Performance Evaluation of Routing Protocols in Wireless Mesh Network

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***Abstract*—Wireless mesh network has been considered as a viable solution to offer broadband connectivity to rural community due to its ability to provide extended coverage and scalable deployment. However, there are still impediments that need to be addressed in terms of throughput degradation, latency and interference due to multi hop transmission and potential isolated nodes. In this contribution, an investigation of suitable routing protocol in the context of providing rural broadband communication is presented by evaluating various of routing approaches, namely reactive, proactive and hybrid routing protocols. Specifically, performance analysis was simulated for ad hoc on demand distance vector (AODV), optimized link state routing (OLSR) and hybrid wireless mesh protocol (HWMP). The impacts of traffic loads, number of sources and the network size on wireless mesh network have been investigated through the simulation. HWMP has a clear advantage compare to AODV and OLSR in terms of maximizing throughput and minimizing end to end delay.**
Keywords: Wireless mesh networks, routing protocols, AODV, OLSR, HWMP.

I. Introduction

At presents, almost one third of the worldwide population will soon be online since the number of Internet users keeps on increase [1]. Hence, connecting the unconnected is a must as to fulfill the global desires. Unfortunately, internet availability is low and inaccessible in several rural areas. Survey results point out that there are 93% TV viewers, 90% mobile phone users, 60.9% radio listeners and 63.4% newspaper readers while only 6% Internet user [2]. In urban and rural area, wireless mesh networks (WMN) have the potential to provide ubiquitous and high-speed broadband access to both fixed and mobile users, with low operation and management costs. WMNs most promising application is to provide access to information where wired infrastructure is difficult or economically infeasible to deploy specifically in rural area. WMN in the context of rural areas is suitable for its features such as high scalability, cheap-to-deploy and ease-of-maintenance [3].

In general, WMN routing protocols can be classified as proactive, reactive and hybrid. Proactive routing protocols maintain routes to all destinations, regardless of whether these routes are needed or not. It may waste the bandwidth since control messages are sent out unnecessarily when there is no data traffic. Reactive routing protocols only set up a route between a source and its destination when required. While, hybrid routing protocols combine both reactive and proactive routing to increase the overall scalability in the networks. In this paper, we focused on Ad hoc On demand Distance vector (AODV), Optimized Link State Routing (OLSR) and Hybrid Wireless Mesh Protocol (HWMP) routing protocol as they represent the reactive, proactive and hybrid routing protocols in WMN respectively.

The rest of the paper is organized as follows. Descriptions about routing protocol in WMN are discussed in Section II. Section III elaborates the simulation environment and the simulation result are analyzed and discussed in Section IV. The conclusion for this simulation is drawn in Section V.

II. Routing Protocols in Wireless Mesh Networks

Three types of routing protocols have been evaluated in this paper, namely AODV, OLSR and HWMP. In this section the mechanism of each routing protocols are explained.

A. Ad hoc On-demand Distance Vector (AODV)

AODV is a reactive routing protocol that based on Dynamic Source Routing (DSR) and Destination Sequenced and Distance Vector (DSDV) [4]. It discover route on as needed basis via a route discovery process. In contrast to DSR, AODV adopts traditional routing tables; one entry per destination while DSR preserves multiple route cache entries for each destination. AODV provides loop free routes in case of link breakage but it does not require global periodic routing advertisement. Route discovery and maintenance for AODV are explain in the following paragraphs.

1) Route Discovery: A route discovery is commencing once a source node without any valid route in its routing table wants to send a packet to some destination. At first, it will broadcast a route request (RREQ) packet to its neighbors, which then forwards the request to their neighbors and so on. The source node use an expanding ring search technique to control network wide broadcasts of RREQ. When the destination node or the in-between node with a route to the destination receives an RREQ message, it sends a route reply (RREP) in the reverse route. The communication path is established once the source node receives an RREP.

2) Route Maintenance: Once the route is established between the source and destination, it remains as long as the source needed. It can reinitiate the route discovery to find out a new route to destination if the source node moves during active session. On the other hand, if the destination or the in-between node moves, the affected active upstream neighbors will receive route error (RERR) message. These nodes in turn propagate the RERR to their precursor nodes, and so on until reaches the source node. The affected source node may choose either to stop sending data or reinitiate new RREQ for that destination.

B. Optimized Link State Routing (OLSR)

OLSR is a type of proactive link-state routing protocol [5]. It updates topological information in each node in the network periodically. Specifically, constant and low control traffic overhead topological information is flooded to all nodes in the network, providing routes immediately available regardless of data load and node mobility causing link breakage.

There are three generic elements in OLSR namely a mechanism for neighbor sensing, a mechanism for efficient flooding of control traffic, and a specication of how to select and diffuse sufficient topological information in the network in order to provide optimal routes. These elements are described in details in the following.

1) Neighbor Sensing: Neighbor sensing is the process through which a node detects changes to its neighborhood. In OLSR, a node will emits HELLO-messages periodically. Changes in the neighborhood are detected from the information in these messages. A HELLO-message contains the emitting nodes own address and the list of neighbors known to the node, including the status of the link to each neighbor.

A node thereby informs its neighbors with which neighbors, and in what direction(s) communication has been confirmed. A node can consequently gather information describing its neighborhood, as well as the quality of the link upon receiving the HELLO-message. The information set are maintained on each node and valid for limited time period of time. Periodical sensing is required as to remain the validity of the information.

2) Generic message flooding: OLSR introduces a generic way of flooding control traffic to all nodes in the network. OLSR retransmit control messages by using only selected nodes. It significantly reduces the number of retransmission required to flood a message to all nodes in the network hence minimizing the overhead.

For computing optimal routes from a node to any reachable destination, OLSR requires only partial link state to be flooded with the purpose of providing shortest path routes. Additional topological information, if present, may be utilized e.g., for redundancy purposes.

3) Topology Information: The final task for routing algorithm is to diffuse a sufficient set of topological information to all nodes in the network. All nodes with Multipoint Relay (MPR) selector set periodically generate a topology control message (TC message). It will be diffuse to all nodes in the network. The topology information in each node is valid for a limited period of time, and must be refreshed periodically to remain valid.

C. Hybrid Wireless Mesh Protocol (HWMP)

HWMP is a hybrid routing protocol that combines the flexibility of on demand routing with a proactive topology extension. The on-demand primitives are based on those of the AODV routing protocol [6]. On the other hand, the proactive component is based on a distance vector protocol.

HWMP is the default routing protocol in IEEE 802.11s in MAC layer. It uses airtime link metric as the default link metric computation method for the path selection in IEEE 802.11s [7]. This airtime link metric is a radio-aware routing metric. By transmitting a frame over the particular wireless link, the metric can measure the amount of channel resources consumed. Four information elements are specified in HWMP which are the root announcement (RANN), path request (PREQ), path reply (PREP), and path error (PERR). All other information elements of HWMP contain three important fields: destination sequence number (DSN), time-to-live (TTL), and metric except for PERR. DSN and TTL prevent the counting to infinity problem, and the metric field helps to find a better routing path than just using hop count.

In reactive routing mode, the process is similar to AODV RREQ packets. A PREQ is broadcast by a source Mesh Point (MP) to a destination MP. Whenever the received PREQ corresponds to a newer or better path to the source, MPs will rebroadcast the updated PREQ. Similarly, the requested destination MP will respond with a path reply message (PREP). If the intermediate MP has no path to the destination MP, it just forwards the PREQ element further.

Mainly, a large proportion of the traffic will be destined for only one or only a few mesh points in a wireless mesh network that offers access to a wired infrastructure and the Internet. Proactive routing to the mesh portals is useful in this kind of usage scenarios. A proactive tree-based routing mode is build with the same distance vector methodology as used in Radio-Metric AODV (RM-AODV). In the proactive PREQ mechanism, the root node periodically broadcasts a PREQ element. An MP in the network receiving the PREQ creates/updates the path to the root, records the metric and hops count to the root, updates the PREQ with such information, and then forwards PREQ. Thus, the presence of the root and the distance vector to the root can be disseminated to all MPs in the mesh. In the proactive RANN mechanism, the root node periodically floods an RANN element into the network. When an MP receives the RANN and also needs to create/refresh a route to the root, it sends a unicast PREQ to the root. When the root receives this unicast PREQ, it replies with a PREP to the MP. Thus, the unicast PREQ forms the reverse route from the root to the originating MP, while the unicast PREP creates the forward route from the originating MP to the root.

III. Simulation Environment

The purpose of this simulation is to analyze the performance of different routing protocols in WMN environment. In this simulation, we used Qualnet 5.2 [8], a software that provides scalable simulations of wireless networks. We consider a network of 100 static nodes that are placed randomly within 800 m x 800 m area as shown in Fig.1. Each scenario was simulated operating over 500 seconds. The collected data is averaged over those runs.

TABLE I: Simulation Parameters

Description	Value
Network Simulator	Qualnet 5.2
Routing Protocol	AODV, OLSR and HWMP
$Hello^{OLSR}$ Interval	2s
TC^{OLSR} Interval	5s
Number of Nodes	10,20,...100
Simulation Time	500 s
Simulation Area	800 m x 800 m
Tx Range	250 m
Data Type	CBR
Traffic Source/Destination	Random
Data Packet Size	512 bytes
Number of Item to Send/per seconds	10,20,...100
Radio Type	IEEE 802.11a/g
MAC Protocol	IEEE 802.11 DCF
Broadcast Data Rate	54 Mbps
Path Loss model	Two-ray propagation

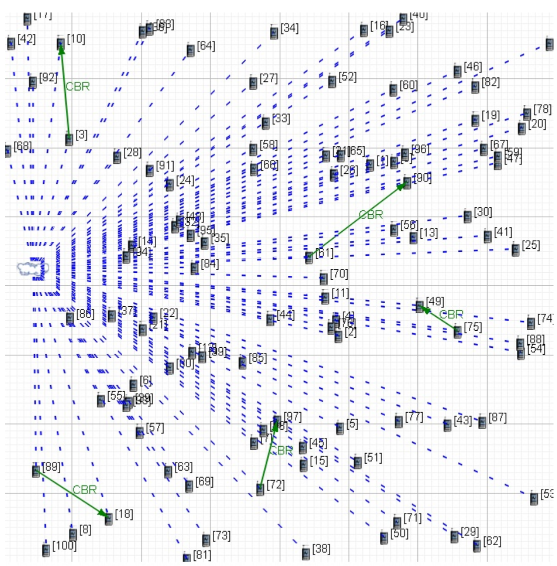

Fig. 1: Simulated wireless network having 100 nodes and 5 CBR sources with random placement using Qualnet 5.2.

802.11a/g is used as the radio type and 802.11s as the MAC protocol. The broadcast data rate in this simulation is 54Mbps with Constant Bit Rate (CBR) traffic source, sending at a rate of 1 packet per seconds. The packets with 512 bytes size is scheduled on a first in first out (FIFO) basis. A constant shadowing model with two-ray propagation path loss model is used in this simulation. Details on simulation parameters are tabulated in Table I.

The performance of the routing protocol in WMN were evaluated by using several routing metrics. Specifically, two different quantitative metrics were employed, namely throughput and average end to end delay. Throughput is measured in term of bit/s. It is the total amount of data receiver, R receives from the sender divided by the time it takes for R to get the last packet. Average end to end delay is the average time needed for all data packets to be delivered from source to destination.

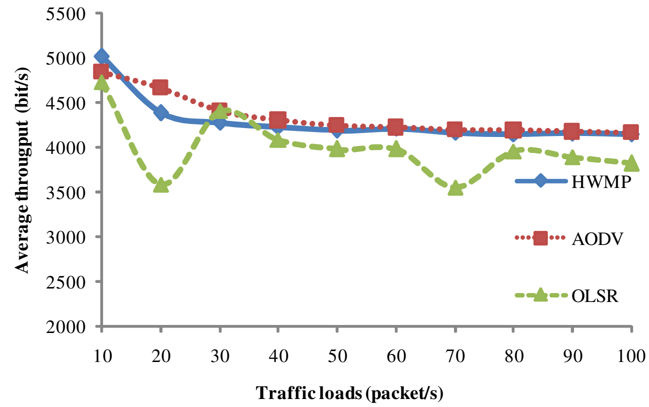

Fig. 2: Average throughput comparison for AODV, OLSR and HWMP for varying traffic loads

IV. Results and Discussions

The performance of AODV, OLSR and HWMP routing protocol was evaluated by varying the number traffic load, network size (number of fixed nodes) and number of sources. Simulation results are discussed in the following.

A. Traffic Loads

Traffic load is varied from 10 packet/s to 100 packet/s with 100 fixed nodes are placed randomly within 800 m x 800 m area. Fig. 2 shows the performance of the three routing protocol in terms of average throughput with various number of traffic loads. From the graph illustrated, the average throughput of all three routing protocols are decreasing as the number of traffic loads increased. OLSR protocol attained lowest throughput as the number of traffic loads increased compared to the other two protocols. The protocol does not require reliable transmission of control messages [5]. Each node sends control messages periodically, and can therefore sustain a reasonable loss of some such messages.

Fig. 3 depicts the average end to end delay induced in the network. It can be observed that HWMP obtained the lowest average end to end delay throughout the simulation as compared to AODV and OLSR. The average end to end delay for HWMP is approximately 2 miliseconds and almost consistent throughout the simulation as the traffic loads increased. OLSR recorded between 40 to 100 miliseconds average end to end delay and it varies as the traffic loads increased. This is the highest in compare to AODV and HWMP due to the required overhead to broadcast control signal. Based on the results, we can conclude that traffic loads have influenced the performance of the routing protocol.

B. Network Size (number of nodes)

We varied the number of nodes in the scenario from 10 to 100 nodes. 5 sources of CBR traffic sending at 100 packets per seconds are place randomly in 800 m x 800 m area. For 10 nodes, all three protocols illustrate slightly similar value of throughput as shown in Fig. 4. However, as the

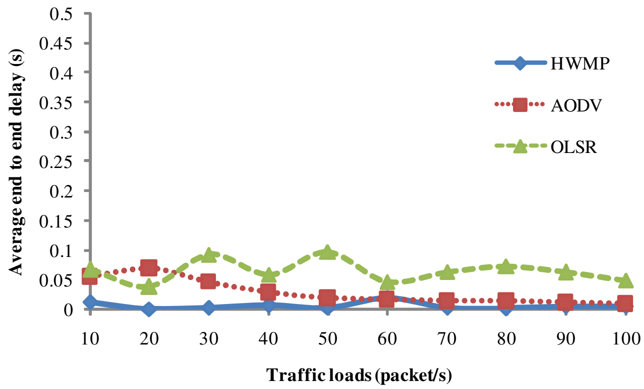

Fig. 3: Average end to end delay comparison for AODV, OLSR and HWMP for varying traffic loads

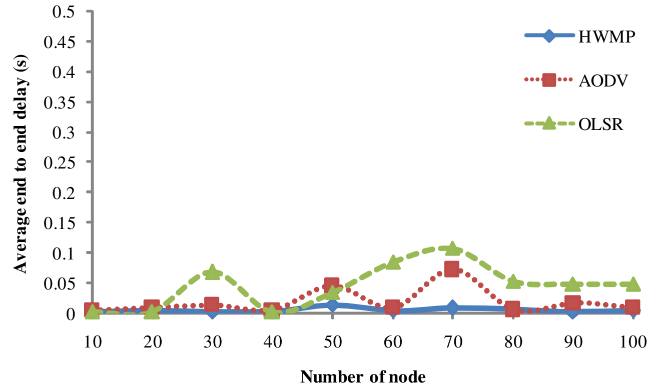

Fig. 5: Average end to end delay comparison for AODV, OLSR and HWMP for varying number of nodes

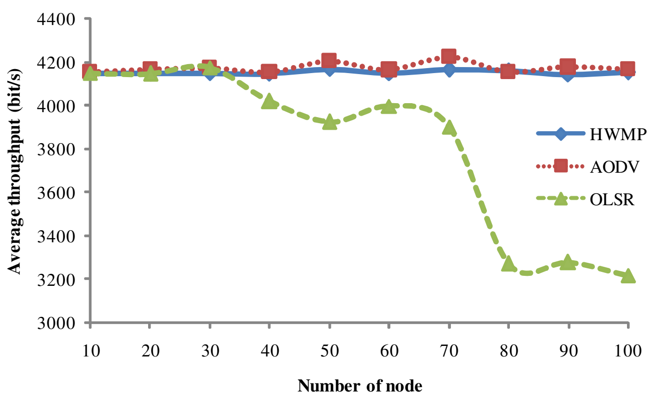

Fig. 4: Average throughput comparison for AODV, OLSR and HWMP for varying number of nodes

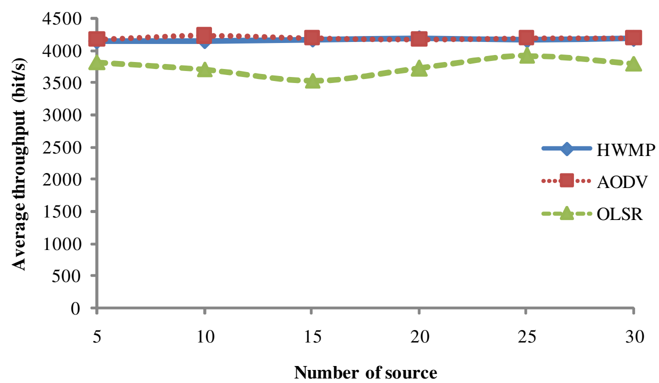

Fig. 6: Average throughput comparison for AODV, OLSR and HWMP for varying number of source

number of node increases, the throughput for OLSR protocol is reduced. This performance degradation is mainly due to the increasing network size and packet losses within the networks. It should be noted that HWMP and AODV provides better throughput performance in comparison to OLSR, by sustaining approximately consistent throughput even when the number of nodes are increasing. OLSR suffers the most as the proactive routing protocol unable to performs link state update efficiently in large network.

Fig. 5 demonstrates the average end to end delay from the source to the destination. The network sizes are getting larger as the number of nodes increased. This in turn results in the increasing of the average end to end delay as the network size grows. Both AODV and OLSR attained approximately between 2 to 100 miliseconds of average end to end delay throughout this simulation. The poor end to end delay of both protocols is mainly attributed by large network size, thus, both routing protocol incapable to carry out the load efficiently. Conversely, HWMP achieved a constant lowest average end to end delay which indicates that the protocol can be applied in a large networks.

C. Number of Sources

Next, we varied the number of CBR traffic sources with fixed number of packet sending at 100 packet/s. Number of CBR traffic source is varied from 5 to 30. As in Fig. 6, the throughput pattern of the three routing protocols are approximately similar. However, OLSR obtained the worst throughput as compared to the other two protocols due to some packet losses that occur frequently in radio networks due to collisions or other transmission problems. HWMP and AODV attained slightly similar average throughput approximately between 4000 to 4200 bit/s.

The average end to end delay for variable number of sources are shown in Fig. 7. It should be noted that the delay for all three routing protocols increases with increasing number of sources. From the illustrated graph, we can see a clear advantage of HWMP over AODV and OLSR. OLSR attained high average end to end delay as it could not perform routing protocol efficiently as the number of sources increases in this simulation scenario.

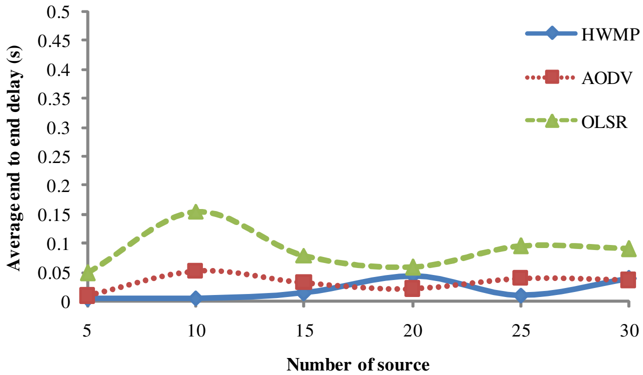

Fig. 7: Average end to end delay comparison for AODV, OLSR and HWMP for varying number of source

V. Conclusion

In this paper, the performance analysis of wireless mesh network in the context rural community mesh network has been considered. The main requirement is fairly static nodes with the aims of achieving satisfactory performance in terms of high throughput and low delay. Computer simulation has been performed to quantify performance of various routing protocols while considering a number of network parameters such as traffic loads, network sizes and the number of source. It was observed that these parameters has different impacts on proactive, reactive and hybrid routing methods. Simulated results indicate that HWMP has an apparent benefits to WMNs as it reached the highest average throughput at lowest end to end delay in comparison to AODV and OLSR.

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