

# Performance Comparison of AODV, OLSR and OFLSR in Wireless Mesh Networks

**Mr.Sikander Singh\*, Mr. Sukhwinder Singh Sran\*\*,Dr. Tirlok Chand\*\*\***

**\*Punjab Engg. College (Deemed University), Chandigarh,**

**\*\*Baba Banda Singh Bahadur Engg. College, Fatehgarh Sahib.**

**\*\*\*CSE Department, Punjab Engg. College, Chandigarh**

*Abstract- Wireless mesh networks are the next step in the evolution of wireless architecture, delivering wireless services for a large variety of applications in personal, local, campus, and metropolitan areas. Unlike WLANs, Mesh networks are self-configuring systems where each Access Point (AP) can relay messages on behalf of others, thus increasing the range and available bandwidth. Despite recent advances in wireless mesh networking, many research challenges remain in all protocol layers. To use existing protocols in wireless mesh network we have to add more features in existing protocols so that they become suitable for use in wireless mesh network. In this paper, We present a detailed simulation study of the performance of the predominant mesh routing protocols being considered in IEEE 802.11s: Ad Hoc On Demand Distance Vector (AODV) and optimized Link State Routing Protocol (OLSR). Moreover, for large-scale wireless mesh networks, we gracefully integrate advantages of OLSR and Fisheye routing protocol (FSR). Results show that OFLSR provides better scalability in terms of traffic load and host mobility than AODV in mesh networks.*

Keywords – AODV, OLSR, OFLSR, wireless mesh network, IEEE 802.11s

## I. INTRODUCTION

The ad hoc wireless networking technology has been gaining increasing visibility and importance in distributed applications that cannot rely on a fixed infrastructure but require instant deployment, dynamically self-organizing and self-configuring. A wireless mesh network, as a variant of Mobile Ad hoc Networks (MANET), is an IEEE 802.11-based infrastructure network in which Access Points (APs) and stations (STAs or hosts) can relay messages on behalf of other APs in ad hoc fashion to create a self-configuring system that extends the coverage range and increases the available bandwidth. The wireless mesh is functionally equivalent to the standard IEEE 802.11 infrastructure network with respect to the stations relationship with the Basic Service Set (BSS) and Extended Service Set (ESS). The novelty is that, if the source and the destination station are not in the same BSS domain, the source AP does not forward the packet to all the APs in the ESS but the packet is sent along a APs/STAs path to reach the destination station. The STAs with relay capability and the mesh APs are called Mesh Points (MPs). Mesh network can be view as a multi-hop ad-hoc, packet switching and

forwarding network between MPs in the same ESS. The Wireless Distribution System (WDS) uses an extension of the IEEE 802.11 MAC/PHY to provide a protocol for autoconfiguring paths between MPs in a multi-hop topology, supporting broadcast, multicast and unicast traffic. Mesh network is self-organizing and simple enough so that users are able to deploy, and maintain with limited technology experience. Mesh networking technology also provides numerous and unique capabilities that can facilitate the deployment of public access wireless networks, as it enables higher reliable Internet access services by providing a fault tolerant infrastructure and redundant access links with respect to traditional wired methods. Moreover, wireless mesh networks enable advanced applications/services through ubiquitous access and reliable connectivity. Recently, an IEEE working group, named 802.11s, has been focusing on how to enhance current IEEE 802.11 standard with routing/forwarding functionality to achieve better efficiency and bandwidth utilization. IEEE 802.11s standard will be built upon the existing IEEE 802.11a/b/g technologies and it will use QoS features of IEEE 802.11e and security features of IEEE 802.11i. It will have extra forwarding functions to allow wireless MPs to discover each other, authenticate and establish connections, and to work out the most efficient route for a particular task. Each node of the network can be mobile, thus, the dynamic discovering and updating of routing information, is unarguably one of the critical challenges for wireless mesh networks. The IEEE 802.11s working group is taking into account several MANET routing protocols. In particular they are evaluating different categories of routing performance, such as Ad Hoc On Demand Distance Vector (AODV) [1] and Optimized Link State Routing Protocol (OLSR) [4], which are based on on-demand and table-driven forwarding technique, respectively. In past years, many researchers have compared the previously mentioned protocols considering a standard wireless ad hoc network [10], [11], [12], [13]. However, wireless mesh networks are different from the traditional ad hoc networks in that only MPs are wireless connected in ad hoc fashion. The STAs views the network as an infrastructure network and they can move between different APs. Some of the MPs, named Portals, have two interfaces and they are participating as gateways for Internet connection. Therefore, it is of practical importance to re-evaluate those ad hoc routing protocols and propose suitable routing protocols in the wireless mesh environment.

As we will explain in next Section, scalability is another critical issue in wireless mesh networks. In this paper, in order to improve the scalability of the routing performance in wireless mesh network, we analyze an extension of OLSR routing protocol, called Optimized Fisheye Link State Routing (OFLSR) [17] to reduce routing overhead, then compare OFLSR with AODV in terms of packet delivery ratio, throughput, routing overhead and packet end-to-end delay. We choose to compare these two algorithms since these are the ones currently interested by the IEEE 802.11s working group.

## II. RELATED ROUTING PROTOCOLS

First we briefly review the most popular ad hoc routing protocols that are the direct candidates for the routing protocol in wireless mesh networks, and then analyze their characteristics and propose a routing protocol suitable for small/large-scale wireless mesh networks. Traditional ad hoc routings can be divided into two categories: on-demand (or reactive) and table-driven (or proactive) protocols. In reactive protocols, a route path is established only when a node has data packets to send. Some of the best known on-demand protocols are Ad-hoc On-demand Distance Vector routing (AODV) [1], Dynamic Source Routing (DSR) [2] and Temporary Ordered Routing Algorithm (TORA) [3]. In contrast to the on-demand routings, proactive routing protocols continuously update regardless of the traffic activity in the network. Normally, each node generates control messages periodically and/or in response topology changes. Some popular proactive routings include Optimized Link State Routing Protocol (OLSR) [4], Destination Sequence Distance Vector routing protocol (DSDV) [5], Wireless Routing Protocol (WRP) [6] and Cluster-head Gateway Switch Routing (CGSR) [7] are the most popular table-driven protocols for mobile ad hoc networks. However, all these routing protocols do not scale well because they periodically propagate routing information of all nodes throughout the whole network. Further the traditional routing schemes, geographic routing [8], [9] has been proposed. With this scheme, packets are forwarded by only using the position information of nodes in the vicinity and the destination node. Thus, topology change has less impact on the geographic routing than other routing protocols. It is more scalable since it only demands local states for communication without end-to-end path setup. However, geographic routing relies on the existence of GPS or similar positioning technologies, which increase cost and complexity of wireless mesh networks. Meanwhile, it needs the Geo-location service for the destination. All these issues increase the complexity of devices and routing protocol. Therefore, we do not consider the geographic routing in the paper. In this paper, we investigate the impact of reactive routing protocol AODV and proactive routing protocol OLSR in wireless mesh networks. The choice of the two algorithms is due to the fact that these two routing schemes have the dominant role in the ad hoc networks, and the working group IEEE 802.11s is currently

focusing on these two protocols, or variation of them, to understand the advantages of both the strategies in the mesh environments. In the following we review the two protocols. As reactive routing protocol, AODV reacts relatively quickly to the topological changes in a network and updates only hosts that may be affected by the change. However, AODV tends to cause heavy overhead due to the flood search triggered by link failures. As a result, AODV does not perform well in heavy load or mobile networks. Optimized Link State Protocol (OLSR) is a proactive routing protocol that is an optimized version of a pure link state protocol by applying Multipoint Relays (MPR) [14] concept. The idea of MPR is to reduce flooding of broadcast packets by shrinking the number of nodes that retransmit the packets. OLSR does not scale well because the routing information are propagate to all the nodes in the network. In case of large network or mobile nodes, more updates are required to keep the information up to date, thus producing a large amount of control overhead. In wireless mesh networks, Mesh Points (MPs) usually have minimal mobility, while STAs can be stationary or mobile. If a STA moves into another Mesh AP and AODV is used as the routing protocol, the STA needs to flood the network again to discover a new path. Therefore, AODV will incur excessive routing overhead. In contrast, with proactive routing protocols, the host can find the path immediately without finding a new route after moving into another mesh router's coverage. Thus, in the paper we propose to adopt the OLSR. In addition, to overcome the drawback of the scalability problem of OLSR, we enhance OLSR protocol with Fisheye (FSR) concept [15], [18]. FSR is a proactive routing protocol based on link state routing that maintains a full topology map at each node and information about closer nodes are exchanged more frequently than the ones about farther nodes. So each node has the most up-to-date information about all nearby nodes and the accuracy of information decreases as the distance from node increases. Although a node does not have accurate information about far away nodes, the packets will be routed correctly because the route information becomes more and more accurate as the packet gets closer to the destination. The advantage of FSR is that it scales well to large networks as the overhead is controlled by different updating frequencies.

*Fisheye State Routing* - Fisheye State Routing (FSR) belongs to the class of proactive (table-driven) ad hoc routing protocols and its mechanisms are based on the Link State Routing protocol used in wired networks. It tries to minimize the routing overhead by using a fisheye technique. Each node assigns other network participants to specific fisheye scopes dependent on their distance to the node itself. The amount of routing information is reduced by assuming longer link-state update intervals for nodes at higher distances than for network participants in the node's vicinity. Thus, FSR is intended to scale well in large mobile ad hoc networks and supports high rates of mobility.

*Optimized Fisheye Link State Routing (OFLSR)*-Optimized Fisheye Link State Routing (OFLSR) protocol combines two existing routing protocols: Optimized Link State Routing (OLSR) and Fisheye State Routing (FSR). As mentioned before, OLSR is based on MPR flooding technique to reduce the number of retransmissions of topology broadcast packets as compared to classical flooding mechanisms, where each node forwards all received non-duplicate packets. In OLSR, a node (selector) independently chooses a minimal subset of its 1-hop neighbors to cover all its 2-hop neighbors to act as multipoint relaying nodes. The process is based on information acquired through HELLO messages which are containing lists of its neighbors' links. When a node sends/forwards a broadcast Topology Control (TC) message, containing the topology information necessary to build the routing tables, only its MPR nodes forward the message reducing duplicate retransmissions. However, we observe that OLSR still causes a lot of routing overhead due to forwarding TC messages, which consumes too much bandwidth resource. Thus, OFLSR limits the flooding of the TC message by adopting FSR technique since a source only needs to know the approximate route towards the destination far away. We propose to have different frequencies for propagating the TC message to different scopes so that the fisheye scope technique allows exchanging link state messages at different intervals for nodes within different fisheye scope distance, leading to a reduction of the link state message size. By this way, a lot of overhead can be saved in large scale mobile ad hoc networks, resulting in improved performances. To apply the Fisheye concept into OLSR, we need to define several terms: Scope, Scope Width (SW), Scope Levels (SL). The Scope is defined in terms of the minimum number of hops needed to reach a certain node. Each node divides the network into different scope levels based on its local view. Then, different TC packet propagation frequencies are defined for each scope. The Scope Width (SW) defines how wide one scope is in terms of number of hops. The Scope Levels (SL) defines how many levels of scopes are specified.

### III.PERFORMANCE EVALUATION

#### *Simulation Environment*

We conduct simulation experiments using the network simulator ns2[16]. In our simulation study, the maximum speed is varied from 0m/s to 10m/s. The source-destination pairs are randomly selected among all nodes in the network. Traffic sources are CBR (constant bit rate) or TCP. For each TCP session packet size is 1460 bytes. For each CBR session, the packet size is 512 bytes and packet rate is 4 packets per second. The number of session pairs is varied to change the traffic load injected into the mesh network. In OFLSR, the reduction of routing update overhead is obtained by using different exchange periods for different entries in routing table. More precisely, entries corresponding to nodes within the smaller scope are propagated to the neighbors with the highest frequency.

When network size grows large, the update message could consume considerable amount of bandwidth, which depends on the update period. In order to reduce the size of update messages without seriously affecting routing accuracy, we simply define three scopes for 2, 4 and 6 hops respectively, corresponding to scope width 2 and scope level 3 in our simulations. Of course, the number of levels and the radius of each scope depend on the size of the network and mobility speed. We are interested in doing further study to see the effect of those parameters on OFLSR performance in the near future. Moreover, to simulate routing protocols for wireless mesh networks, only MPs are allowed to exchange routing update messages with each other, and a host information is embedded in the routing message sent from its associated AP. In the following we will mainly show results ranges from 0 - 4 m/s because results for other host speeds are similar.

#### *Wireless Mesh Networks*

We report the aggregate effective delivery ratio as a function of offered load over AODV and OFLSR respectively. As the offered load increases, the aggregate delivery ratio decreases for both routing protocols because of the increased interference and contention. However, the performance over AODV drops sharply, while the delivery ratio of OFLSR degrades gracefully for the increasing traffic load. The aggregate delivered throughput results confirm again the resilience of OLSR to increasing load. In fact, they show that OFLSR clearly outperforms AODV when traffic load (number of traffic pairs) is large. Note that the aggregate throughput of AODV first increases with the number of flows, while decreases when the number of flows further increases. AODV generates remarkable less routing overhead than OFLSR for a few CBR sessions, thus AODV can achieve better throughput for more flows. However, when traffic load further increases, AODV generates much more routing overhead for finding routes and repairing link breakages. Therefore AODV first increases the throughput, and then tends to reach a saturation point according to the network conditions. After the peak point, AODV performs worse for more injected traffic. In contrast, the throughput consistently increases over OFLSR, which means the saturation point of OFLSR is way beyond AODV. All the simulation results consistently proved that when compared with AODV, OFLSR exhibits a much better scalability of traffic loads. Generally, when there are just a few CBR sessions, AODV generates less routing overhead than OFLSR, and achieves better performance in terms of delivery ratio and routing overhead. Things change drastically when load increases. AODV overhead increases considerably with the increase of traffic load at any speed. In AODV the destination node generally replies with a single RREP per route discovery. However, if the RREP is not received, another RREQ is sent, up to a maximum RREQ retries. For each new attempt, the timeout is doubled (binary exponential backoff). In the process, packets are dropped (due to overflow), or stored for future forwarding - but this generally leads to almost certain loss. After the maximum number of

retries, all packets are dropped. To make things worse, when traffic load increases, congestion forces nodes to declare links failed although the links still exist. This leads to more routing overhead for repairing broken links. Consequently, the control overhead grows very rapidly in AODV when load increases. This growth is directly related to the throughput drop. In AODV the numbers of broadcast routing update packets grows orders of magnitude faster than that of OLSR control packets. In fact, in OFLSR, the number of control packets is a constant because of the nature of proactive routings. It is independent of number of traffic pairs. Thus, when the number of traffic pairs increases, the aggregate routing overhead does not change. One may still wonder why the AODV control load is lower than OLSR, yet the throughput is lower. For example, for 40 CBR sessions, AODV overhead is half that of OLSR, but AODV throughput is also one half! This is contrary to the perception that throughput reduction is due to the fact that control overhead “steals” channel capacity. There are two reasons why this simple argument does not hold here. First, AODV routing protocol is less efficient at high load, so, it is not just a matter of “stolen capacity”, rather of inefficient use of capacity. Secondly, the OLSR overhead is spread over “all” network links periodically and constantly, while AODV control overhead is concentrated on the links actually used by data. Thus, on active links, the ratio of routing overhead versus data might be higher for AODV than for OLSR even though the aggregate overhead may be lower. We have judged average end-to-end packet delay over AODV and OFLSR respectively when host mobility is 4 m/s. AODV gives much longer packet delivery delay than OFLSR because of route setup/repair latency and queue built-up by burst routing flood in the wireless mesh network. In contrast to AODV, the packet delay in OFLSR is robust to the increasing traffic load.

#### *Wired and Wireless Mesh Networks*

A wireless mesh network is often hooked up with wired networks (e.g. Internet) and therefore the hook spots, the portals, become the most congested points. It is extremely important to study the performance of AODV and OFLSR in such scenarios. In this subsection, we study the performance of the protocols OFLSR and AODV with 6 selected APs as portals gateways on the edges of a wireless mesh networks. Through these portals, all STAs in the wireless mesh network are able to communicate with other nodes in wired networks. In this set of experiments, the sources of CBR/TCP sessions are randomly selected among all mobile hosts and a portal is randomly selected as a destination of one session. Each portal has same number of connections. Among these connections, half of them are CBR connections and half are TCP. Again, OFLSR has significant better delivery ratio than AODV. Similar with what we have observed, in OFLSR, varying traffic load and mobility have no much impact on the routing overhead compared to AODV. Thus, OFLSR still maintains

much better scalability to traffic load and mobility in hybrid wireless-wired networks.

#### CONCLUSION AND FUTURE WORK

In this paper we have studied the impact of routing protocols for wireless mesh networks. We note that both on-demand and table-driven routing protocols work very well in wireless networks with small traffic load. However, when the traffic load and the mobility increase, the selected on-demand routing protocol like AODV, is not scalable. On the contrary, the proposed tabledriven routing protocol OFLSR, always provides a better performance in terms of data packet delivery ratio, throughput, packet latency and routing overhead, under different traffic and mobility instances. Other important requirements of mesh networks include not only scalability for load and mobility, but also quality of service, security and energy efficiency. We plan to address them with an extension of OFLSR to make it more efficient and suitable for providing all requirements of wireless mesh networks in the future work.

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