we show the Average End to End Delay versus Number of nodes at Low load conditions where DSR gives low End to End Delay at lower load conditions and TORA and DSDV gives high End to End Delay respectively. AODV gives Moderate End to End delay at low Conditions and also gives high throughput.

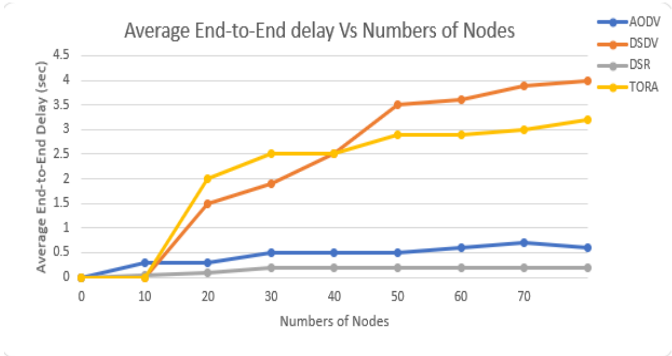


Fig.5: Average End to End Delay Vs Number of Nodes at Low load conditions

Here in Figure 6. we show the Average Packet loss (%) versus Number of nodes at high mobility conditions where DSDV gives low Average Packet loss at higher mobility conditions and DSR and TORA gives high Average Packet loss respectively.

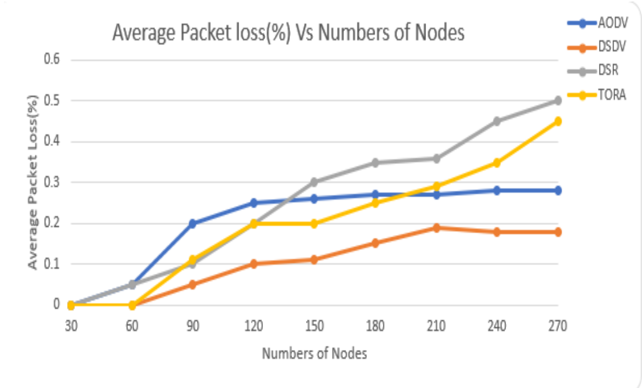


Fig.6: Average Packet loss Vs Number of Nodes at High Mobility conditions

Here in Figure 7. we show the Average Packet loss (%) versus Number of nodes at Low mobility conditions where AODV gives low Average Packet loss at Lower mobility conditions and DSR and TORA gives high Average Packet loss respectively.

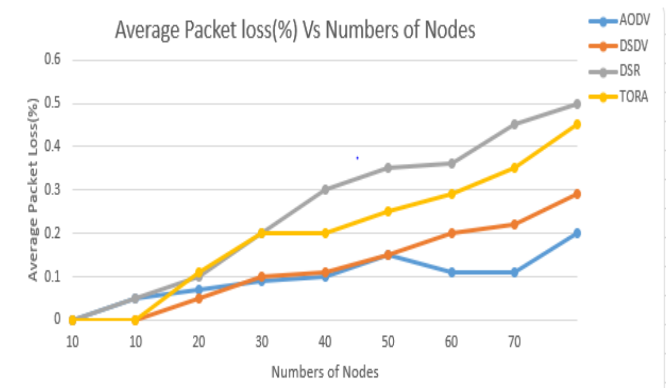


Fig.7: Average Packet loss Vs Number of Nodes at Low Mobility conditions

VI. CONCLUSION

We have successfully compared the performance metrics of the routing protocols: AODV, DSDV, DSR, TORA. Different protocols gives good results at different conditions. From the NS-2 simulation, we have performed, in the case of wireless mesh networks, DSDV gives high throughput at higher loads. DSR and AODV gives low end-end delay at lesser load and higher load condition respectively. At lower mobility conditions AODV experiences lesser packet loss, while at higher mobility conditions DSDV performs better. In the case of Adhoc networks, the throughput performance is better with DSR. Almost all the protocols exhibit same end to end delay at lower bit error rates , while AODV performs well at higher bit error rates. When the number of nodes in the network increases DSDV performs better, while AODV performs well at lesser congested networks.

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