Research on Implementation and Comparison of Routing Protocols in MANET Using NS2

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Abstract: ***A Mobile Ad hoc Network (MANET) is a type of temporary computer-to-computer connection. In Ad hoc mode, you can set up a wireless connection directly to another computer without having to connect a wireless access point or router. Ad hoc networks are useful when you need to share files or other data directly with another computer but don't have access to a wireless network. Mobile Ad-hoc wireless networks holds the promise of the future, with the capability establish networks at anytime, anywhere. The Efficient routing protocols can provide significant benefits to Mobile Ad hoc Networks, in terms of both performance and reliability. Many routing protocols for such networks have been proposed so far. Among the most popular ones are Ad hoc On-demand Distance Vector (AODV), Dynamic Source Routing Protocol (DSR) and Destination-Sequenced Distance-Vector Routing protocol (DSDV). This paper presents a research on implementation and comparison of wireless routing protocols AODV, DSR and DSDV based on metrics such as throughput, packet delivery ratio and average end-to-end delay by using the NS-2 simulator.***

Keywords: MANET, Throughput, Packet Delivery Ratio, End-to-End delay.

1. Introduction

The Mobile Ad hoc Networks (MANET) or infrastructure less networks is a collection of mobile nodes which forms a temporary network without the aid of centralized administration or standard support devices regularly available unconventional networks. Mobile Ad hoc Networks are wireless networks which do not require any infrastructure support for transferring data packet between two nodes. In these Networks, nodes work as a router and it is the route packet for other nodes. Nodes are free to move, independent of each other, topology of such networks keep on changing dynamically which makes routing much difficult. Therefore routing is one of the most concern areas in these networks. Normal routing protocol which works well in fixed networks does not show same performance in Mobile Ad hoc Networks. In these networks routing protocols should be more dynamic so that they quickly respond to topological changes. There is a lot of work done on evaluating performances of various MANET routing protocols AODV, DSR and DSDV based on metrics such as Throughput, Packet Delivery Ratio and End-to-End delay by using the NS-2 simulator. Our study has shown that reactive protocols perform better than proactive. The DSR has performed better than AODV in terms of Delivery Ratio and Routing Overload while AODV performed better in terms of Average Delay. The rest of this paper is organized as follows. We can briefly describe the routing protocols that we evaluate. We discuss the most important previous studies on the subject and explain our work and present the Simulation environment.

1.1 Classification of routing protocols in MANETs

It can be done in many ways, but most of them are depending on routing strategy and network structure. According to the routing strategy, the routing protocols can be categorized as proactive and reactive routing protocols as shown Figure 1 while depending on the network structure they are classified as Flat, Hierarchical and Position Based routing. Both the Proactive and Reactive protocols come under the flat routing.

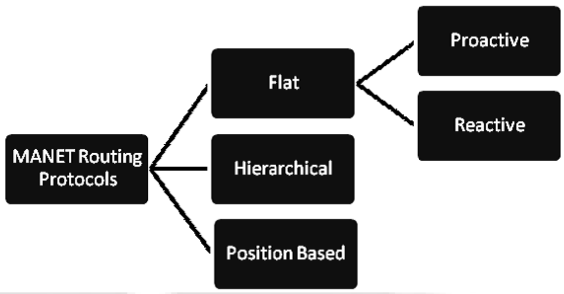

Figure 1: Classification of MANET routing protocols

2. MANET Routing Protocols

2.1 Flat Routing Protocols

In this routing protocol can be classified into two categories:

- Proactive Routing Protocols
- Reactive Routing Protocols

2.1.1 Proactive Routing Protocols

A proactive routing protocol is also called "Table-Driven" routing protocol. By using a proactive routing protocol, nodes in a Mobile Ad hoc Network continuously evaluate routes to all reachable nodes and attempt to maintain consistent, up-to-date routing information. Therefore, a source node can get routing path immediately if it needs one. When a network topology change occurs, respective updates must be propagated throughout the network to notify the change. So if a network topology changes in MANETs, the control overhead to maintain up-to-date network topology information is relatively high. Wireless Routing Protocol (WRP), the Destination Sequence Distance Vector (DSDV) and the Fisheye State Routing (FSR) are examples for proactive routing protocols.

2.1.2 Reactive Routing Protocol

Reactive routing protocols for Mobile Ad hoc Networks are also called "On-Demand" routing protocols. In a reactive routing protocol, routing paths are searched only when needed. When a source node wants to send packets to the destination when route is not available, it initiates a route discovery operation. In the route discovery operation, the source broadcasts Route Request (RREQ) packet. When the destination or a node that has a route to the destination receives the RREQ packet, a Route Reply (RREP) packet is created and forwarded back to the source. Each node usually uses hello messages to notify its existence to its neighbours. Therefore, the link status to the next hop in an active route can be monitored. When a node discovers a link disconnection, it broadcasts a Route Error (RERR) packet to its neighbours, which in turn propagates the RERR packet towards nodes whose routes may be affected by the disconnected link. Then, the affected source can re-initiate a route discovery operation if the route is still needed.

Compared to the proactive routing protocols, less control overhead is a distinct advantage of the reactive routing protocols. Thus, reactive routing protocols have better scalability than proactive routing protocols. However, when using reactive routing protocols, source nodes may suffer from long delays for route searching before they can forward data packets. Hence these protocols are not suitable for real – time applications. The Dynamic Source Routing (DSR) and Ad hoc On-demand Distance Vector routing (AODV) are examples for reactive routing protocols.

2.2 Hierarchical Routing Protocols

Typically, when wireless network size increase (beyond certain thresholds), current "Flat" routing schemes become infeasible because of link and processing overhead. One way to solve this problem and to produce scalable and efficient solutions is hierarchical routing. Wireless hierarchical routing is based on the idea of organizing nodes in groups and then assigning nodes different functionalities inside and outside of a group. The Zone Routing Protocol (ZRP), Zone based Hierarchical Link State Routing Protocol (ZHLSRP) and Hybrid Ad hoc Routing Protocol (HARP) are examples for hybrid routing protocols.

2.3 Position Based Routing Protocols

The advances in the development of Global Positioning System (GPS) nowadays make it possible to provide location information with a precision in the order of a few meters. It can also provide universal timing, while location information can be used for directional routing in distributed Ad hoc systems, the universal clock can provide global synchronizing among GPS equipped nodes. In position based routing protocols, instead of using routing tables and network addresses, the routing decisions are on the basis of the current position of the source and the destination nodes. Location Aided Routing (LAR) and Distance Routing Effect Algorithm for Mobility (DREAM) are typical position based routing protocols proposed for Mobile Ad hoc Networks. According to several experimental works, routing schemes that use positional information scale well.

In the routing protocols, the robustness of the route is generally not involved as a requirement for its selection. Consequently, route breakups will frequently occur induced by nodal mobility or nodal link failures as well as by fluctuations in the communications transport quality experienced across the network's communications links. The later are caused by signal interferences, fading and multi path phenomena and other causes producing ambient and environmental noise and signal interference processes. On the other hand, route breakups lead the frequent operation of rebuilding routes that consume lots of the network resources and the energy of nodes.

3. Wireless Ad Hoc Routing Protocols

In this section we briefly describe the protocols that we investigate. A detailed discussion and comparison of most popular Wireless Ad hoc routing algorithms is available in.

3.1 AODV Protocol

AODV is an improvement of DSDV protocol described below. It reduces number of broadcast by creating routes on demand basis, as against DSDV that maintains mutes to each known destination. When source requires sending data to a destination and if route to that destination is not known then it initiates route of discovery. AODV allows nodes to respond to link breakages and changes in network topology in a timely manner. Routes, which are not in use for long time, are deleted from the table. Also AODV uses Destination Sequence Numbers to avoid loop formation and Count to Infinity Problem.

An important feature of AODV is the maintenance of timer based states in each node, regarding utilization of individual routing table entries. A routing table entry is expired if not used recently. A set of predecessor nodes is maintained for each routing table entry, indicating the set of neighboring nodes which use that entry to route data packets. These nodes are notified with RERR (Request Error) packets when the next-hop link breaks. Each predecessor node, in turn, forwards the RERR (Request Error) to its own set of predecessors, thus effectively erasing all routes using the broken link. Route Error propagation in AODV can be visualized conceptually as a tree whose root is the node at the point of failure and all sources using the failed link as the leaves.

3.2 DSR Protocol

The DSR is a simple and efficient routing protocol designed specifically for use in multi-hop Wireless Ad hoc Networks of mobile nodes. DSR allows the network to be completely self-organizing and self-configuring, without the need for any existing network infrastructure or administration. The protocol is composed of the two main mechanisms of "Route Discovery" and "Route Maintenance", which work together to allow nodes to discover and maintain routes to arbitrary destinations in the Ad hoc Network All aspects of the protocol operate entirely on DSR protocol include easily guaranteed Loop-Free Routing, operation in networks containing unidirectional links, use of only "soft state" in routing, and very rapid recovery when routes in the network change. In DSR, Route Discovery and Route Maintenance each operate entirely "On Demand". Unlike other protocols, DSR requires no periodic packets of any kind at any layer within the network. For example, DSR does not use any periodic routing advertisement, link status sensing, or neighbor detection packets, and does not rely on these functions from any underlying protocols in the network. This entirely on demand behavior and lack of periodic activity allows the number of overhead packets caused by DSR to scale all the way down to zero, when all nodes are approximately stationary with respect to each other and all routes needed for current communication have already been discovered.

The sender of a packet selects and controls the route used for its own packets, which together with support for multiple routes also allows features such as load balancing to be defined. In addition, all routes used are easily guaranteed to be loop-free, since the sender can avoid duplicate hops in the routes selected. The operation of both Route Discovery and Route Maintenance in DSR are designed to allow unidirectional links and asymmetric routes to be supported.

3.3 DSDV Protocol

The DSDV described is a table-driven proactive protocol, based on the classical Bellman-Ford Routing Mechanism. The basic improvements made include freedom from loops in routing tables, more dynamic and less convergence time. Every node in the MANET maintains a routing table which contains list of all known destination nodes within the network along with number of hops required to reach to particular node. Each entry is marked with a sequence number assigned by the destination node. The sequence numbers are used to identify stale routes thus avoiding formation of loops. To maintain consistency in routing table data in a continuously varying topology, routing table updates are broadcasted to neighbor's periodically or when significant new information is available. In addition to the time difference between arrival of first and arrival of the best route to a destination is also stored, so that advertising of routes, which are likely to change soon, can be delayed. Thus avoiding the advertisement of routes, which are not stabilized yet, so as to avoid rebroadcast of route entries that arrive with node is supposed to keep the track of settling time for each route, so that fluctuations can be damped by delaying advertisement of new route to already known as reachable destination thus reducing traffic. Fluctuating routes occurs as a node may always receive two routes to a destination with same sequence number but one with better metric later. But new routes received which take to a previously unreachable node must be advertised soon. Mobiles also keep track of the settling time of routes, or the weighted average time that routes to a destination will fluctuate before the route with the best metric is received. By delaying the broadcast of a routing update by the length of the settling time, mobiles can reduce network traffic and optimize routes by eliminating those broadcasts that would occur if a better route was discovered in the very near future.

4. Simulation Tool (Network Simulator 2)

After setting up the platform, software named NS2 was set up on it which was used for all the analysis and simulation work apart from other tools used. NS2 is the de facto standard for network simulation. Its behavior is highly trusted within the networking community. It is developed at ISI, California, and is supported by the DARPA and NSF. NS2 is an object oriented simulator, written in C++, with an OTcl interpreter as a frontend. This means that most of the simulation scripts are created in Tcl. If the components have to be developed for NS2, then both Tcl and C++ have to be used. NS2 uses two languages because any network simulator, in general, has two different kinds of things it needs to do. On the one hand, detailed simulations of protocols require a systems programming language which can efficiently manipulate bytes, packet headers, and implement algorithms that run over large data sets. For these tasks run-time speed is important and turn-around time (run simulation, find bug, fix bug, recompile, re-run) is less important. On the other hand, a large part of network research involves slightly varying parameters or configurations, or quickly exploring a number of scenarios. In these cases, iteration time (change the model and re-run) is more important. Since configuration runs once (at the beginning of the simulation), run-time of this part of the task is less important. NS2 need two languages, such as C++ and OTcl. C++ is fast to run but slower to change, making it suitable for detailed protocol implementation. OTcl runs much slower but can be changed very quickly and interactively, making it ideal for simulation configuration.

The simulator supports a class hierarchy in C++, and a similar class hierarchy within the OTcl interpreter. The two hierarchies are closely related to each other; from the user's perspective, there is a one-to-one correspondence between a class in the interpreted hierarchy and one in the compiled hierarchy. The root of this hierarchy is the class TclObject. Users create new simulator objects through the interpreter; these objects are instantiated within the interpreter, and are closely mirrored by a corresponding object in the compiled hierarchy. The interpreted class hierarchy is automatically established through methods defined in the class TclClass. User instantiated objects are mirrored through methods defined in the class TclObject. There are other hierarchies in the C++ code and OTcl scripts; these other hierarchies are not mirrored in the manner of TclObject.

4.1 Network Animator (NAM)

NAM is a Tcl/TK based animation tool for viewing network simulation traces and real world packet trace data. The first step to use NAM is to produce the trace file. The trace file should contain topology information, e.g., nodes, links, as well as packet traces. Usually, the trace file is generated by NS2. During NS2 emulation, user can produce topology configurations, layout information, and packet traces using tracing events in NS2. When the trace file is generated, it is ready to be animated by NAM. Upon startup, NAM will read the trace file, create topology, pop up a window, do layout if necessary and then pause at the time of the first packet in the trace file. Through its user interface, NAM provides control over many aspects of animation.

4.2 Trace Graph

Trace graph is a free tool for analyzing the trace files generated by NS2. Trace graph can support any trace format if converted to its own or NS2 trace format. Trace graph runs under Windows, Linux, UNIX and MAC OS systems.

Some of the program features are as follows:

1. 238 2D graphs: Trace graph supports drawing 238 different graphs depending upon different parameters in 2 Dimensional areas.
2. 12 3D graphs: Trace graph supports 12 graphs in 3 Dimensions.
3. Delays, Jitter, processing times, round trip times, throughput graphs and statistics can be plotted with the help of Trace graph. These are described below:
   a. Delay: This is the delay encountered between the sending and receiving of the packet.
   b. Jitter: This is the unwanted variation in the output.
   c. Processing Time: The time it takes for a node to process the input.
   d. Round Trip Time: The time required for a signal pulse to travel from a specific source to a specific destination and back again.
4. Whole network, link and node graphs and statistics.
5. All the results can be saved to text files, graphs can also be saved as jpeg and Tiff any graph saved in text file with 2 or 3 columns can be plotted Script files processing to do the analysis automatically.

The program does have some disadvantages though, such as it hangs or takes a very long time while trying to open large trace files. Also it sometimes hangs after displaying the graph in 3D. The reason why this tool was used in the simulation work is that there are not too many graph plotting tools available in the market. Further, it is free and open source and it doesn't have a steep learning curve.

4.3 Simulation Result and Analysis

The simulations were performed using Network Simulator (Ns-2), which is popularly used for Ad hoc Networking community. The routing protocols were compared based on the following 3 performance metrics:

a. **Packet Delivery Fraction (PDF)**: The ratio of Data packets delivered to those generated by the sources both (Sending and Receiving Throughput bit).

b. **Routing Load (Simulation Time)**: The time taken by Routing and Delivered packet to reach its destination.
c. **End to End delay**: Delay in delivering a packet to the destination which is inclusive of all kinds of delay.

4.3.1 AODV

AODV (Ad Hoc On-Demand Distance Vector) is a reactive routing protocol that discovers route on a demand basis, reducing the unneeded propagation of routing information. In order to discover a route to a destination, the source node broadcasts a route request package (RREQ) to all neighbors, which in turn record the sending address and forward the package to their neighbors. Such a process continues until the route request package reaching the destination or an intermediate node with a fresh enough route to the destination. The sending address is used to thereby establish a reverse path. Like DSDV, AODV uses a sequence number that distinguishes obsolete routes from new ones and avoids the occurrence of routing loops.

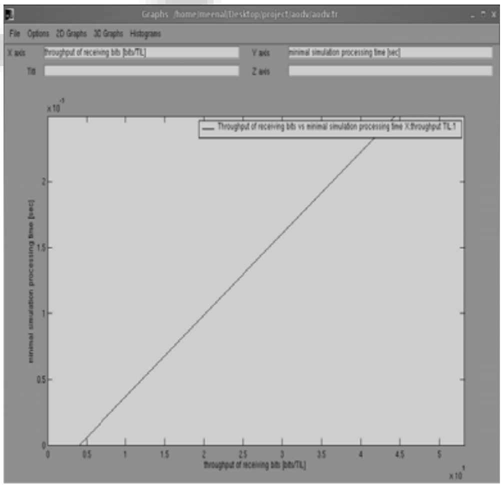

Figure 2: Throughput of Receiving Data (AODV)

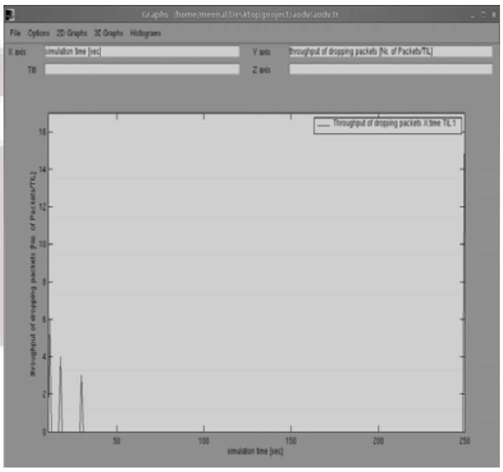

Figure 3: Simulation time (AODV)

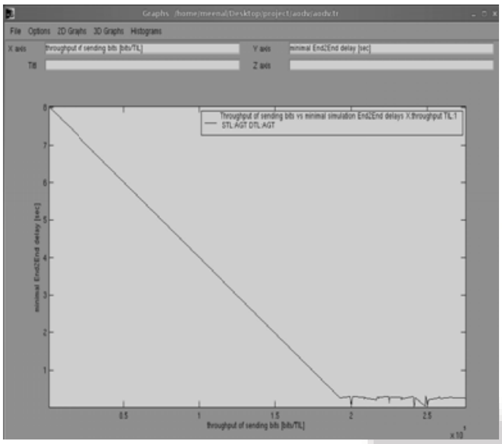

Figure 4: End – to – End delay (AODV)

4.3.2 DSR (Dynamic Source Routing)

DSR is a reactive protocol that explores the concept of source routing, in which the sequence of nodes composing a route ism informed in the header of each packet. Hence, the source node ought to know the complete route to destination nodes. All nodes maintain a route cache that contains previously identified routes.

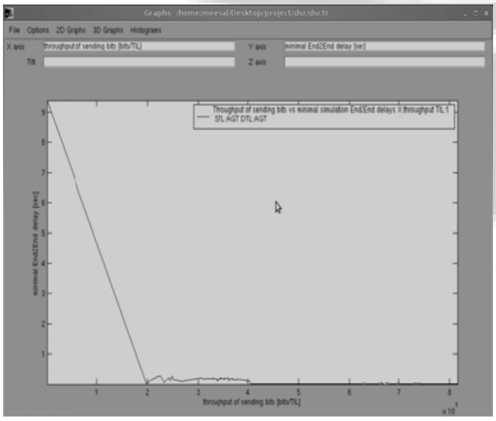

Figure 5: Throughput of Receiving Data (DSR)

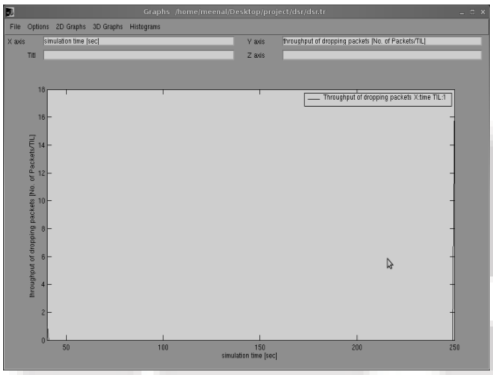

Figure 6: Simulation Time(DSR)

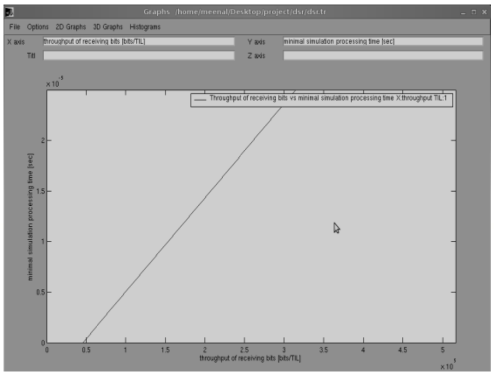

Figure 7: End – to – End delay (DSR)

4.3.3 DSDV (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. Routing information is distributed between nodes by sending full dumps infrequently and smaller incremental updates more frequently.

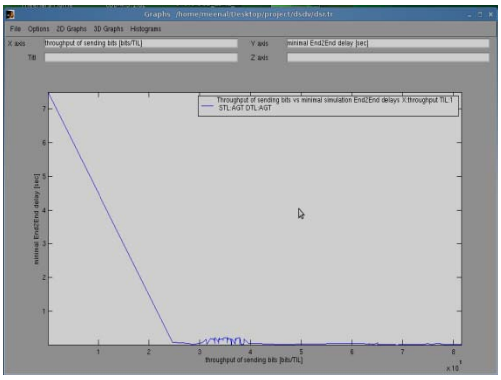

Figure 8: Throughput of Receiving Data (DSDV)

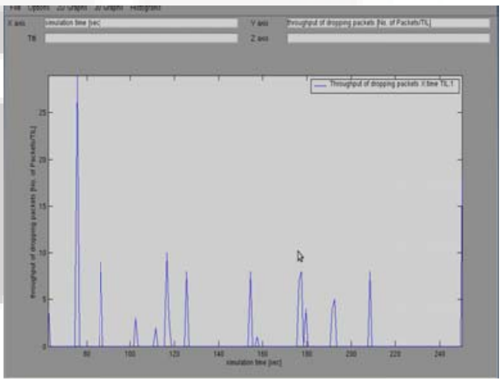

Figure 9: Simulation Time (DSDV)

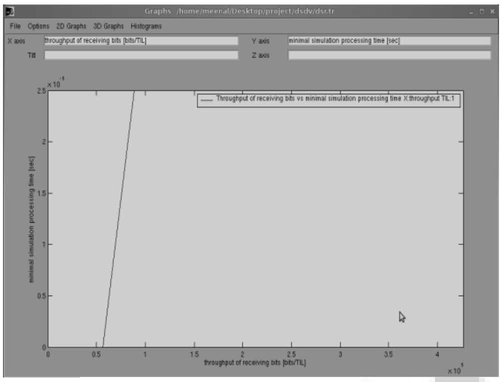

Figure 10: End to End Delivery (DSDV)

4.4 Comparison of Packet Delivery Ratio (PDR)

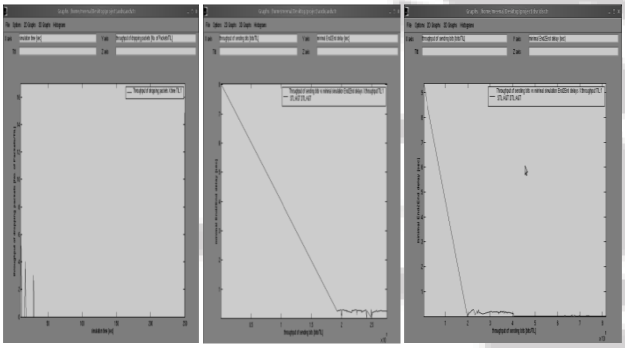

Figure 11: PDR in AODV, DSR and DSDV Protocol

5. Comparison Result

Table 1: Comparison of AODV, DSR and DSDV

Metrics	*AODV*	*DSR*	*DSDV*
Throughput	Medium	Low	High
Packet Delivery Ratio	High	Medium	Low
End to End Delay	Low(<2)	Medium(2)	High(>2)

6. Results and Discussion

Our simulation has compared and identifies which one is exhibiting less packet loss among AODV, DSR protocol which belongs to Reactive protocols family and DSDV protocol which is a table-driven proactive protocol. In this paper, the performance of the three MANET Routing protocols such as AODV, DSR and DSDV was analyzed using NS-2 Simulator. We have done comprehensive simulation results of Throughput, Packet Delivery Ratio and End-to-End Delay over the routing protocols by varying network size, simulation time. DSDV is suitable for limited number of nodes with low mobility due to the storage of routing information in the routing table at each node. Comparing DSR with DSDV and AODV protocol, byte overhead in each packet will increase whenever network topology changes. Since DSR protocol uses source routing and route cache. As AODV routing protocol needs to find route by on demand, End-to-End delay will be lower than other protocols. DSDV produces high end-to-end delay compared to other protocols. Finally, comparing the above three routing protocols, DSR is preferable for moderate traffic with moderate mobility.

7. Conclusion

The wireless routing protocols AODV, DSR and DSDV based on metrics such as Throughput, Packet Delivery Ratio and End-to-End Delay provides a classification of these schemes according to the routing strategy (i.e., Table-Driven and On-Demand). We have presented a comparison of these two categories of routing protocols, highlighting their features, differences, and characteristics. Finally, we have identified possible applications and challenges facing Mobile Ad-hoc Wireless Networks.

8. Acknowledgement

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