# PERFORMANCE ANALYSIS OF UNICAST ROUTING PROTOCOL IN IEEE 802.11S WIRELESS MESH NETWORK

Aneri Fumtiwala[1], Himani Modi[2], Pinal Patel[3], Mrs.Payal T. Mahida[4]
[1,2,3,4]Department of Computer Science & Engineering
Shri S'ad Vidya Mandal Institute of Technology - SVMIT Bharuch,India.
Email: annufumtiwala94@gmail.com[1], himani.modi93@gmail.com[2], pinalprem1988@gmail.com[3], payal_mahida@yahoo.co.in[4]

**Abstract— Wireless Mesh Network is a rising technology in the wireless network world to deliver last mile broadband access. It has amazing features such as low deployment cost, easy network maintenance, robustness, wide area coverage, self-healing, self-configuring and self-organizing which are responsible for growing rapid progress of wireless mesh networks and inspiring numerous applications. In order to take the advantage of this, wireless mesh networks need the new and improved routing protocols. This paper is the analysis of unicast routing protocol such as Ad-hoc On-demand Distance Vector Routing Protocol (Reactive Routing), Optimized Link State Routing Protocol (Proactive Routing), Hybrid Wireless Mesh Protocol (hybrid Routing) on the basis of performance metric like Packet Delivery Ratio, End-to-End Delay and Bit-rate in IEEE-802.11s Wireless Mesh Network using Network Simulator 3 (NS3).**

***Index Terms*— Wireless Mesh Network, IEEE 802.11s, Unicast Routing Protocol, AODV, OLSR, HWMP, NS3, PDR, Delay, Bit-rate**

## I. INTRODUCTION

Wireless Mesh Networks (WMNs) can be considered as an integral part of Mobile Ad-hoc Networks (MANETs). MANET is a network that is composed of mobile client devices which represent fully dynamic topology whereas the WMN is a network that is composed of mobile client devices as well as routers which represents both dynamic and static topology. In order to understand mesh networking, first thing we need to understand is mesh topology. If we have n nodes which represent communication device in network, each node can communicate with other (n-1) nodes; this kind of structure is known as mesh topology. A wireless mesh network (WMN) is a promising technology composed of radio node connected through wire or wirelessly in mesh topology which provide high speed internet to end user.

WMNs have two types of nodes [1] [8]: mesh router and mesh client. A Mesh router is similar to conventional router in addition of having a capability of mesh networking. Mesh routers are a static node in mesh network which are connected to stable source of power and that is why they have less mobility. Mesh routers play the role of spine for mesh clients. Mesh Clients are devices which are dynamic in nature such as mobiles, PDAs or laptops. They have limited power compare to mesh router and basically they operate on batteries which have limited power capacity. Mesh clients can also be work as mesh router in WMN with fewer amounts of the hardware platform and software requirements and designs are much simpler than those of mesh routers. Although mesh networking consists of mesh routers and mesh clients, mesh router are also having capability of the gateway/bridge gateways are one type of router that has direct access to the wired infrastructure or Internet. As the mesh gateways can connect to wired or wireless network through multiple interfaces, so for this reason they are expensive. Therefore, a less number of Mesh gateways are used in wireless mesh network. Wireless mesh networks can be accepted with a variety of wireless technologies. The main intention at the back of the development of wireless mesh networks are to beat the restrictions of single hop communication, and consequently data packets have to navigate over multiple wireless hops. Since 2004 Task Group S has been raising an amendment to the 802.11 standard to precisely give attention to the aforementioned necessitate for multi hop communication. The IEEE 802.11 TGs has continuing to effort in developing a functionalities which help in the incorporation of WMNs with various other networks. Mesh mesh standard for local area wireless networks. [2]

[2][3]Any IEEE 802.11 based components which are either access point (AP) or station (STA) having mesh functionality or we can say carry a mesh relay function to form IEEE 802.11s mesh network. IEEE 802.11s mesh network contain: mesh station (MSTA), mesh access point (MAP), and mesh point portal (MPP). A mesh point (MP) is an either AP or STA which partially or completely bring a mesh-relay function in IEEE 802.11s mesh network. The MP performs few operations which comprise neighbor finding, channel association, and structure a relationship with neighbors. MPs have a capability of directly communicating with their neighbors and by using bidirectional wireless mesh link forward traffic on behalf of other MPS

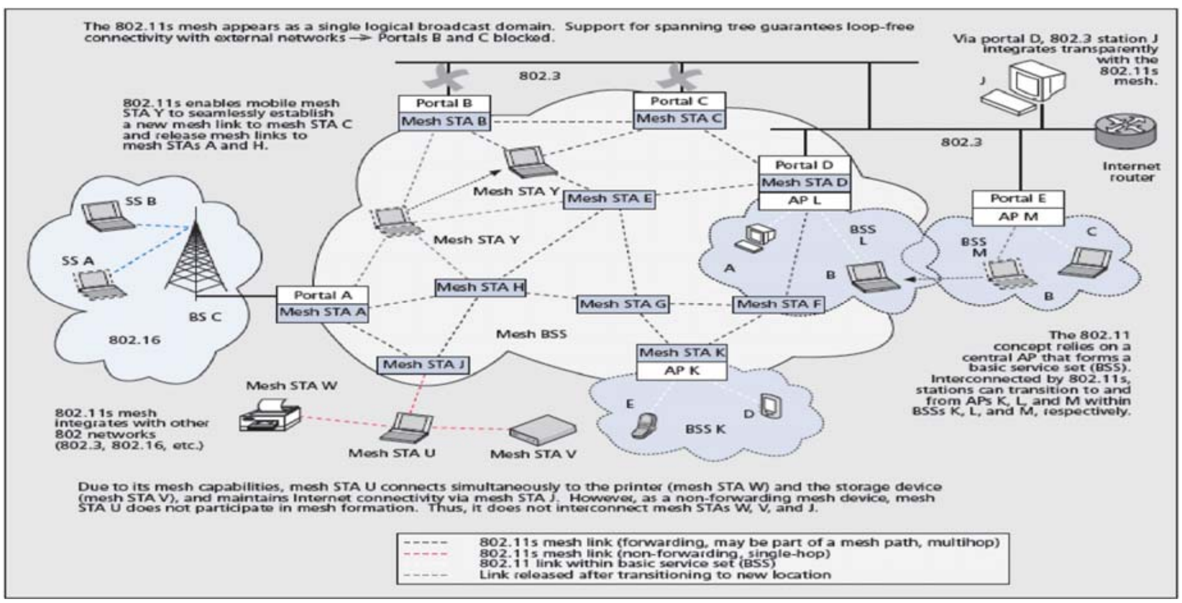


Fig. 1. IEEE 802.11s Mesh Network [2]

The BSS in traditional IEEE 802.11 is differentiated by a set of MPs and the mesh links which represents Wireless distributed system (WDS) in IEEE 802.11s mesh network. A mesh access point in IEEE 802.11s is a mesh point having functionality of access point (AP). A mesh point portal is an entity in Mesh network which allow numerous WLAN meshes to communicate with each other. An MPP can also act as the IEEE 802.11 point portal and operate as a bridge/gateway between the WLAN mesh and other type of networks in the DS.

## II. ROUTING PROTOCOL

Routing is an elementary attribute of Wireless Mesh Network (WMN). The performance of WMNs is directly affected by the strengths and weakness of routing protocols. The competing technologies can take the several advantages of WMNs by enabling the routing protocols.

Wireless Mesh Networks are the part of mobile ad-hoc networks. So routing protocol used in MANET can easily used for WMN. Still there are some differences between them. First is, most of the time all the traffic starts from gateway and trimmings ups on gateway in WMNs. Second one is nodes are clearly separated from each other either in the form of stagnant nodes or mobile nodes.

### A. *Ad-hoc On-demand Distance Vector Routing Protocol (AODV)*

[11] The Ad hoc On Demand Distance Vector (AODV) (Huhtonen 2004) is a reactive type routing protocol or on-demand protocol. In on-demand routing protocol, routes are creates and maintains only when nodes in network want to communicate with the other node in network. A node in network maintain the routing table which stores information regarding to the next hop to the preferred destination and a sequence number received from the destination, which is use for preserving the freshness of the information stored.

Algorithm: AODV routing protocol use three type of messages: Route REQuests (RREQ), Route REPlies (RREP) and Route ERRors (RERR). This protocol works in two phases: route discovery and route maintains. In a route discovery, route is initiated between two nodes only when they want to communicate. It is made by broadcasting a route request message with the destination and sequence number to the neighbors. When every node in network receives the route request message, they increase their hop metric and revised its own routing table. Upon receiving the route request message, the destination node throws a route reply message back to the source node. Route maintained is responsible for repairing a broken route or finding a new one when a route failure occurs. AODV have capability to notify the affected set of nodes when links fails. A route error message is propagated to transmitting node, so that they are able to cancel the routes using the lost link. AODV algorithm facilitates dynamic, self-configuring, self-healing, loop free, multi-hop routing between nodes which is suitable for WMN’s characteristic.

### B. *Optimized Link State Routing Protocol (OLSR)*

[12][13] The Optimized Link State Routing is a table driven proactive link state protocol. OLSR contain various optimizations that aim to drop the price of forward information in the network. In particular, for each node there is a subset of neighbors which is called the multipoint relays and is used to reduce the duplicate retransmission in the same region.

Algorithm: In order to wrap all two hop neighbor nodes, each node chooses its multipoint relay set among its one-hop neighbors. A bidirectional link is provided to each of those neighbors by OLSR. The MPR is used to occasionally broadcast information about its one-hop neighbors in the network. Each node calculates or updates its routes on the basis of this MPR selectors list. The route is made up of sequence of hops through MPRs. Each node periodically broadcasts HELLO messages containing a neighbor list and their link status in order to detect bidirectional links with neighbors. The HELLO messages permits every node to recognize the existence of neighbors up to two-hops. It also allows the selection of its MPRs. By using that information each node can construct its MPR selector table.

In routing table each node broadcasts specific control messages called Topology Control (TC), which is used to build the routing table for forwarding purposes. TC messages are sent from time to time by nodes to declare its MPR selector set. TC messages are used to maintain topology tables for each node. Because of that there is no route discovery delay and even if we do not increase the number of routes, routing overhead is still larger than a reactive protocol. If hello messages have been received freshly, OLSR assumes that a link never fails but is not always true in WMNs.

### C. *Hybrid Wireless Mesh Protocol (HWMP)*

[5][14] The 802.11s specifies the Hybrid Wireless Mesh Protocol (HWMP) which operates on the MAC layer. HWMP is a Hybrid type of routing protocol which incorporates both proactive and reactive components. HWMP use routing metric or combination of routing metric. HWMP inherit advantage of both the routing scheme that is the reactive routing provides great flexibility in dynamic environments and proactive tree based routing which is more efficient for static mesh networks. HWMP by

default uses airtime metric and can be combined with other metrics to achieve better performance.

Algorithm: The reactive mode of HWMP is based on

AODV, which works at MAC layer. AODV routing protocol use three type of messages: Route REQuests (RREQ), Route REPlies (RREP) and Route ERRors (RERR). This protocol works in two phases: route discovery and route maintains. In a route discovery, route is initiated between two nodes only when they want to communicate. It is made by broadcasting a route request message with the destination and sequence number to the neighbors. When every node in network receives the route request message, they increase hop metric of its own and revised its own routing table. Upon receiving the route request message, the destination node throws a route reply message back to the source node. Route maintained is responsible for repairing a broken route or finding a new one when a route failure

occurs. In the Proactive mode of HWMP, one of the nodes in network plays the role of ROOT node. This ROOT node periodically broadcasts proactive type PREQs. PREQs contains address field of broadcast address. After receiving such message, every node sends PREP back to ROOT node. Through this process, a tree is build and ROOT node maintains the routing table which stores all possible destinations within the network. HWMP protocol contain following elements,

1. Root Announcement (broadcast) which informs mesh points about the existence and distance of Root Mesh Point.
2. Root Request (Broadcast/Unicast) which requests the destination mesh points to structure a reverse route to the source.
3. Route Reply (Unicast) which organized a forward route to source and validates the reverse route.
4. Route Error (Broadcast) which notify about the source which no longer supports certain route for receiving mesh points.

HWMP operate in two phase:

1. Route Discovery: In HWMP, Route discovery is done by on-demand routing. Route Request packet from the source node forms the forward paths and Route Reply Packet sends from destination node forms the reverse paths.
2. Route Maintenance: In active routes, the link state of nest hops is supervised by other nodes. In the case of link fails, a Route Error message which is a broadcast message is used to notify other nodes.

## III. SIMULATION ENVIRONMENT

### A. Performance Metric

The comparison is made between aforementioned routing protocols on the basis of following performance metric.

#### 1) Packet Delivery Ratio

Packet delivery ratio is a very important factor to compute the performance of routing protocol in any network. The packet delivery ratio can be defined as ratio of the total number of data packets received at destinations and the total number of data packets sent from sources. High PDR indicate superior performance of network. Mathematically it can be shown as:

$$PDR = \frac{\Sigma \text{ (Number of RECEIVED packets)} * 100}{\Sigma \text{ (Number of SEND packets)}}$$

#### 2) End-to End Delay

Average End-to-end delay defines the time taken by a data packet to reach from source to destination through the network. The average end-to-end delay can be obtained by calculating the average of delay of successfully delivered messages. So, it is clear that end–to-end delay in some measure depends on the PDR. The probability of packet drop is depends on the distance between source and destination which is increased when distance is more between source node and destination node.

Mathematically it can be shown as:

$$\text{Delay} = \frac{\Sigma \text{ (arrive time – send time)}}{\Sigma \text{ Number of connections}}$$

#### 3) Bit Rate

The bit rate is defining as the number of bits which bypass all the way through the network from a source to destination in an agreed quantity of time, generally a second.

### B. Simulation Parameter

The network simulator NS3 version 3.20 is used to establish 802.11s mesh network.

IEEE802.11s draft3.0 was preconfigured in NS3. We have used grid topology and the result is taken by varying the number of nodes. The traffic application used is of type constant bit rate, with a maximum data rate of 50packet/sec.

TABLE I. SIMULATION PARAMETER

| Parameter | Values |
|---|---|
| Wifi Model | Yans WiFi Helper |
| Topology | Grid Topology |
| Routing Protocol | AODV,OLSR,HWMP |
| Agent | UDP |
| No. of Packets | 50 |
| Packet Size | 1024 |
| Speed | Random |
| No. of Nodes | 10,20,30,40,50 |
| MAC | 802.11s |
| Simulation Time | 240 sec |

## IV. PERFORMANCE ANALYSIS

### A. *Packet Delivery Ratio*

The fig 2 shows that performance of OLSR is better than AODV and HWMP. But when we increase the node density, performance of AODV constantly decreased. AODV gives very poor result when numbers of nodes are increased. Initially a performance of AODV is better than HWMP but after when we have increased numbers of nodes HWMP gives better performance than AODV. When there are large numbers of nodes HWMP is more preferable compare to AODV. Among these three routing protocols, performance of OLSR is the best in context of PDR.

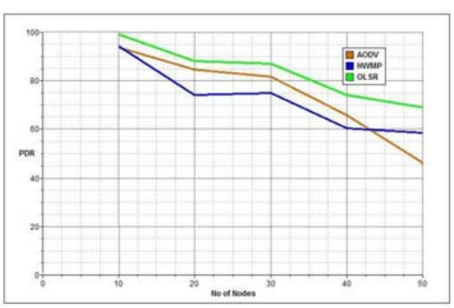


Fig. 2. No of Nodes verses Packet Delivery Ratio

### B. *End-to-End Delay*

The Fig 3 demonstrates the performance of mentioned routing protocol on the basis of End-to-End Delay. It can be clearly seen from the figure that the delay of AODV is extremely high because it is an on demand protocol, it starts route discovery whenever two nodes want to communicate. While OLSR is a table driven protocol so it updates their routing table at certain time intervals so their delays are lesser compared to AODV. OLSR has less delay than that of AODV and HWMP which remains constant even after increasing number of nodes.

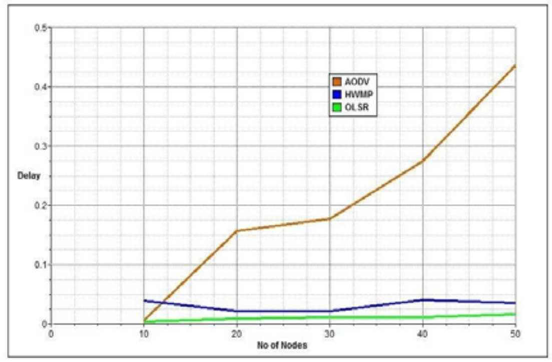


Fig. 3. No of Nodes verses End-to-End Delay

### C. *Bit Rate*

The graph of bit-rate illustrates that initially OLSR is a superior in terms of data transfer speed than AODV and HWMP. But after increasing the numbers of nodes its performance is affected. Even after increasing the numbers of nodes, its bit rate remains constant. The performance of AODV is also decreased after some time when numbers of nodes are increased to some extent.

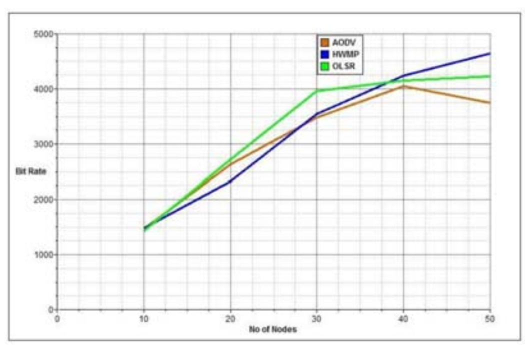


Fig. 4. No of Nodes verses Bit Rate

## V. CONCLUSION

We have evaluated performance of unicast routing protocols named as AODV, OLSR and HWMP on the basis of some metrics. First metric is a PDR which shows the reliability of protocol. In terms of PDR, performance of OLSR is better than AODV and HWMP. AODV gives very poor result when numbers of nodes are increased. Second is End-to –End Delay, AODV having extremely high delay in compare to OLSR and HWMP. OLSR has less delay than that of AODV and HWMP which remains constant even after increasing number of nodes. Third one is bit rate; initially OLSR is a superior in terms of data transfer speed than AODV and HWMP. But after increasing the numbers of nodes its performance is affected. The performance of AODV is decreased after some time when numbers of nodes are increased to some extent.

We conclude that In WMN, OLSR is superior to HWMP and AODV in terms of PDR and End-to-End delay. If we want more data transfer speed than we can also go for HWMP instead of OLSR. But the performance of HWMP is not as better than OLSR in terms of PDR. The delay rate of HWMP is tolerated if we want more data transfer speed. The performance of AODV is very poor than HWMP and OLSR.

REFERENCES

[1] Ian F. Akyildiz, Xudong Wang, and Weilin Wang, “Wireless Mesh Networks: A Survey”, Computer Networks, March 2005.

[2] Guido R. Hiertz, Sebastian Max, Rakesh Taori,Javier Cardona, Lars Berlemann and Bernhard Walke, “IEEE 802.11s: The WLAN Mesh Network”, IEEE Wireless Communications, February 2010

[3] Myung J. Lee And Jianliang Zheng, Young-Bae Ko And Deepesh Man Shrestha “Emerging Standards For Wireless Mesh Technology”, IEEE Wireless Communications, April 2006

[4] Camp, J.D., Knightly, E.W., “The IEEE 802.11s Extended Service Set Mesh Networking Standard”, IEEE Communications Magazine, August 2008

[5] Xudong Wang and Azman O. Lim, “IEEE 802.11s wireless mesh networks: Framework and challenges”, Ad Hoc Networks, August 2008

[6] S. M. Faccin et al., “Mesh WLAN Networks: Concept and System Design”, IEEE Wireless Communication, April. 2006.

[7] S. Waharte, B. Ishibashi, R. Boutaba, “Performance Study of Wireless Mesh Networks Routing Metrics”, Computer Systems and Applications, April 2008.

[8] Er.Pushpender Sarao , Dr. Sohan Garg, Prof. (Dr.) YashPal Singh “Wireless Mesh Networks: WMN Architecture, Issues and Challenges”, International Journal of IT, Engineering and Applied Sciences Research (IJIEASR), September 2013.

[9] NS-3, http://www.nsnam.org

[10] Venkat Mohan.S, Dr. Kasiviswanath.N, “Routing Protocols for Wireless Mesh Networks”, International Journal of Scientific & Engineering Research, August-2011

[11] C. Perkins, E. Belding-Royer, and S. Das, “Ad Hoc on-Demand Distance Vector (AODV) Routing”, IETF RFC 3561, July 2003.

[12] Thomas Clausen and Philippe Jacquet, “Optimized Link State Routing Protocol (OLSR)”, IETF RFC 3626, October 2003

[13] Christopher Dearlove, ThomasClausen and Philippe Jacquet, The Optimized Link State Routing Protocol version-2, IETF draft, September 2009

[14] Md.Shariful Islam, Md. Abdul Hamid, Choong Seon Hong, “A Secure Hybrid Wireless Mesh Protocol for IEEE802.11s Wireless Mesh Networks”, December 2009