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Performance evaluation of two on-demand routing protocols using three different entity based mobility models

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Abstract

Different wireless mobile nodes form a network that is developed purely on temporary basis and therefore it is named as Mobile Adhoc Network or MANET. A MANET faces many issues and challenges because of its Adhoc nature. An important issue/challenge among those challenges that a MANET faces is continuously changing topology. This continuously changing topology further arises two big issues. The first one is selecting an efficient and reliable routing protocol and the second one is selecting a suitable and appropriate mobility model.

This research work has explored the behavior of AODV and DSR (Two On-Demand Routing Protocols) against three different entity based mobility models; Random Waypoint, Random Walk and Random Direction Mobility Models. This performance exploration was conducted regarding four routing performance metrics; Packet Success Percentage (PSP), Average End to End Delay (AED), Normalized Control Load (NCL) and Throughput. Experiments concluded that performance of AODV was excellent in terms of Packet Success Percentage (PSP) and Average End to End Delay (AED) while using Random Waypoint and Random Walk mobility models. In some cases (Scenarios) DSR performed well in terms of Throughput and Normalized Control Load (NCL) along with RWP and RW mobility models. But the performance of DSR was very much fluctuating and poor while using RD model.

Overall performance graph of AODV remained much higher than DSR while using any one of the three selected mobility models. This research work also explored that in comparison with Random Direction mobility model, Random Waypoint and Random Walk mobility models produced excellent results along with AODV, regarding all the selected parameters.

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Introduction to Ad hoc Networks

An Adhoc network (formerly named packet radio network) is a combination of different wireless nodes. These wireless nodes make communication with each other over multihop wireless links. These nodes are situated within a simulation area that has some boundary. Each and every node behaves likewise a router because Adhoc network has no concept of stationary base station. Topology table is maintained by each and every node on the basis of which a routing table is created and maintained. For the purpose of maintaining coverage and connectivity, each and every node retains a specific radio range. Nodes can only communicate within the radio ranges of each other. Connectivity looses when two mobile nodes get out of radio range of each other. A MANET is an important form of Adhoc network and it is a self configuring network of wireless mobile nodes. MANETs are formed on temporary basis and are established without any predefined infrastructure and are famous in conferencing areas, disaster hit areas and battlefield grounds and for the

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rescue operations. No centralized administration is present here and no stand alone infrastructure exists for MANETs. Topology changes occur continuously. MANETs are very easy to deploy. As topology changes occur continuously and frequently, so, For MANETs efficient routing protocols play important role. Routing in MANETs is a complex and challenging issue. The selection of a suitable routing protocol within the simulation area is a very tough task due to high mobility and on-the-fly behavior of MANETs. Arrangement and movement of nodes badly affects the performance of the routing protocols. Therefore the selection of an appropriate mobility model is another challenging issue for MANETs.

Classification of Routing in MANET

In MANETS routing is another big and challenging issue. As topology changes rapidly and dynamically therefore it is very difficult to select a suitable routing protocol and also it is very difficult to select the best route for data transmission. Routing is also difficult because of the low and poor quality links that are bandwidth-constrained. Also routing is a big challenge because nodes have limited energy or low battery time. Many suggestions and solutions are given to solve these problems and to make the routing more effective in MANETs. It is not required that a routing protocol should have all the qualities to solve all the routing problems stated formerly. It is very much difficult to develop such a routing protocol having ability to solve all the problems. Each routing protocols works according to the situation for which it is actually designed. Presently MANET Routing protocols are categorized into the following five broader categories: Proactive, Reactive, Hybrid, Hierarchical and Geographical Assisted Routing protocols.

Reactive or On-Demand Ad hoc Routing Protocols

Ad hoc On-demand Distance Vector Routing (AODV)

AODV (Ad hoc On-demand Distance Vector Routing) is an important reactive routing protocol which is basically design on the algorithm of DSDV. In other words AODV is an improved or advancement of DSDV. Basically AODV creates route when a demand is present therefore number of broadcasts are minimized by it. But AODV does not behave like DSDV although AODV is an advancement of DSDV. On the other side DSDV maintains a list of all the routes completely. AODV routing protocol performs in such a way that if a source node that is willing to reach the destination sends a route request by flooding the entire network with the packets of Route Request (RREQ) in searching for all possible or available routes that are leading to the destination. When an intermediate node receives a RREQ (Route Request), this intermediate node checks the early existence of the reverse entry (for source node) for the destination. If reverse entry is not present and it is a new RREQ then this intermediate node creates a reverse routing entry for the source. If a reverse entry exists already, this intermediate node generates a Route Reply (RREP) packet and then unicast that RREP (Route Reply) packet back to the source along with the reverse route RREQ. If a RREQ already exists with this intermediate node then this node rebroadcasts the first one received RREQ and deletes the duplicate RREQs. When the first RREQ or a RREQ that came from a smaller or shorter route and reaches to the destination node then the destination node sends a RREP (Route Reply) back to the source node. Upon receiving the RREPs all the nodes (along with this newly discovered route) create forward routing entries for the destination node. To prevent from looping problems control packets and routing entries include Source and destination sequence numbers. A Route entry is deleted from the routing table if that is not used for a long time, for the purpose of making space for active or new entries. Requirement of AODV is that all nodes must reserve a big enough memory space for the storage of possible Routing entries for active or new senders and receivers. Network latency is very high while using AODV because routes are established or formed on demand. (Singh *et al.,* 2012)

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Dynamic Source Routing Protocol (DSR)

DSR is basically a source routing protocol. Here a complete path is created on demand basis but whole path to the destination node is specified by the source node. Packet header stores this path information. Each and every intermediate node just passes on that packet to the next node as stated in the path information contained in the packet header. DSR offers the facility of Route Cache. It means that DSR offers to use the last or previously established (used/discovered) routes because it has the capability to save the previously established/discovered routes. A source node, before transmission, checks its route cache to find out whether it has an already used path to the destination or not. Now if a previously used path is present (available) in its cache then the source node uses that path for data transmission to the desired destination node. But if no previously used route to the destination founded then the source node tries to discover a new suitable path to the destination with the help of route discovering protocol. Whenever there a need arises then a source node checks the route.

Route discovery process in DSR is done in the following way. A source node sends a query packet by flooding the whole network. The node that may complete this route query packet or Route Request (RREQ), answers back to the source node in the form of Route Reply (RREP). The replying node may be the desired destination node or may be any intermediate node that may complete the route request from its route cache. Every Route Request packet has a specific identification and an empty list along with it. When a node receives the RREQ it checks the specific identification of that RREQ, whether it is a new RREQ or not. The node also checks that whether this RREQ includes the address of this node in its list or not. After checking the node deletes the duplicate RREQs stops forwarding the RREQ. If the RREQ is fresh then this node attaches it address along with the list present in the RREQ and forwards the RREQ to its neighboring nodes. If the route cache of a node fulfils the RREQ coming from a source node, then this node replies to the source node with the help of a route reply packet and stops forwarding that RREQ. All the intermediate nodes involved in the process of path finding, store the information (related to different paths/routes) into their route cache. Internet's ARP (Address Resolution Protocol) works in the similar way to find out the routes. But the only difference is that requests of ARP are not forwarded beyond a router.

As nodes are mobile and moving here and there so failure of a route can take place. Link-level protocol can find out the failure of a route with the help of hop-by-hop acknowledgements. Route failure can also be identified if some neighbor is not broadcasting for some time. The node which detects the failure of route broadcasts an error message in the form of error packet to the source node. The source node again repeats the process of route discovery with the help of route discovery protocol for finding a new path. It is important to know that to maintain the route DSR do not uses the control packets which are periodically sent. (Singh *et al.,* 2012).

Introduction to Entity based Mobility Models

Node's mobility pattern is a big problematic thing in MANETs. It is an important factor in MANETs that how the movement of nodes should be? Mobility pattern of a node is concerned with speed, direction and rate of change. As in physical world or in real world mobility cannot be predicted. In real world mobility is often unrepeatable. Mobility affects the routing protocols developed for the support of movement of nodes. Therefore for the simulation of new protocols many different "Synthetic" types of mobility models have been introduced and suggested. These Synthetic mobility models represent the movement of nodes in a realistic way, but they do not use traces of the network (Camp *et al*., 2002).

Three important entity based mobility models selected were; Random Waypoint Model, Random Direction Model and Random Walk Model.

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Random Waypoint Model (RWP)

The main and important feature of Random Waypoint Mobility Model is that it includes a pause time when a change occurs in speed and direction.

Using RWP mobility model, if a mobile node wants to choose another speed and direction then it must have to wait for some period of time. This period of time is called pause time. In RWP mobility model after the end of pause time a mobile node selects a new random direction with in the boundary of the area of simulation. After completing the pause time the mobile node also chooses a uniform speed between (Minimum speed, Maximum speed). After the selection of new speed and direction this mobile node moves toward the selected destination. When the mobile node reaches to the destination it stops and waits for a specific period of time to take start again the whole procedure towards new destination. (Camp *et al.,* 2002)

Central area of simulation is highly dense in RWP mobility model when simulation starts but with the passage of time mobile nodes are dispersed to the boundary of the simulation area. RWP mobility model behaves like Random Walk mobility model when the pause time becomes zero. Another important characteristic of RWP is suddenly stop and start. RWP is suitable in urban areas and it is used mostly. The main disadvantage of RWP is that it creates density waves as central area of simulation is highly dense in RWP at the start of simulation.

Random Direction Model

To overcome the density waves generated in RWP mobility model a new mobility model came into being named as Random Direction mobility model. Density waves are generated by the group of nodes that are gathered in the form of a cluster in a place within the boundary of simulation area. In RWP this gathering of nodes or clustering occurs in the central area of simulation. Here in Random Direction Mobility Model a Mobile Node selects a direction randomly in which it starts travelling same like in Random Walk Mobility Model. The Mobile Node then goes to the boundary of area of simulation as per selected direction. When this Mobile Node reaches to the border of the area of simulation it becomes paused for some time (pause time). After the pause time it selects the new direction between 0 and 360 degrees and the procedure goes on. (Camp *et al.,* 2002).

Random Walk Model

Einstein firstly had given the mathematical form to the Random Direction Mobility Model in 1926. This mobility models was designed to overcome the Brownian and unpredictable movement of real world. As in real world objects, by nature, move in an unpredictable way. Random Walk Mobility Model tries to overcome this unpredictable movement of objects. Here in Random Walk Mobility Model, a Mobile Node starts movement from its present position towards a new position by the random selection of speed and direction in which it wants to travel. The new random speed is selected between (Minimum speed, Maximum speed) and new random direction is selected between (0, 2π). In Random Walk Mobility Model every move takes place with respect to a constant distance covered “d” and with respect to a constant time period “t” and after the completion of one move new speed and directions are selected. No pause time is taken in Random Walk Mobility Model. The main disadvantage of Random Direction Mobility Model is that it contains no information about the previous moves. (Camp *et al.,* 2002).

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Tools used

NS-2 (Network Simulator -2)

Network simulator is basically used for the purpose of research work in the field of networking. Network simulator plays an important role in simulation of routing protocols and mobility models. Code of Network simulator-2 is written in C++ programming language and with an object oriented version of Transmission Control Language (TCL, known as OTCL).

NS-2 was developed by Monarch research group in Carnegie Mellon University (CMU) for the simulation of multi-hop wireless networks. Installation of NS-2 includes all the software extensions needed in simulation.

MS-EXCEL (Microsoft Excel)

Microsoft Excel is a tool offered by the Microsoft office. It is a powerful spreadsheet that is used to store, manipulate, analyze and visualize data. It can be used to visualize data in the form of graphs and charts. It has the capability to take data in the form of figures and convert that data into graphs and charts.

AWK Language

AWK is a powerful programming language developed in 1970s at Bell Labs. It was basically designed to process data that is in the form of text. The text may be in the form of data streams or in the form of files and figures. As it was created by Alfred Aho, Peter Weinberger, and Brian Kernighan so its name became AWK. An AWK program is very different from the program written in some other language because AWK is a "Data Driven" language. Basically AWK program uses the data obtained from another program and it manipulates that data according to the rules/instructions given in the program. An AWK program may be a combination of rules, functions and definitions. Using these rules, functions and definitions an AWK program manipulates data and give the results. (Aho *et al.,* 1988).

Simulation environment

Mobility parameters

Simulator	NS2
Terrain Size	600m x 500m, 600m x 600m
Number of Nodes	20 and 50
Speed	1 to 20 m/sec
Pause time	0 and 20 seconds
MAC Type	IEEE 802.11
Propagation Model	Two Ray Ground
Antenna Type	Omni directional
Transmission Range	250m
Movement Models	RWP, RD, RW
Traffic Model	CBR
CBR Sources	20, 40
Packet Size	512 bytes
Packet Rate	4 , 5 packets/sec
Routing Protocol	AODV, DSR
Simulation time	800 seconds, 850 seconds

Simulation of Mobility Parameters

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This simulation work is conducted by varying different mobility parameters. Performance of both the routing protocols (AODV and DSR) is checked under three selected mobility models by using NS-2. Four scenarios for simulation work were designed as follow:

1). Sparse Area without Pause time
2). Dense Area without Pause time
3). Sparse Area with Pause time
4). Dense Area with Pause time

In these four scenarios both AODV and DSR were tested by considering the four routing parameters PSP, AED, NCL and Throughput, by varying different mobility parameters. Simulations are done for the network of 20 and 50 nodes with MAC 802.11 wireless channel. Two Ray Ground propagation model and Omni-directional antenna having transmission radio range of 250 meters used. Initially nodes were deployed with in a rectangular area and in a random way. Movement of nodes was according to the RWP, RD and RW Mobility Models respectively. Speed of a node distributed uniformly from 1 to 20 m/s. Pause time selected between 0 and 20 seconds for the complete 800 seconds period of simulation. Two terrain areas were taken as follow: 1). 600m x 500m 2). 600m x 600m

CBR (Constant Bit Rate) traffic patterns were used. 20 and 40 CBR connections were used respectively. Each CBR source could send 512-byte data packets with the sending rate of 5 and 4 packets per second.

Performance metrics

In this research work the following routing performance metrics are used to check out the performance of the AODV and DSR MANET routing protocols;

Packet Success Percentage (PSP)

PSP can be defined as the ratio between the data packets sent by the CBR sources node and the data packets received by the CBR destination node.

Normalized Control Load (NCL)

NCL can be defined as the ratio of the number of control packets sent with each data packet received at the destination.

Average End to End Delay (AED)

AED is the combination of all the possible delays caused due to buffering for route discovery latency, queuing at the interface queue, retransmission delays at the MAC, propagation and transfer times.

Throughput

Throughput is counted by dividing the total number of delivered data packets with the total period of simulation. In other words messages per second. It is measured in Kbits/sec or mbits/sec.

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Simulation results, analysis and discussion

Scenario 1: (sparse area without pause time)

Packet Success Percentage Graph

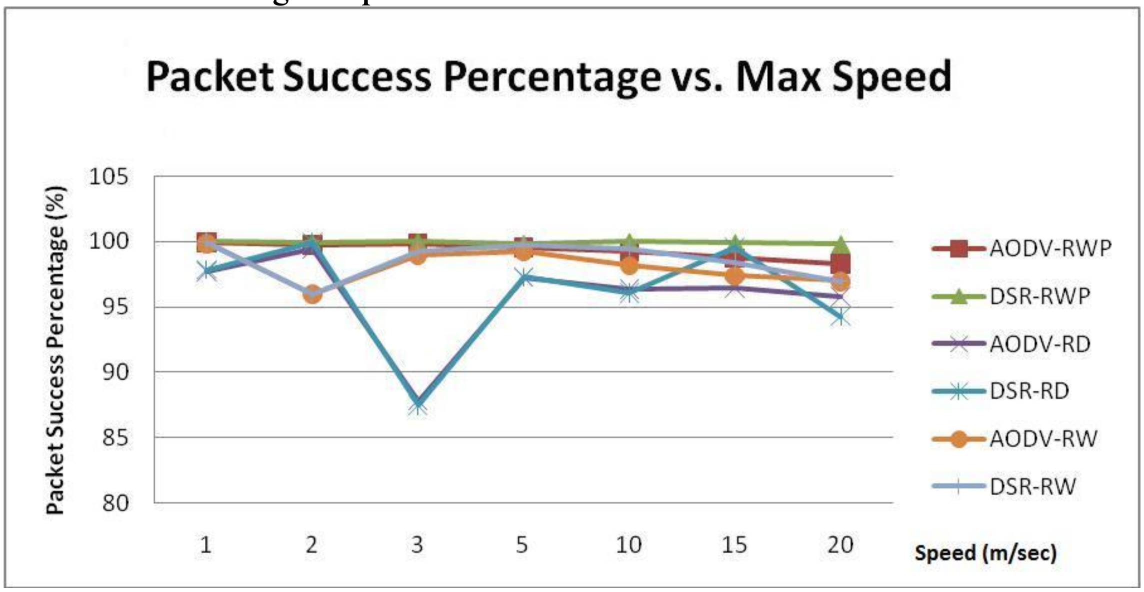

Figure 4.1: Packet Success Percentage of AODV and DSR vs. Max Speed (Nodes=20, Area= 600x500m, CBR connections=20, Pause time=0 seconds)

Average End to End Delay Graph

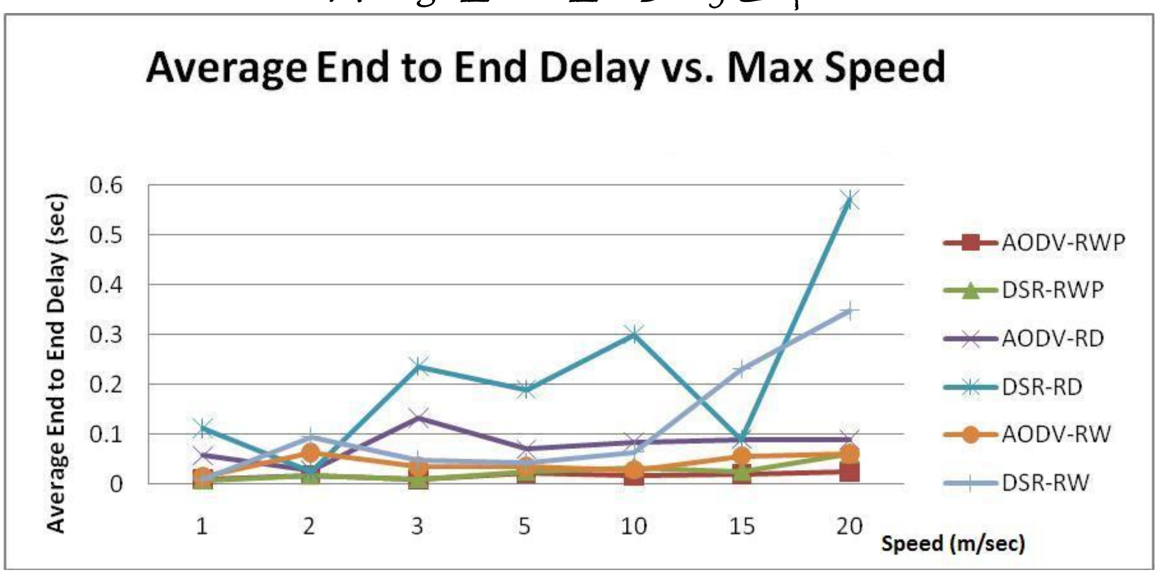

Figure 4.2: Average End to End Delay of AODV and DSR vs. Max Speed (Nodes=20, Area= 600x500m, CBR connections=20, Pause time=0 seconds)

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Normalized Control Load Graph

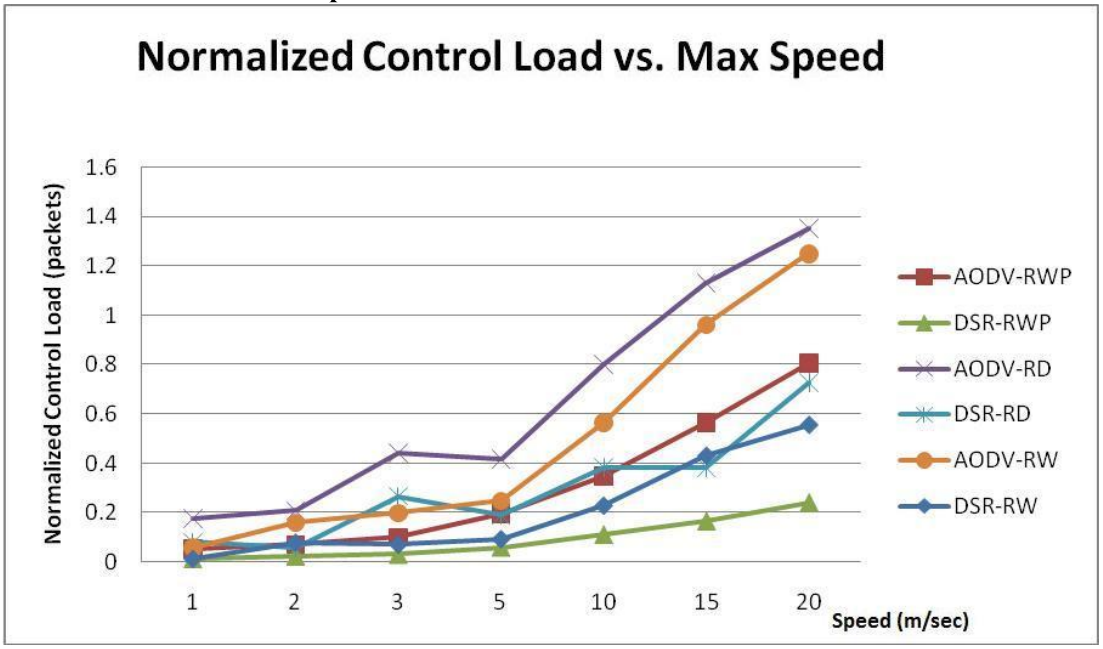

Figure 4.3: Normalized Control Load of AODV and DSR vs. Max Speed
(Nodes=20, Area= 600x500m, CBR connections=20, Pause time=0 seconds)

Throughput Graph

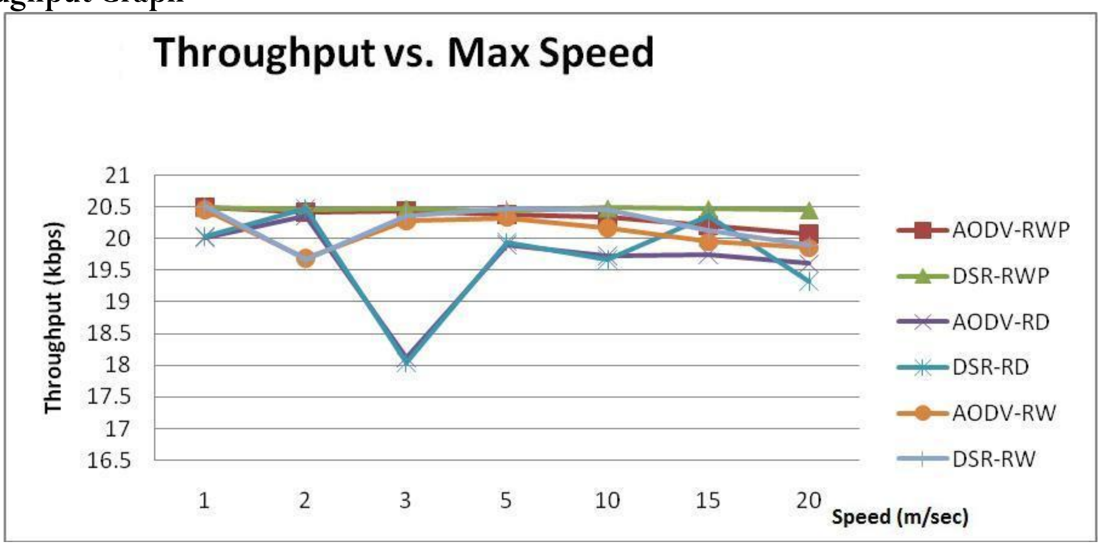

Figure 4.4: Throughput of AODV and DSR vs. Max Speed
(Nodes=20, Area= 600x500m, CBR connections=20, Pause time=0 seconds)

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Scenario 2: (Dense Area without Pause time)

Packet Success Percentage Graph

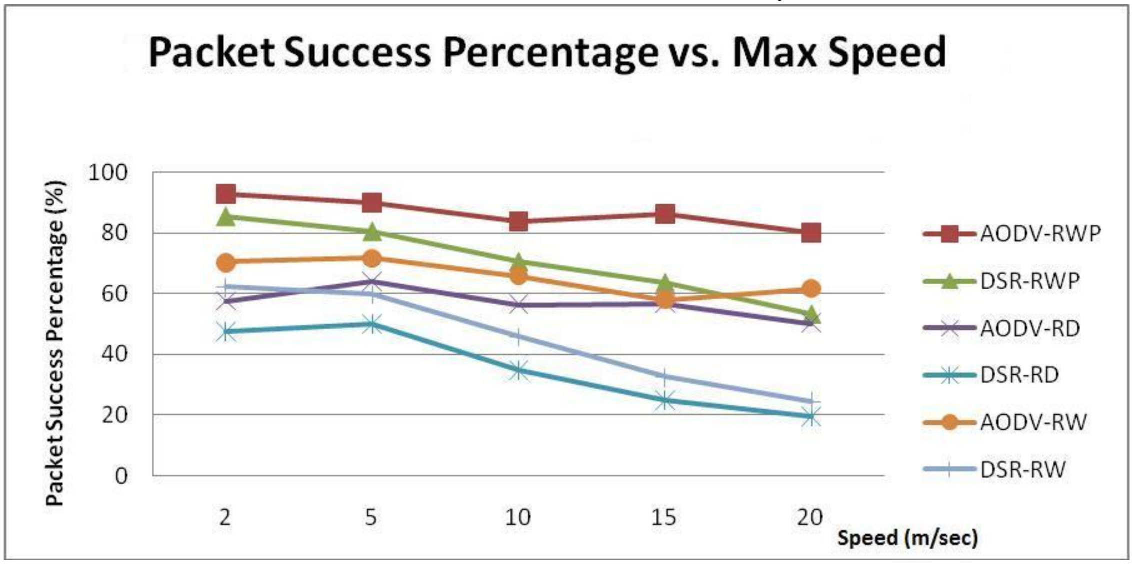

Figure 4.5: Packet Success Percentage of AODV and DSR vs. Max Speed
(Nodes=50, Area= 600x600m, CBR connections=40, Pause time=0 seconds)

Average End to End Delay Graph

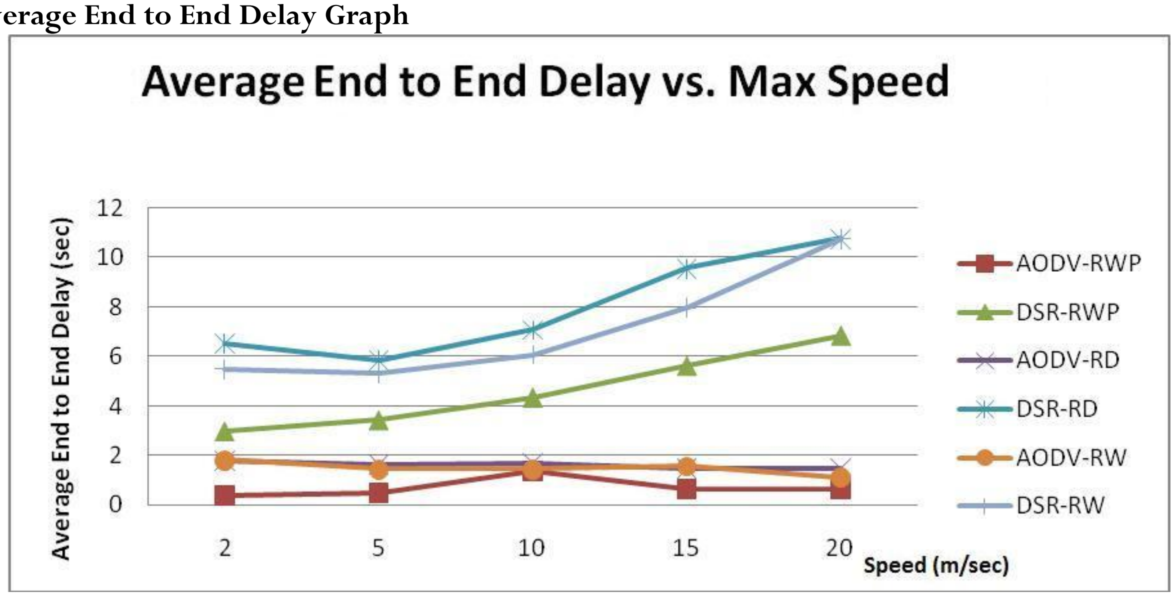

Figure 4.6: Average End to End Delay of AODV and DSR vs. Max Speed
(Nodes=40, Area= 600x600m, CBR connections=40, Pause time=0 seconds)

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Normalized Control Load Graph

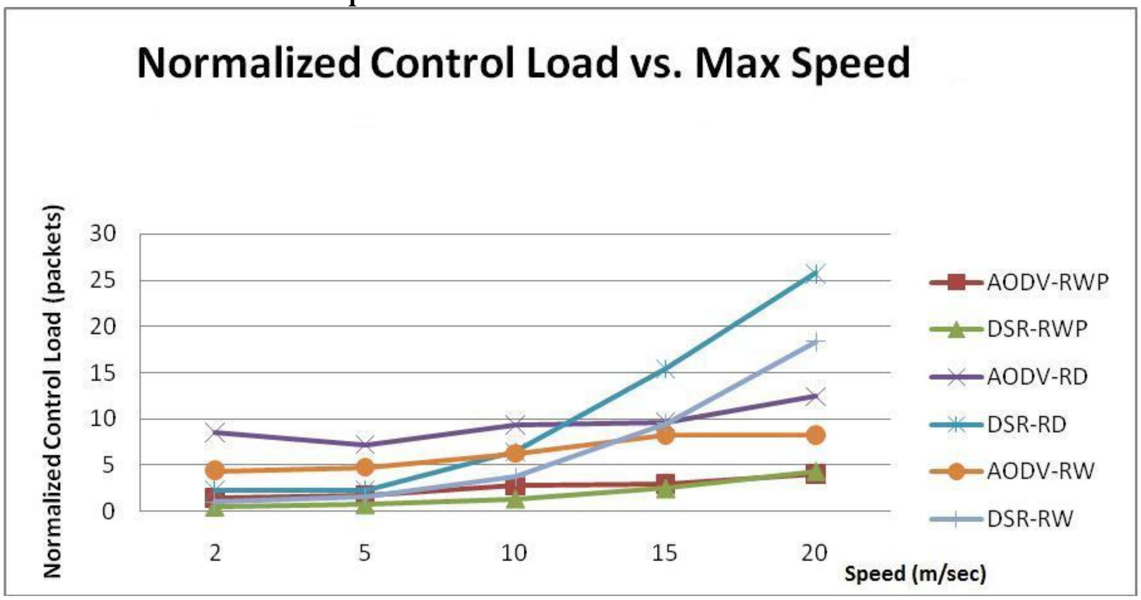

Figure 4.7: Normalized Control Load of AODV and DSR vs. Max Speed
(Nodes=50, Area= 600x600m, CBR connections=40, Pause time=0 seconds)

Throughput Graph

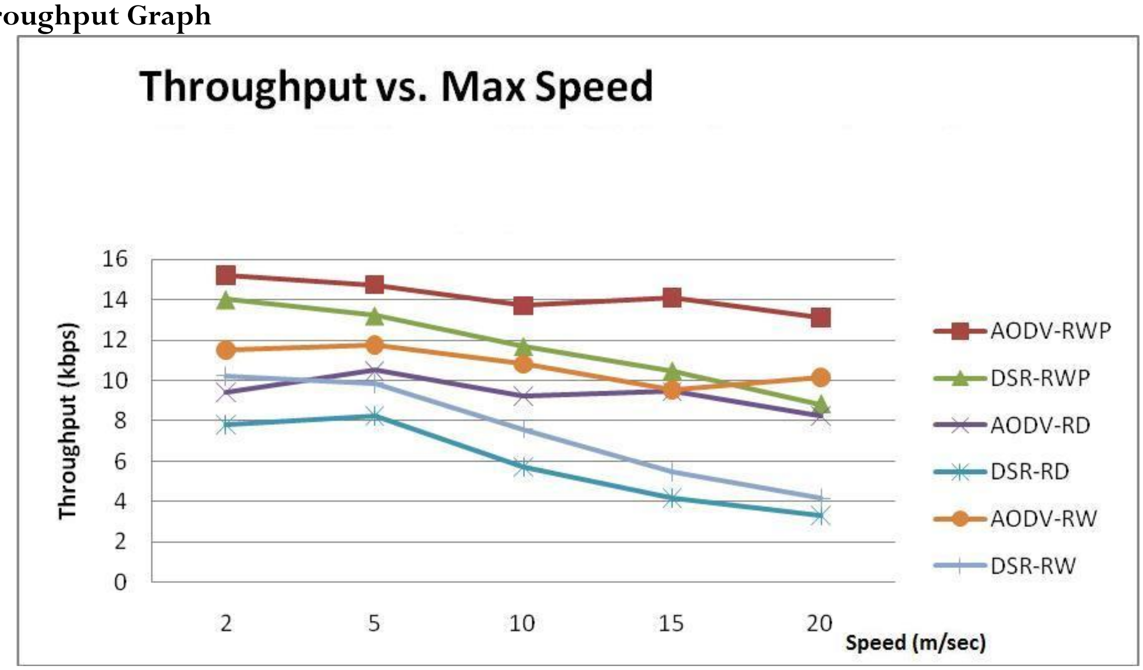

Figure 4.8: Throughput of AODV and DSR vs. Max Speed
(Nodes=50, Area= 600x600m, CBR connections=40, Pause time=0 seconds)

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Scenario 3: (Sparse Area with Pause time)

Packet Success Percentage Graph

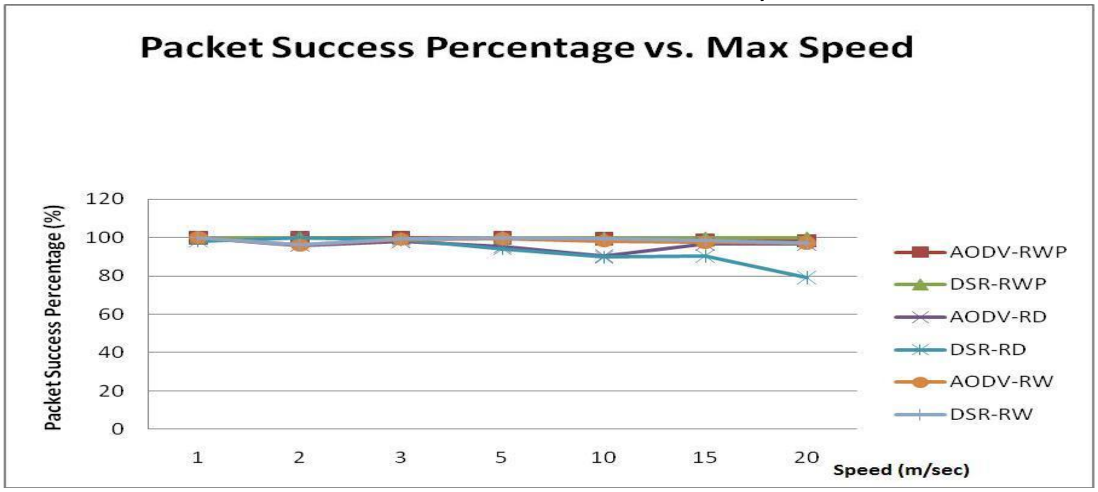

Figure 4.9: Packet Success Percentage of AODV and DSR vs. Max Speed
(Nodes=20, Area= 600x500m, CBR connections=20, Pause time=20 seconds)

Average End to End Delay Graph

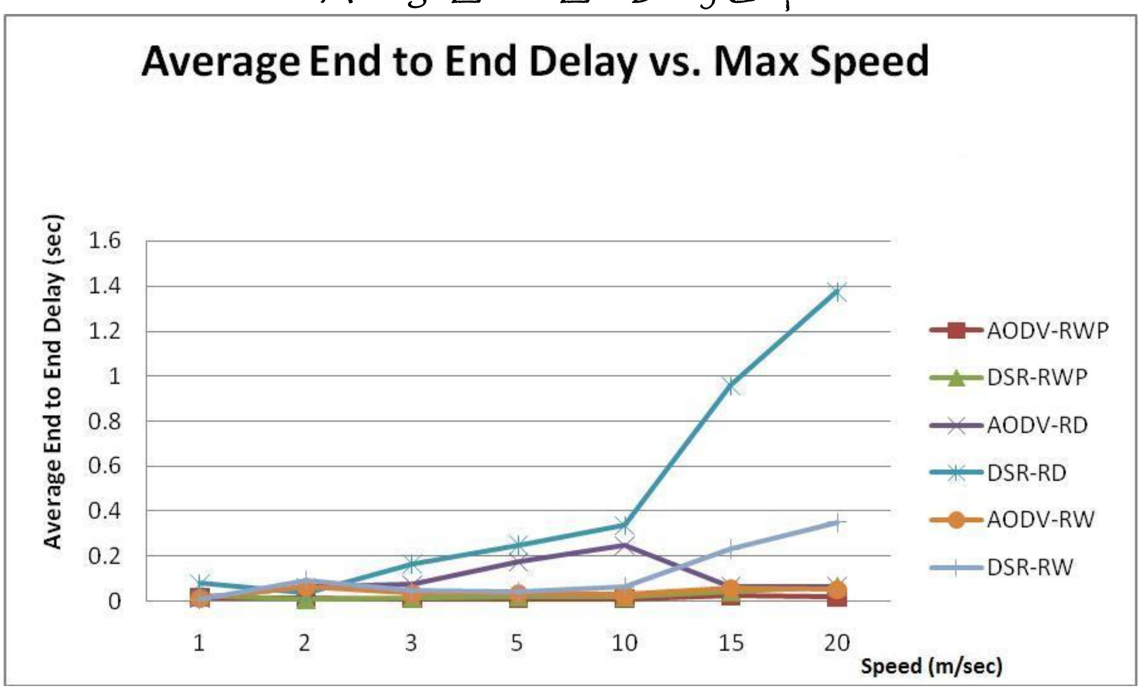

Figure 4.10: Average End to End Delay of AODV and DSR vs. Max Speed

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(Nodes=20, Area= 600x500m, CBR connections=20, Pause time=20 seconds)

Normalized Control Load Graph

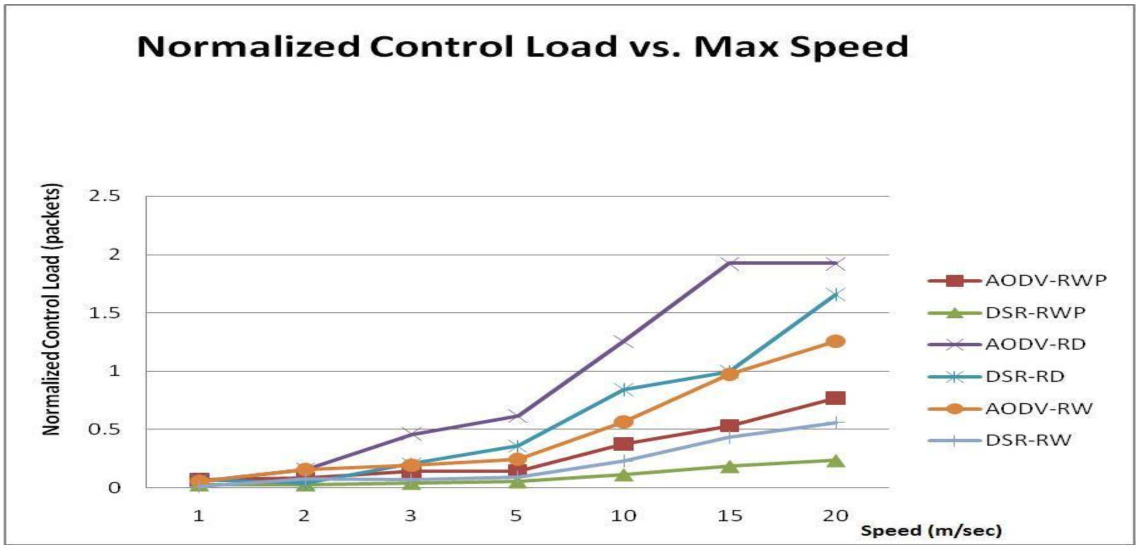

Figure 4.11: Normalized Control Load of AODV and DSR vs. Max Speed
(Nodes=20, Area= 600x500m, CBR connections=20, Pause time=20 seconds)

Throughput Graph

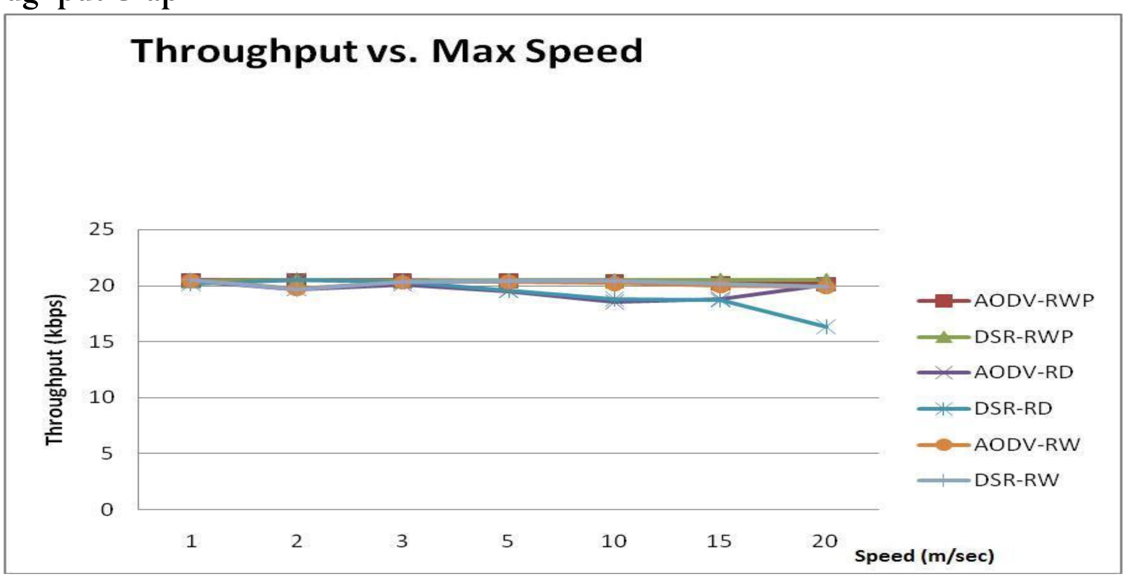

Figure 4.12: Throughput of AODV and DSR vs. Max Speed
(Nodes=20, Area= 600x500m, CBR connections=20, Pause time=20 seconds)

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Scenario 4: (Dense Area with Pause time)

Packet Success Percentage Graph

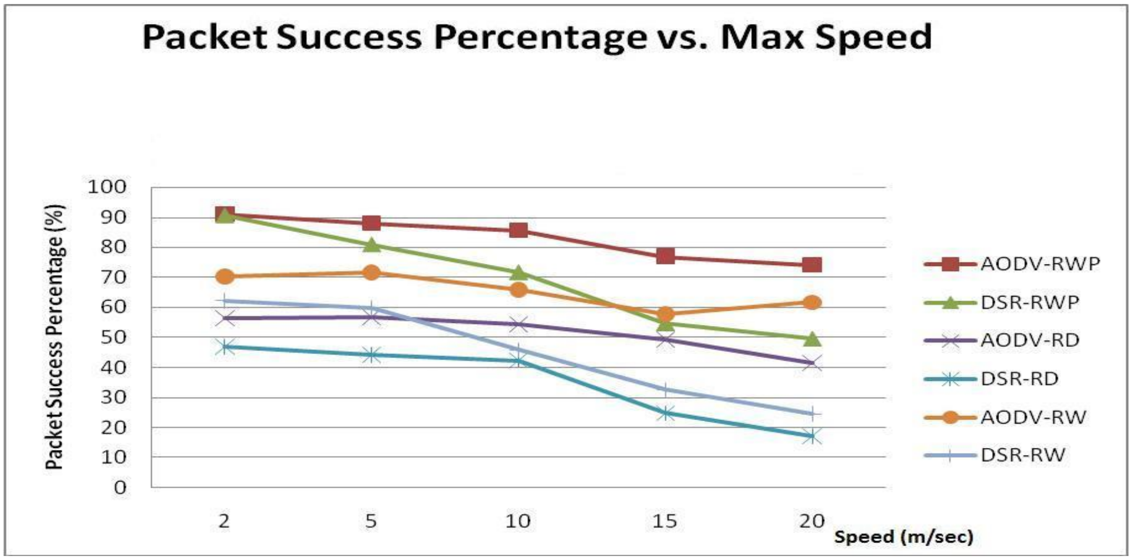

Figure 4.13: Packet Success Percentage of AODV and DSR vs. Max Speed
(Nodes=50, Area= 600x600m, CBR connections=40, Pause time=20 seconds)

Average End to End Delay Graph

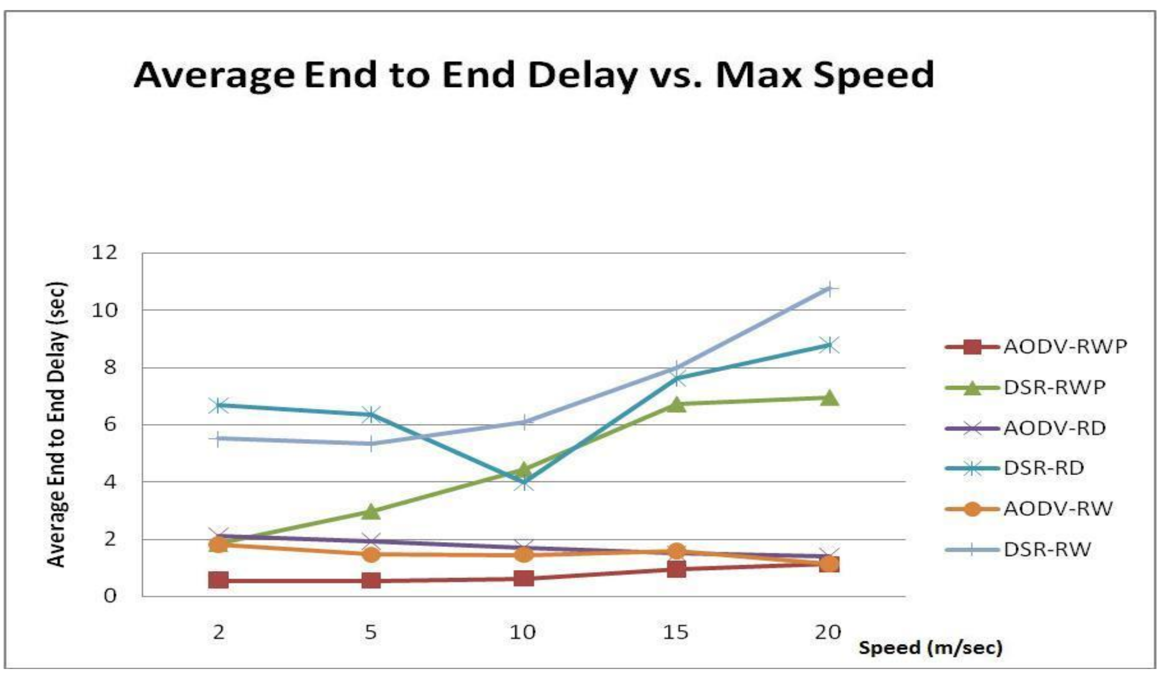

Figure 4.14: Average End to End Delay of AODV and DSR vs. Max Speed

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(Nodes=50, Area= 600x600m, CBR connections=40, Pause time=20 seconds)

Normalized Control Load Graph

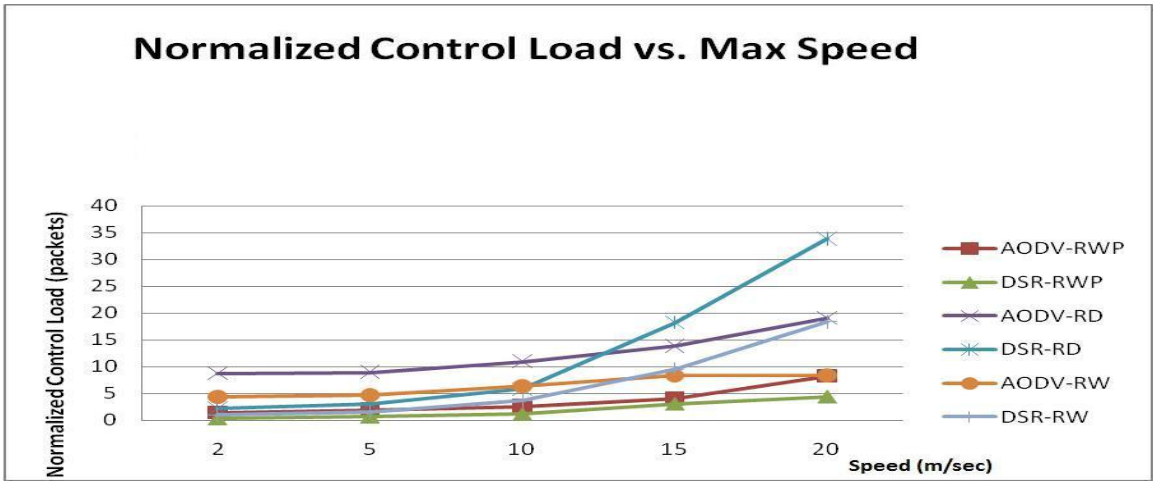

Figure 4.15: Normalized Control Load of AODV and DSR vs. Max Speed
(Nodes=50, Area= 600x600m, CBR connections=40, Pause time=20 seconds)

Throughput Graph

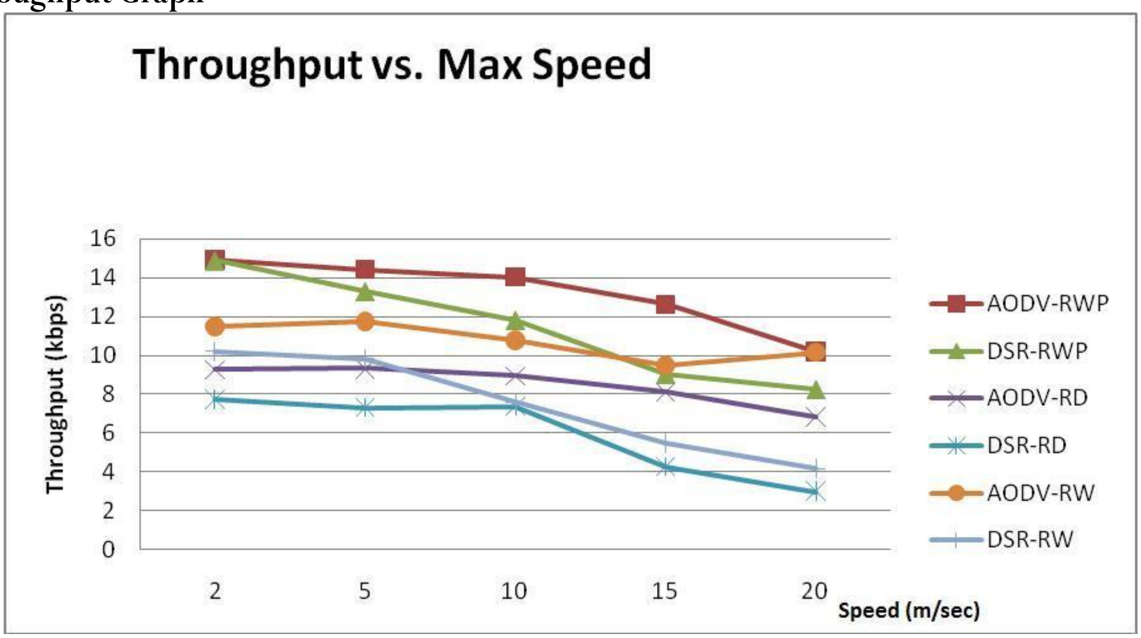

Figure 4.16: Throughput of AODV and DSR vs. Max Speed
(Nodes=50, Area= 600x600m, CBR connections=40, Pause time=20 seconds)

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Summary

This is a thorough research work in which the performance analysis of two MANET routing protocols AODV and DSR is done along with three different entity based mobility models; Random Waypoint, Random Direction and Random Walk. This performance analysis of AODV and DSR is done on the basis of four selected routing performance metrics. The selected routing performance metrics were; Packet Success Percentage (PSP), Average End to End Delay (AED), Normalized Control Load (NCL) and Throughput.

In this research work four different scenarios were designed. First scenario was designed for Sparse Area but without any pause time. Second scenario was designed for Dense Area having zero/no pause time. The third scenario was designed for Sparse Area having 20 seconds pause time. The fourth scenario was designed for Dense Area having 20 seconds pause time. In all the scenarios many things were varying such as Speed, Number of nodes, Number of traffic source (CBR connections), Moving area topology dimensions (Size of the area of simulation). All the simulation work is carried out by using NS-2 (NS-2.29 all in one version). The data generated after the simulation of all the four scenarios was manipulated in AWK language. After the manipulation AWK language generated some values which were used in MS-Excel 2010. MS-Excel 2010 produced Graphs that showed all the simulation work in a pictorial/graphical form to understand all the simulation results more easily. Many different results generated from this simulation work conducted to check the performance of AODV and DSR considering four routing performance metrics PSP, AED, NCL and Throughput, along with Three different Mobility Models; RWP, RD and RW.

Conclusion

This research work shows that the variation of different factors (such as; speed, number of nodes, number of CBR connections, topology area size and pause time) effects the performance of AODV and DSR and also effects the performance of RWP, RD and RW mobility models. After simulating all the four scenarios it is concluded that in comparison with DSR the performance of AODV routing protocol remained excellent while using RWP and RW mobility models. RWP and RW mobility models performed very well and produced good results along with both the routing protocols but especially with AODV.

In terms of Packet Success Percentage (PSP), Average End to End Delay (AED) and Throughput the performance of AODV was excellent but in terms of Normalized Control Load (NCL) performance of AODV remained low.

Regarding all the scenarios, in some cases DSR performed well in terms of Throughput and Normalized Control Load while using RWP and RW models. Regarding all the scenarios overall performance graph of AODV along with RD model remained low in all the scenarios.

Regarding all the selected routing metrics the performance graph of DSR remained very low along with either mobility model, in all scenarios. Especially along with RD model DSR showed very bad performance. Also with the increase of speed performance of DSR was fluctuating and DSR was not stable at increasing speed using either mobility model especially along with RD model.

In short, from all the results it is concluded that change in different factors affects the performance of routing protocols as well as the performance of mobility models is affected. This research work concludes that AODV has dominated DSR in all the scenarios. AODV is the best routing protocol along with RWP and RW mobility models while considering the four routing parameters; PSP, AED, NCL and Throughput.

Future work

This research work has examined two on-demand routing protocols (AODV and DSR) along with three different entity based mobility models (RWP, RD and RW), on the behalf of four routing metrics (PSP, AED, NCL and Throughput). But it is not enough because routing in MANETs is a vast field of study and is

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a big issue. Further in future, as a research work, other routing protocols and some other entity based mobility models can be taken into consideration along with the selection of some other important routing metrics to check out the performance of different routing protocols as well as to check the performance of mobility model to make fruitful changes.

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