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Implementation and Evaluation of Wireless Mesh Networks on MANET Routing Protocols

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Abstract—Wireless Mesh Network (WMN) is a kind of network which is made up of Mesh router and Mesh clients where Mesh router having lesser mobility and form the heart of WMNs. In this paper, Wireless Mesh Network over MANET implemented using routing protocols such as AODV, DSR. In this work NS-2.34 simulator is used for simulations. Various measurements and calculations were figure out in this work like throughput, Average end-end delay, PDR, NRL and Routing packets in Random way point mobility model. WMN have features such as self configuration, self healing and low cost of equipment. This work specifically aims to study the performance of routing protocols in a wireless mesh network, where static mesh routers and mobile clients participate together to implement networks functionality such as routing and packet forwarding in different mobility scenarios

Keywords- Ad hoc Network, Routing Protocols, Wireless Mesh Network, Performance, Throughput, PDR, NRL and Routing packets in Random way point mobility model, Simulation on Network simulator NS-2, AODV,DSR , Routing Overhead.

I. INTRODUCTION

A Mobile Ad-hoc network (MANET) is an autonomous system of wireless mobile nodes without any fixed infrastructures. This kind of network promises many advantages in terms of cost and flexibility compared to network with infrastructures. MANET’s are very suitable for a great variety of applications such as data collection, seismic activities, medical applications...Unfortunately nodes in MANET are limited in energy, Bandwidth...These resources constraints pose a set of non-trivial problems, in particular, routing and flow control [1].

Emergence of wireless network is in 1970 and it became popular in computing as well as communication industries. Mobile wireless network are of two types [2][8] infrastructure network and infrastructure less mobile network. In infrastructure less nodes can move freely and make their own route with the help of topology and it may change rapidly according to time. Infrastructure less network is known as Ad hoc network. MANETs stands for Mobile Ad hoc Networks. Mobile Ad hoc Network is a collection of mobile nodes in wireless technique. It never uses the existing network infrastructure and made its own temporary network. Ad hoc networks setup is not expensive and no access points or base stations are needed for it.

A geographical area in which there are a number of mobile devices or users are present makes Wireless multi hop ad hoc network. Devices or mobile user which makes wireless multi hop ad hoc network is called as nodes. Nodes communication takes place with the help of radio transmitter and receiver. The performance is measured by its routing protocols. These protocols have two categories re-active and pro-active. Proactive protocol DSDV is considered to be a traditional protocol which finds routes between all source –destination pairs regardless of the use or need for such routes. The key motivation behind the development of reactive routing protocols like DSR and AODV is the reduction of routing load. We are taking consideration over the re-active protocols DSR and AODV. A re-active protocol does not take

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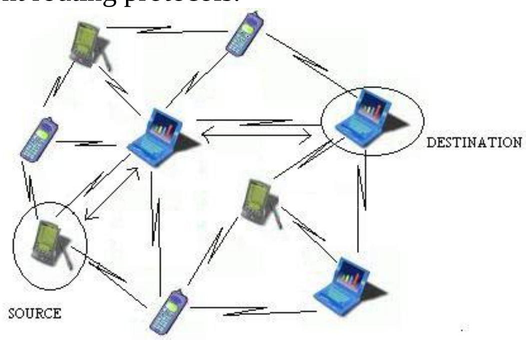
initiative for finding routes. Re-active protocols find their routes with the help of flooding query. The main perspective behind MANET is that in today's life, the majority uses wireless technology and they need an infrastructure less network so they can move easily (for e.g. mobile). So to provide them mobility we are making the network as best as we can with the help of different routing protocols.



Figu1 [4] General Mobile Ad Hoc Network Architecture

The Role of QoS routing strategy is to compute paths that are suitable for different type of traffic generated by various applications while maximising the utilization of network resources. But the problem of finding multi-constrained paths has high computational complexity, and thus there is a need to use algorithms that address this difficulty. The major objective of QoS routing are i) To find a path from source to destination satisfying users requirements. ii) To optimize network resource usage and iii) To degrade the network performance when unwanted things like congestion , path breaks appear in the network.

The main problem to be solved by QoS routing algorithm is a multi constrained path problem. Algorithms to solve this family of problems are known to be heuristics which can reduce the complexity of path computation , however, at the expense of not attaining the optimal solution for the problem and finding just a feasible solution.

I(A). WIRELESS MESH NETWORKs (WMN)

Wireless Mesh Network (WMN) is a highly promising technology and it plays as an important architecture for the future wireless communications [9]. WMNs consist of mesh routers and mesh clients, and could be independently implemented or integrated with other communication systems such as the conventional cellular systems. In addition, WMN are dynamic, self-organized, self-healed and self-configured network that enables quick deployment. They provide easy maintenance, low cost, high scalability and reliable service. WMN is an ad hoc network extension and is becoming an important mode complimentary to the infrastructure based wireless networks because they can enhance network capacity, connectivity and resilience. We can define a WMN as a network that has either a partial or full mesh topology. In practice, WMNs are characterized by static wireless relay nodes which provide a distributed infrastructure for client nodes over the partial mesh topology. As WMN are self-organized and self-configured networks, the nodes in the network automatically establish an ad hoc network and maintain the mesh connectivity [9].

Along with the routing capability for gateway/bridge functions existing in a conventional wireless router, a mesh router supports additional routing functions to provide a platform for mesh networking. Using multi-hop communications, the coverage can be extended by a mesh router with much lower transmission power requirements [13]. To further enhance the adaptability of mesh networking, a mesh router is normally equipped with multiple wireless interfaces built on either the same or different wireless access technologies [9]. Mesh routers generally have minimal mobility and their purpose is basically the formation of mesh backbone for the mesh clients [9]. The gateway/bridge functionalities in mesh routers enable the integration of WMNs with various other networks. Wireless mesh routers enable conventional nodes equipped with wireless network interface cards (NICs) to connect directly to WMNs [9]. Ethernet can be used to access WMNs by connecting to wireless mesh routers when wireless NICs are not available. WMN caters to the need of the users to be always on line anywhere, anytime [12]. Instead of being another type of ad hoc networking, WMNs diversify and enhance the capabilities of ad hoc networks.

The devices like laptops, mobile phones, wireless mouse, wireless keyboards, PDA etc come under the category of mesh clients. Even though mesh clients can also work as a router, the hardware platform and software for them can be made simpler than those for mesh routers. For instance, communication protocols for mesh clients can be light-weight, as gateway or bridge functions are not needed by mesh clients. Only

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a single wireless interface is often needed in a mesh client [11].

In many ways WMNs have become preferable over MANETs, as they have advantages such as low installation costs, easy network maintenance, robustness, service coverage that can be relied on [12]. Today, WMNs are a widely accepted technology in the traditional application areas of ad hoc networks, and they are also undergoing rapid commercialization application scenarios such as broadband home networking, community networking, building automation, high-speed metropolitan area networks, and enterprise networking etc [9].

WMN ARCHITECTURES:
(a) Infrastructure/Backbone WMNs:

This type of WMNs consists of mesh routers for forming an infrastructure for clients that connect to them. The clients can be mesh clients or conventional clients. The WMN infrastructure/backbone may be built using various types of radio technologies, in addition to the mostly used IEEE 802.11 technologies (as shown in Fig-2- [9]). The mesh routers form a mesh of self-configuring, self-healing links among themselves, which acts as a backbone. The gateway functionality enables mesh routers to connect to the Internet [9]. This approach, also referred to as infrastructure meshing, provides backbone for conventional clients and its main purpose is integration of WMNs with existing wireless networks, which is achieved through gateway/bridge functionalities present in mesh routers. Conventional clients with Ethernet interface are connected to mesh routers via Ethernet links, so the mesh routers have multiple interfaces. The conventional clients with the same radio technologies as mesh routers can directly communicate with mesh routers and do not require any Ethernet link between them [9]. When different radio technologies are used, clients must communicate with the base stations that have Ethernet connections to mesh routers.

This type of WMNs is the most commonly used type because of its ease of deployment.

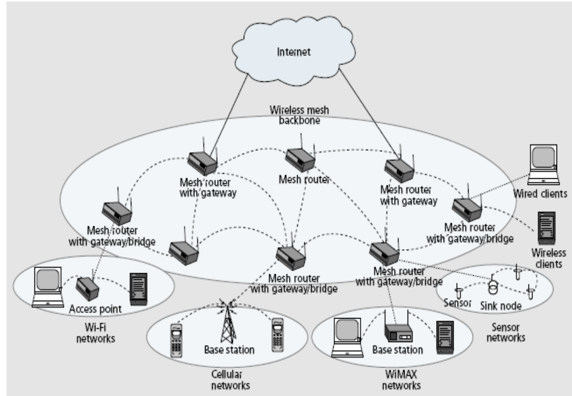

Figure-2[9] Infrastructure/Backbone Mesh Network

(b) *Client WMNs:*
Client WMNs (Fig-3[9]) have almost the same characteristics as a mobile ad hoc network. Client meshing is used to enable peer-to-peer networking among client devices.

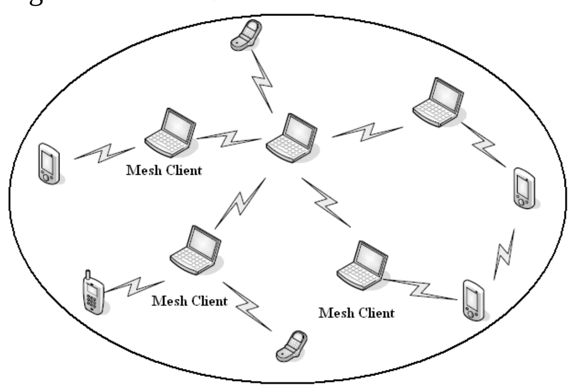

Figure-3[9] Client WMN

In this architecture, client nodes constitute the actual network to perform routing and configuration functionalities as well as provide end-user applications to the customers. This type of WMNs does not constitute mesh routers. In Client WMNs, a packet destined to a node in the network hops through multiple nodes to reach the destination [9]. Client WMNs are formed using one type of radios on devices. Moreover, the requirements on end-user devices are increased due to the added routing and configuration functions.

(c) HYBRID WMNs:

Hybrid WMN (Fig-4 [9]) is the combination of infrastructure and client meshing. Mesh clients are able to access the network through mesh routers as

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well as directly meshing with other mesh clients. While the infrastructure provides connectivity to other networks such as the Internet, Wi-Fi, WiMAX, cellular, and sensor networks, the routing capabilities of clients provide improved connectivity and coverage inside the WMN [9]. Of all the architectures it is the best and has maximum applicability.

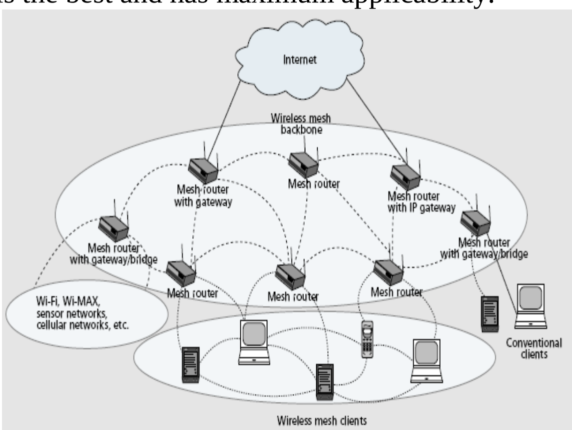

Figure-4[9] Hybrid WMN

II. AN OVERVIEW OF AD HOC ON DEMAND DISTANCE VECTOR (AODV), DSR

A. ADHOC ON-DEMAND DISTANCE VECTOR PROTOCOL (AODV)

The Ad hoc On-demand distance vector routing [3] protocol based on Destination Sequenced Distance Vector (DSDV) protocol. It was introduced in 1997. AODV is designed for networks with ten to thousands of mobile nodes. One feature of AODV is the use of a destination sequence number for each routing table entry. The sequence number is created by the destination node. The sequence number included in a route request or route reply is send to requesting nodes. Sequence number are very important because they ensures loop freedom and is simple to program. Sequence numbers are used by other nodes to determine the freshness of routing information. If a node has the choice between two routes to a destination, a node is required to select the one with the greatest sequence number. When a node want to find route to another node it sends a RREQ to the entire network till either the destination is found or another node is reached. The RREP is sent back to the source and the search route is made available. When a node searches a route and found that this route is not valid then it removes entry from routing table and sends a RERR message to neighbours that are uses the route; this is possible by making an active neighbour lists. This procedure is repeated again and again at nodes that receive RERR messages. When a source receives an RERR then it reinitiate a RREQ message. AODV does not allow handling unidirectional links.

AODV deals with routing table. Every node has a routing table. When a node knows a route to destination, it sends a route reply to the source node.

It entries are Destination IP address, Prefix size, Destination sequence number, Next hop IP address, Lifetime(expiration or deletion time of route), Hop count(number of hops to reach the destination), Network interface , Other state and routing flags (e.g. valid, invalid) Route requests(RREQs), Route Replies(RREPs) and Route Errors(RERRs) are message types define AODV.

Let us take an example in which a node S wants to communicate with D Figure 2, the node sends a RREQ to find a route to the destination. S generates a Route Request along with destination address.

Sequence number and Broadcast ID and sent it to his neighbour nodes. Each node receiving the node request sends a route back (Forward Path) to the node.

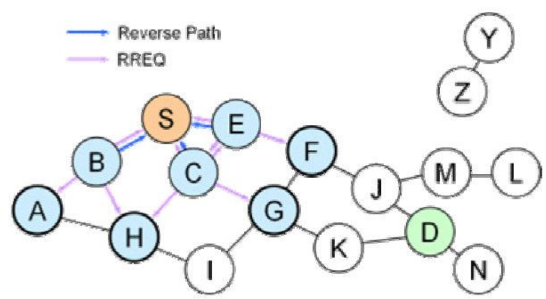

FIGURE 5[8]: Path finding in AODV

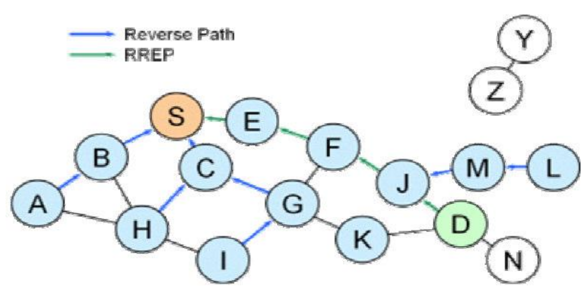

FIGURE 6[8]: Path finding in AODV.

Here in figure 3, 4 S can able to communicate with node D.

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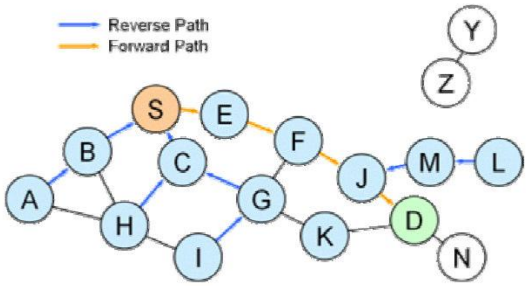

FIGURE 7[8]: Path finding in AODV

When a link break in an active route is detected, the broken link is invalid and a RERR message is sent to other nodes, Figure 5. If the nodes have a route in their routing table with this link, the route will be erased. Node S sends once again a route request to his neighbor nodes. Or a node on the way to the destination can try to find a route to D. That mechanism is called: Local Route Repair.

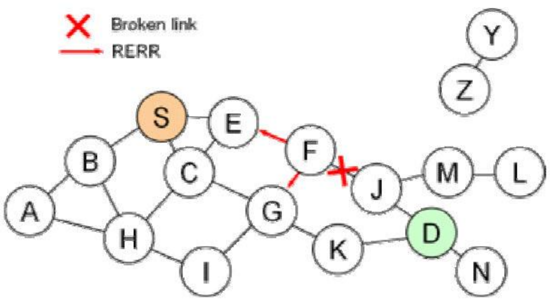

FIGURE 8[8]: Path finding in AODV

B. DYANMIC SOURCE ROUTING PROTOCOL (DSR)

DSR is a reactive routing protocol which is able to manage a MANET without using periodic table update message like table driven routing protocols do. DSR was specifically designed for use in multi hop wireless ad hoc networks. Ad hoc protocol allows the network to be completely self-organizing and self-configuring which means that there is no need for an existing network infrastructure or administration. For restricting the bandwidth, the process to find a path is only executed when a path is required by node (on-demand routing). In DSR the Sender (source, initiator) determines the whole path from the source to the destination node (source routing) and deposits the address of the intermediate node of the route in the packets. DSR was developed for MANET's with a small diameter between 5 and 10 hops and the node should only move around at a moderate speed. DSR is based on the link-state-algorithms which mean that each node is capable to save the best way to a destination. Also if a change appears in the network topology, then the whole network will get this information by flooding.

Route source is the sequences of hops that the packet has to follow on its way to the destination node the intermediate nodes are stored in the header. All the route sources are stored in the route cache. Every node has its own route cache. The route cache can store the learned source routes. After an execution time, source routes are defined from the route cache. DSR having two phases: Route Discovery and Route Maintenance.

The advantage is that intermediate nodes do not need to maintain up-to-date routing information in order to route the packets they forward. Due to the on-demand characteristics of DSR, periodic route updates and neighbour detection are eliminated to minimize bandwidth consumption. DSR has two basic mechanisms of operations, Route Discovery and Route Maintenance. Ad hoc On-demand distance vector (AODV) is an on demand routing protocol that combines the capabilities of both DSR and DSDV. It uses the on-demand mechanisms of Route Discovery and Route Maintenance from DSR in addition to the hop-by-hop routing sequence numbers and periodic beacons from Destination-Sequenced Distance-Vector (DSDV) as described by [5]. Therefore, a source node "S" that wants to route packets to a destination node "D" that does not already have the route will initiate a route discovery process to locate the other node.

III. PERFORMANCE EVALUATION

A. Simulation setup

We have setup this by using Network Simulator NS-2 and compared Routing Protocols AODV, DSR. First

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we have generated the scenario files by taken an area of 600mx600m and divide them into four categories.

1. Fix Pause time (10 sec), Max Speed (0 m/s) and Simulation Time (200 sec) constant and number of nodes are fixed (30) and by varying speed.

2. Fix Pause time (10 sec), Max Speed (5 m/s) and Simulation Time (200 sec) constant and number of nodes are fixed (30) and by varying speed.

3. Fix Pause time (10 sec), Max Speed (10 m/s) and Simulation Time (200 sec) constant and number of nodes are fixed (30) and by varying speed.
.
4. Fix Pause time (10 sec), Max Speed (15 m/s) and Simulation Time (200 sec) constant and number of nodes are fixed (30) and by varying speed.

Now after generating the scenario files, we have generated traffic files using *cbrgen* utility of ns2. The no of maximum connections were mentioned as no of nodes for a particular file and data communication rate was defined as 4 packets per second.

For simulation, the computer system was having a good processing speed and large storage capacity as 120 trace files were generated and each file was of the capacity in the range of 1gigabyte to 50 gigabytes. *Tcl* script was run over to generate the trace files for various protocols DSR, AODV.. After analysing these 120 file trace files with *awk* script we concluded the results for various parameters to be calculated.Every simulation was done for 200 seconds.

B. Metrices

a. Packet Delivery Ratio: Total number of delivered data packets divided by total number of data packets transmitted by all nodes. This performance metric will give us an idea of how well the protocol is performing in terms of packet delivery at different speeds using different traffic models.

b. Average end-end delay: Average time taken by a packet to reach from source to destination. This metric is calculated by subtracting "time at which first packet was transmitted by source" from "time at which first data packet arrived to destination". This includes all possible delays caused by buffering during route discovery latency, queuing at the interface queue, retransmission delays at the MAC and propagation and transfer times.

c. Packet Loss: It is the measure of the number of packets dropped by the routers due to various reasons.

d. Routing Overhead: Total number of routing packet divided by total number of delivered data packets.

Simulation Parameters-Random waypoint scenario

Simulation Parameter	Value
Simulation Time	200 Seconds
Simulation Area	600m x 600m
Examined routing protocol	AODV, DSR
Number of Mesh Routers	16 in grid formation
Number of Mesh Clients	30
Mobility model for Mesh Clients	Random waypoint
Propagation Model	Two ray ground reflection
Transmission Range	250m
Maximum Speed of Mesh Clients	0, 5, 10, 15, 20 m/s
Pause time	10s
Traffic Type	CBR (UDP)
Maximum Connections	12
Payload Size	512 bytes
Packet rate	4 ptks/sec

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B. Result Discussion

a. *Packet Delivery Ratio*: It tells about the number of packets delivered from the whole packets. So by our simulation result the following Graph in Figure 9 shows that packet delivery percent of DSR is 100% when network is static, but degrades gracefully to 99 % at maximum speed of 15 m/s. Up to the speed of 5 m/s performance of both the protocols is comparable. AODV has poor performance at higher speed. This is because at very high levels of mobility more timeouts expires before a failure link is declared lost.

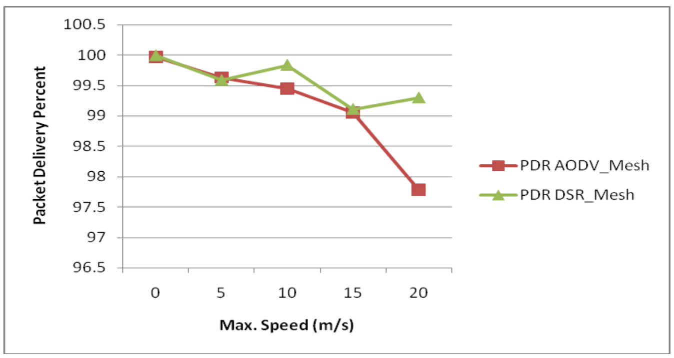

Figure 9

b. Throughput: It is found that DSR routing protocol outperforms in terms of throughput. When maximum speed of all mesh clients is 0, network is static both the protocols give same throughput. But as the maximum speed is varied from 0 to 20 m/s, DSR gives better throughput at high speeds too. Throughput of AODV is comparable and is almost steady (Figure-10)

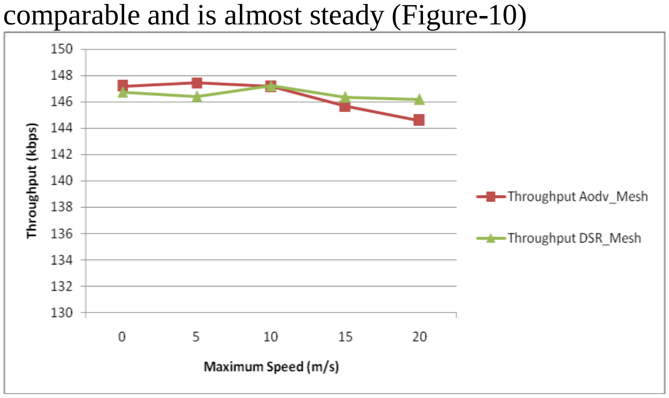

Figure 10

c. NRL: All possible delays caused by buffering during route discovery latency, queuing at the interface queue, retransmission delays at the MAC, propagation and transfer times [7]. This metric is crucial in understanding the delay introduced by path discovery. Graph for Normalized Routing Load (Figure-11) are very much the same because the packet delivery percent is very high in this scenario.

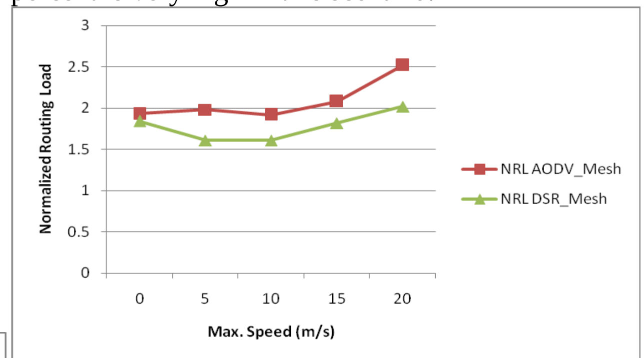

Figure 11

d. Routing Overhead: As shown by the graph in Figure 12 AODV generates greater number of routing packets as compared to DSR and hence has greater routing overhead. Both being reactive protocol it requires to maintain complete information of the network at all the nodes whenever topology changes.

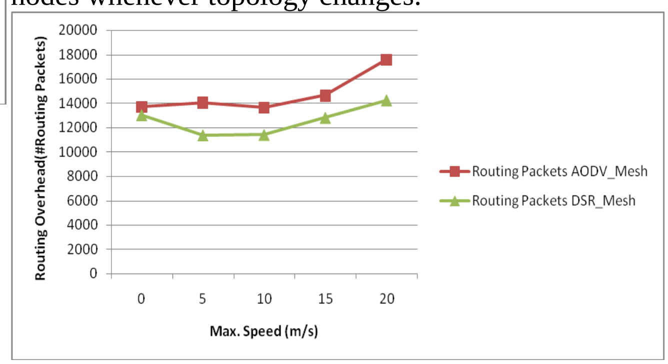

Figure 12

IV. **CONCLUSION**

Conclusion that we can draw from this scenario based simulation is that when the network is static both the protocols gives almost similar performance in terms of packet delivery percent and throughput. But as the mobility increases DSR outperforms AODV in Random waypoint mobility model. This shows that DSR is a more reliable, correct and complete protocol for mesh networks. Routing overhead measures the scalability of the protocol and the degree to which the protocol can function in a congested or low-bandwidth environment. It also shows the protocols efficiency in terms of consumption of battery power at a node. In our scenario DSR generated least routing overheads and lowest NRL. This shows that DSR can be selected in cases where there is low-bandwidth requirement.

As the number of mesh points were varied all performance parameters performed optimally with small number of mesh points. Packet delivery percent reduced with 16 mesh points but increased with 25 mesh points. No effect was seen on routing overheads in case of DSR and AODV. Therefore, the optimized mesh deployment in the area is to form a structure that provides full coverage with as small mesh density as possible.

As the traffic load in terms of connection pairs was increased, packet delivery percent increased to a maximum value and then reduced on further increase in traffic load in random waypoint mobility scenario. This suggests that each network has a maximum traffic capacity after which all protocols perform poorly. Routing overhead increased in Random waypoint model due to increase in traffic load. All observations with increasing traffic load suggests that routing algorithms will perform well if is number of connections pairs are kept less than or equal to half of the traffic nodes.

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