Performance Evaluation of Mesh Protocols in Real Time Mesh Test Bed

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Abstract - *Studies in Wireless Mesh Networks have often focused on the comparison of various mesh protocols, or the design of new mesh protocols in a simulation environment (such as NS2, OPNET etc.). However the results obtained in a simulation environment are sometimes not valid in a real site where the network is meant to be deployed. Routing protocols in modern arena of telecommunications, internet systems and in seamless communication play a prominent role to develop better communication between end users. Different routing protocols have different attributes according to their environmental scenarios. The selection of suitable protocol according to the network definitely increases the reliability of that network. This paper aims at design of a real-time mesh test-bed to compare various mesh protocols and perform a detailed testing. This forms a basis for the development of a large scale wireless mesh network test bed. A preliminary analysis of two mesh protocols i.e., OLSR (Optimized Link State Routing Protocol) and BATMAN-Adv (Better Approach To Mobile Ad-Hoc Network) is carried out on this reliable and highly configurable real-time mesh test-bed. The metrics used for the performance evaluation include throughput, bandwidth, jitter, packet delivery ratio and latency. The results shows that Batman-Adv outperforms OLSR on considered performance metrics.*

Key Words: OLSR, Batman-adv, Mesh protocol, WMN

1. INTRODUCTION

A wireless mesh network (WMN) is an interconnection of radio nodes wirelessly in a mesh topology to form a communication network. It comprises of gateways, clients and routers as its prime components. A wireless mesh network has a wide range of advantages like good coverage, speed, inter-connectivity [1]. It is useful in Non-line of sight (NLoS) communication. Apart from these; it is self-healing, self-organizing, self-adaptive, self-forming and dynamic within a network. A general mesh network is as shown in figure 1.

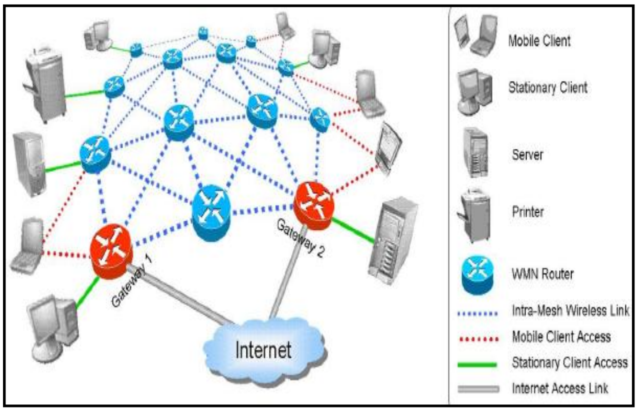

Fig -1: General wireless mesh network

Mesh routers have less mobility and perform dedicated routing and configuration, which considerably decreases the traffic on the mesh clients and their end nodes, thus preventing congestion [2]. The gateways are used as a bridge between two different mesh networks and also to give access to the internet for the rest of the nodes and clients in the mesh network. The information or data in the form of packets is transmitted or routed from one point to another in the network. Routing refers to the process of selection of the most suitable protocol for data transmission. This process is enabled by certain routing protocols (pro-active, reactive or hybrid).The performance of a protocol in a network is measured by the various performance parameters like latency, jitter, bandwidth and throughput. The parameters vary according to the topology and are also site dependent. A proper tradeoff between these parameters is to be ensured in order to obtain the maximum output for a given topology like maintaining an optimum distance between the nodes to have a lesser jitter and latency. The comparative analysis of performance parameters like latency, jitter, bandwidth, throughput of OLSR and BATMAN-ADV protocols are considered in this paper. The result obtained through the real time implementation of the mesh network provides the basis for comparison as the results obtained in a simulation environment are sometimes not valid in a real site where the network is meant to be deployed due to various environmental conditions like LOS, temperature, humidity, pressure ,fog ,cloudy conditions and etc.. Which are not taken for consideration during simulation implementations [3].

2. ROUTING PROTOCOLS

The following protocols were considered for real time deployment and performance evaluation.

A. OLSR

OLSR [4] was an was an initial attempt at standardizing a proactive link-state routing protocol. OLSR was first implementation by Tonnesen [5] and has been continued by numerous contributors. It is currently the most used ad hoc routing protocol. The initial OLSR RFC, 3526 [4], used hop count as a metric, however, problems with this metric surfaced in Tonnesen's initial OLSR implementation [5]. Thus, real world implementations have long since broken conformance with this RFC. OLSRv2 [6] uses the ETX [7] metric for routing. The characteristic feature of OLSR, which differentiated it from competing link state routing protocols, were MPRs. MPRs reduce the number of redundant link state transmissions by electing specific nodes as relays. Selection is performed in a manner such that every OLSR node is a direct neighbour of a MPR. The OLSR protocol also uses FSR techniques which will frequently update nearby nodes and infrequently update distant nodes. FSR reduces the overhead of link state messages in larger networks. Anecdotal criticisms of OLSR state that a significant amount of MPR redundancy is needed to prevent link state databases from becoming desynchronized and forming routing loops. The additional MPR redundancy increases overheads; reducing performance. These criticisms led others to explore a fundamentally different approach to routing [8].

B. BATMAN-ADV

BATMAN-ADV [9], [10] is a new and different approach to routing. In BATMAN-ADV, routing tables are built, hence it is a proactive routing protocol and however, routes are acquired in a biologically inspired manner, sharing similarities with AntHocNET [11]. The BATMAN-ADV protocol is fundamentally different from classic link state and distance vector routing. It does not try to discover or calculate routing paths, instead it tries to detect which neighbor offers the best path to each originator [10]. In BATMAN-ADV, routing information is not communicated directly; instead, each node broadcasts packets called Originator Messages (OGMs) every second. When received by neighboring nodes, OGMs get re-broadcasted. Route selection for a given destination is based on the node from which the most OGMs have been received for a particular destination. The number of OGMs that can be accepted is limited to a constantly moving window. This window limits the history of OGMs that are allowed to describe a given route. The scalability of BATMAN-ADV counts on packet loss and thus, like other algorithms, OGMs are broadcast as unreliable UDP packets. As nodes continuously broadcast OGMs; without packet loss, these messages would overwhelm the network. The scalability of BATMAN-ADV depends on packet loss and thus it is unable to operate in reliable wired networks. This mechanism also means that OGMs from nearby nodes will be frequently received whereas OGMs from distant nodes will be infrequent. The BATMAN-ADV algorithm can also use different TTLs in OGMs to limit dissemination. This function is similar to the limited dissemination FSR concept [4]. As route selection is based on the number of received OGMs, the metric is ultimately a form of reliability and therefore conceptually similar to ETX [7]; the metric used by both OLSR and Babel[8].

3. PERFORMANCE PARAMETERS

The selection of a protocol for a given topology and application plays an important role in determining the efficiency of a network. The right choice of the protocol can help in achieving maximum efficiency whereas the wrong choice can be detrimental for the performance efficiency of the network. The following performance parameters are considered to evaluate the two protocols in real time.

3.1 Throughput

Network throughput is the rate of successful messages delivered over a communication channel in a given period of time. Throughput is usually measured in bits per second (bit/s or bps), and sometimes in data packets per second or data packets per time slot. Throughput is always less than Bandwidth of the network. Throughput refers to the actual measured performance of the system when delay is considered.

Throughput= (Total bytes received * 8) / (Last packet received - First packet received)

3.2 Bandwidth

In a Mesh Network, bandwidth is the amount of data that can be carried from one point to another in a given time period (usually a second). Network bandwidth is usually expressed in bits per second (bps). Modern networks typically have speeds measured in millions of bits per second (megabits per second, or Mbps) or billions of bits per second (gigabits per second or Gbps). Bandwidth is a theoretical value independent of real-time considerations.

3.3 Latency

Latency in a mesh network is the time delay measured from the source sending packet to the destination receiving it and the destination acknowledging the packet sent by the source. Network latency in a packet-switched network is measured either one-way (the time from the source sending a packet to the destination receiving it), or round-trip delay time (the one-way latency from source to destination plus the one-way latency from the destination back to the source). Round-trip latency is more often quoted, because it can be measured from a single point. Note that round trip latency excludes the amount of time that a destination system spends processing the packet.

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3.4 Jitter

Jitter is the time difference in the packet arrival to the destination or can be defined as the deviation of the packet delivery rate from the true periodicity. Or jitter is the variation in latency as measured in the variability over time of the packet latency across a network. A network with constant latency has no variation (or jitter). Packet jitter is expressed as an average of the deviation from the network mean latency.

3.5 Packet Delivery Ratio

Packet Delivery Ratio, in a Mesh network can be defined as the ratio of number of data packets successfully received by the destination to the total number of data packets sent by the source [13]. The greater value of packet delivery ratio means the better performance of the protocol.

PDR=Σ Number of packets received / Σ Number of packets sent

4. REAL-TIME TEST-BED DEPLOYMENT

For the comparative analysis of the various performance parameters of the two routing protocols considered, laptops and COTS(commercially off the shelf) TP Link routers (which uses 802.11b/g/n IEEE standard) flashed with Open-Wrt firmware (open source Linux distribution for embedded devices) are considered as nodes. Open-Wrt provides flexible file systems that help in customizing all the available packages. Such routers are strategically placed to achieve the desired hops. The routers communicate with each other in ad-hoc mode. This mode allows all wireless nodes within range of each other to discover and communicate in peer-to-peer fashion. To set up an ad-hoc wireless network, each and every router needs to be configured in the ad-hoc mode.

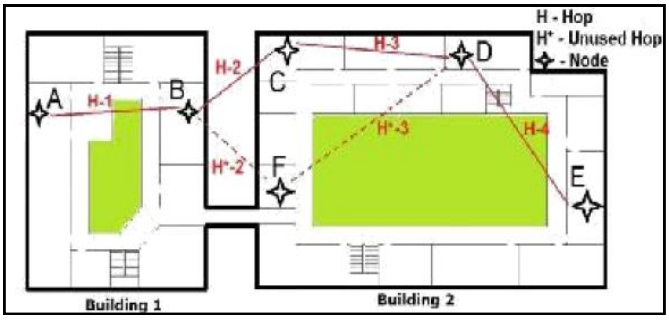


Fig -2: Deployed Topology

In addition, all the wireless routers on the ad-hoc network must use the same SSID (Service Set Identifier) and channel number. Keeping into account the wireless range, directivity of antenna, bandwidth of the link, the routers are placed in the 5th floors of two buildings as shown in the figure 2. The approximate loss due to the obstructions in the transmission path because of the structure of the building is considered. The topological analysis is ensured before the routers are deployed. The routers deployed have daemon tool like OLSRD and Batman-adv installed in them.

5. RESULTS

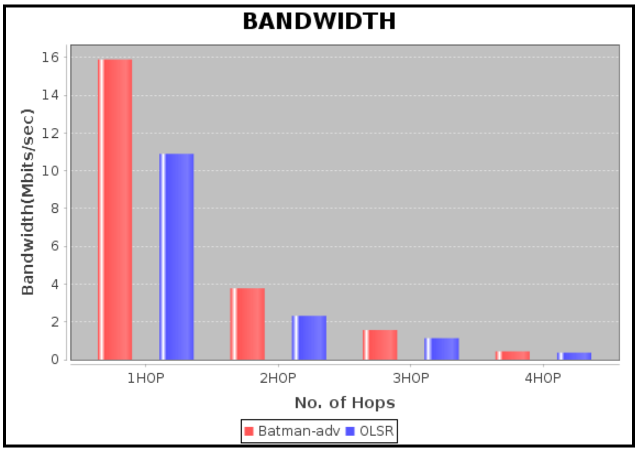
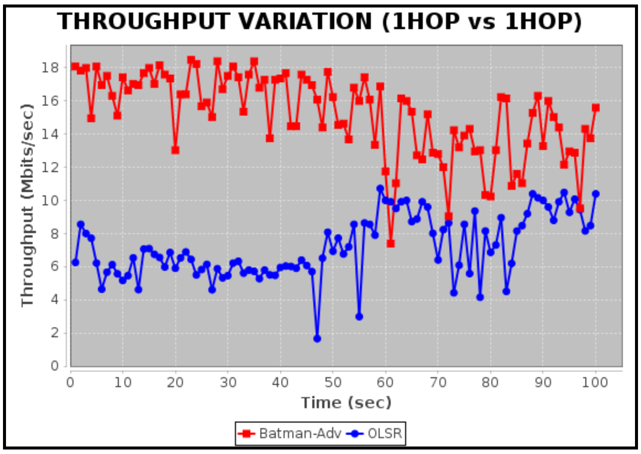


Fig -3: Deployed Topology



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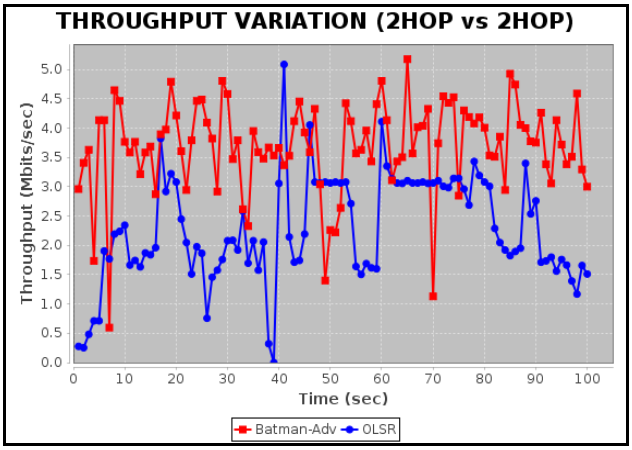

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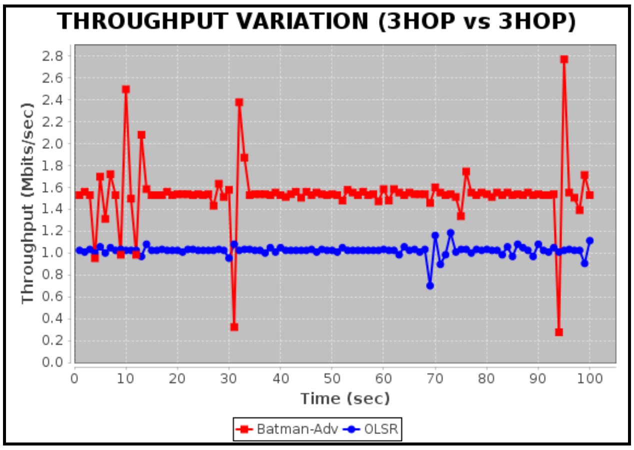

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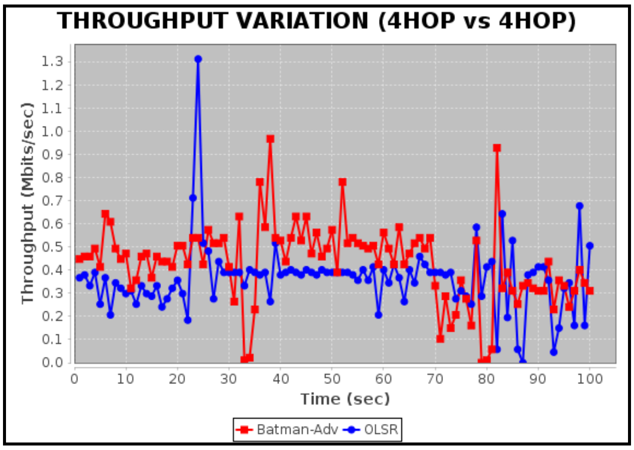


(d)

Fig -4: Throughput variation for (a) 1Hop, (b) 2Hop, (c) 3Hop and (d) 4Hop

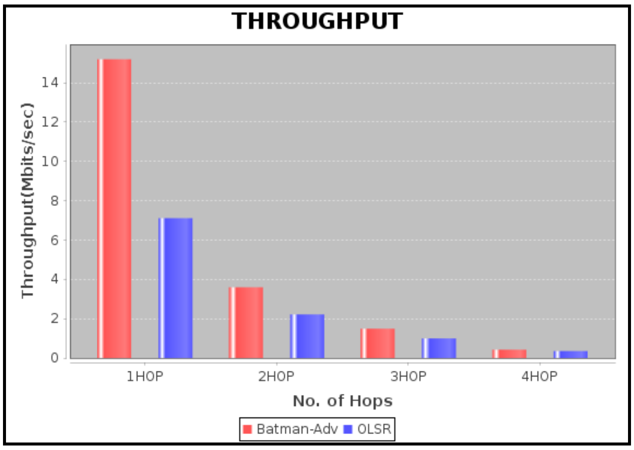


Fig -5: Throughput Comparison

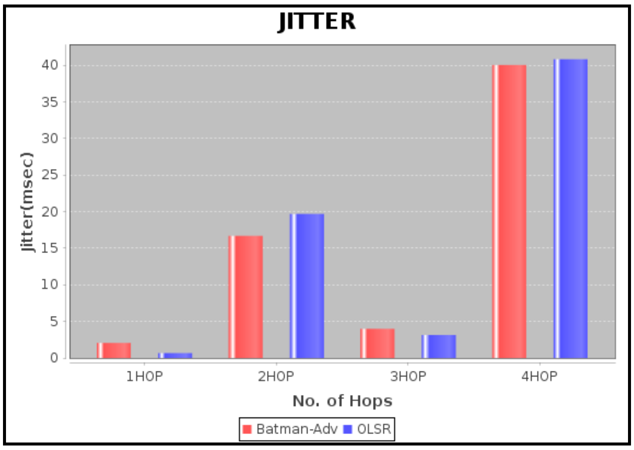
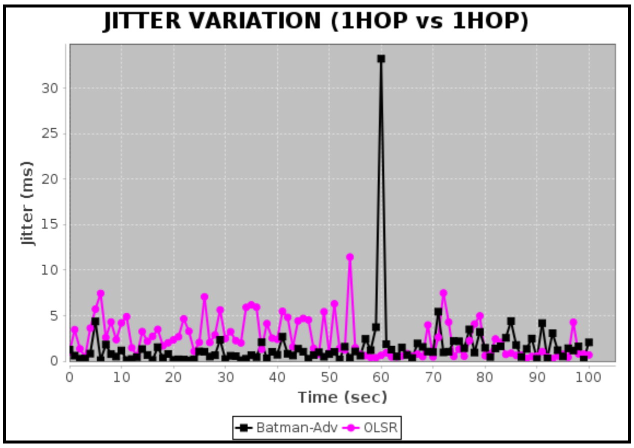


Fig -6: Jitter Comparison



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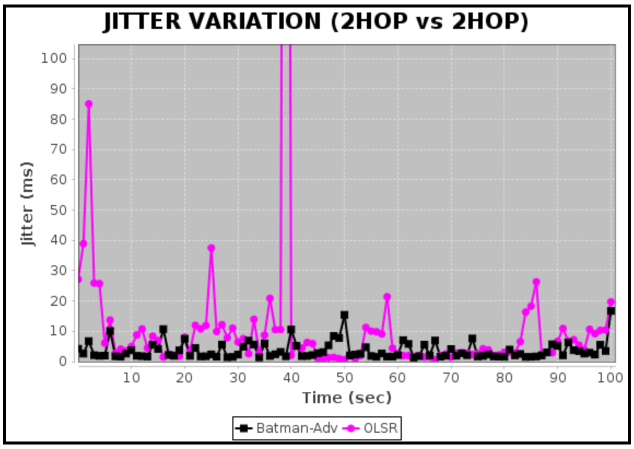

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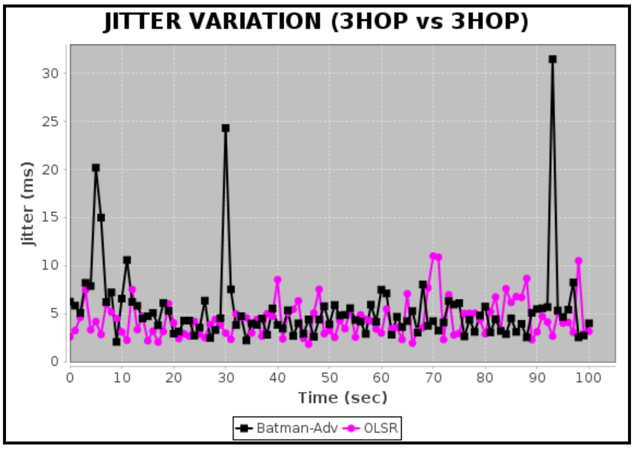

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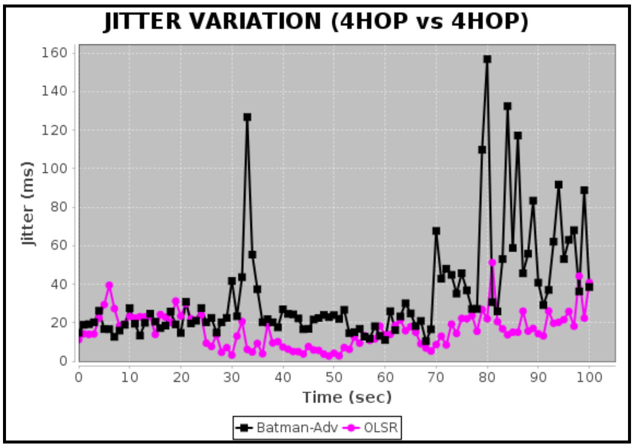


(d)

Fig -7: Jitter variation for (a) 1Hop, (b) 2Hop, (c) 3Hop and (d) 4Hop

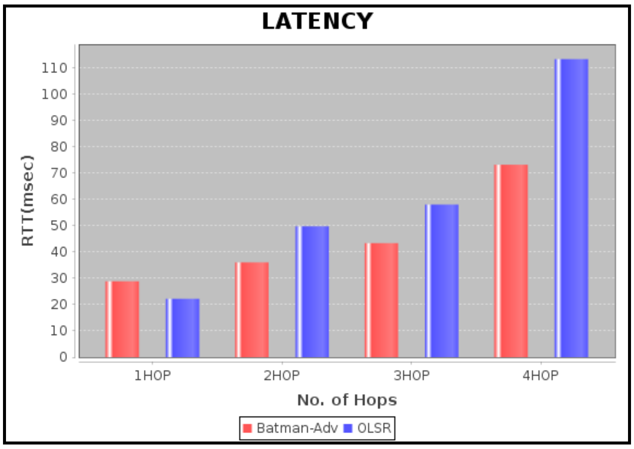
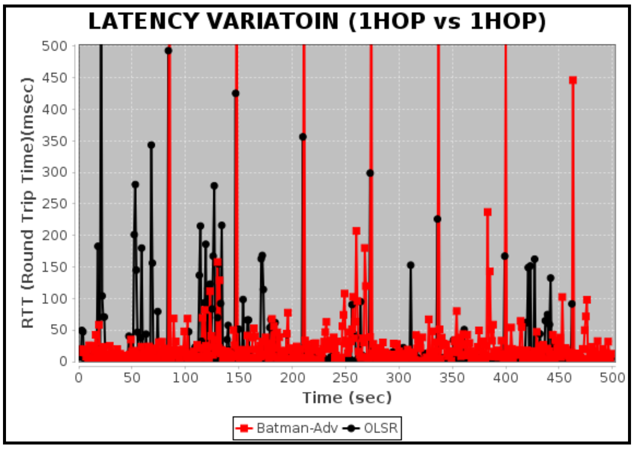
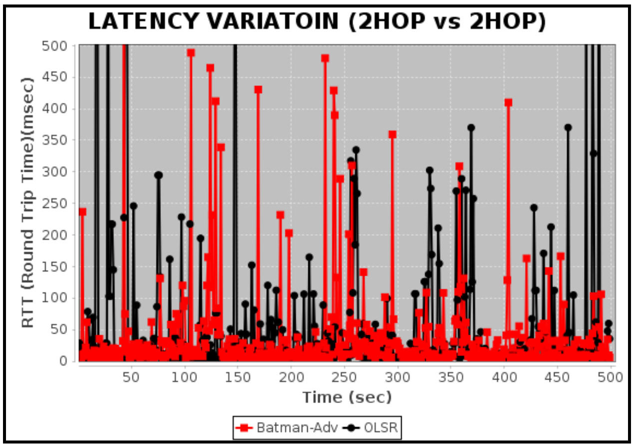


Fig -8: Latency Comparison



(a)



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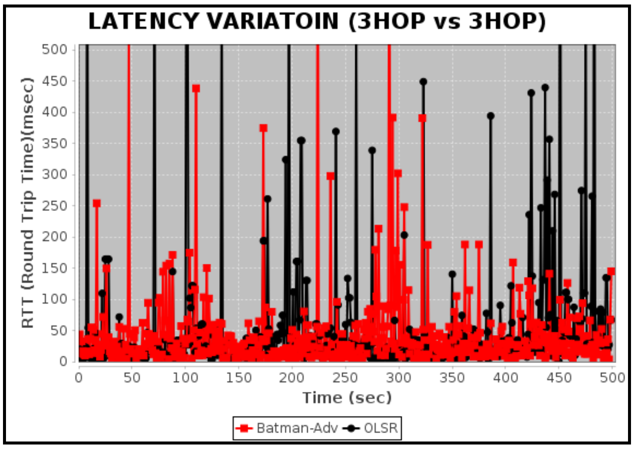
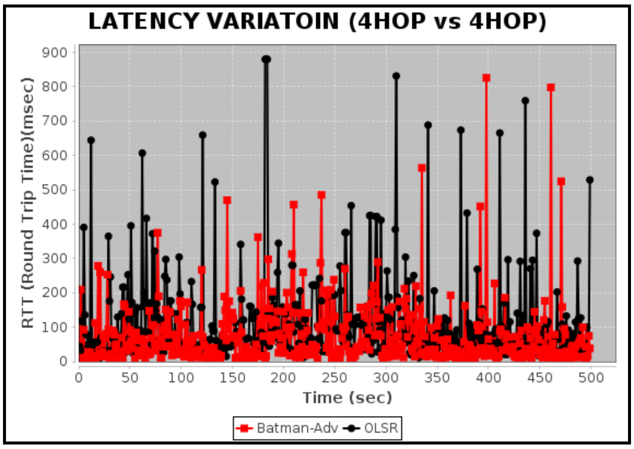


(c)



(d)

Fig -9: Latency variation for (a) 1Hop, (b) 2Hop (c) 3Hop and (d) 4Hop

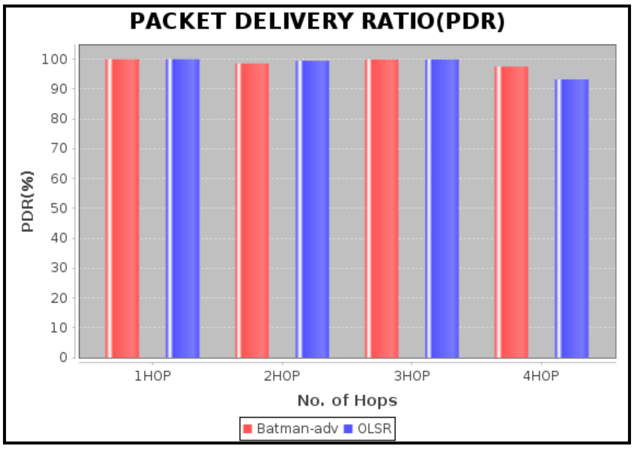


Fig -8: PDR Comparison

This experimental test bed satisfies the properties of a mesh network being self-adaptive, self-forming, self-configuring etc. Among the two routes, the route A-B-C-D-E is chosen as a better route by the protocols as compared to the route A-B-F-D-E based on distance and strength of the links due to various factors. It is found that on disabling node C, the alternative route (A-B-F-D-E) would be chosen as the best route, thus proving the nature of the network being self-adaptive. Self- configuring nature was proved on addition of a new node to the network. The routing tables are dynamically updated with the new cost to the destination and the new information, based on the new node added.

The protocols (OLSR, Batman-Adv) are made to run on all the nodes (routers and laptops). The required parameters are obtained using various tools like iperf, traceroute and ping. The optimal Bandwidth and throughput were computed by using iperf. Here the node acting as a server uses UDP packets of 1470 byte datagram for 500 seconds. Two cases were considered, where in the first case the network was saturated with UDP packets to test the network's limits whereas in second case smaller loads were used to check the performance of the network. Here the node acting as a server uses UDP packets to calculate the bandwidth and throughput. The latency was calculated using ping and the hops using traceroute, which displays the path that the node takes to the destination. On setting up the network, the calculation of parameters were carried out for a brief period of 500 seconds and an average of 500 values are considered so as to provide a better analysis of the real time test bed.

Throughput and optimal bandwidth for the two protocols for the topology considered is shown in the figure 3 to 5. It is found that on an average the throughput and bandwidth for Batman-Adv is high as compared to OLSR. Batman-Adv shows consistency in its values with the increase in number of hops making it suitable for dense networks. But if the nodes are close to each other with a higher percentage of LOS then OLSR shows a better bandwidth and throughput. Jitter for the two protocols for the topology considered is as shown in the figure 6 to 7. Jitter for both the protocols increase abruptly with increase in hops but there is an increase in jitter for second hop may be due to the larger bandwidth, bad link quality and other disturbances. Latency for the two protocols for the topology considered is shown in the figure 8 to 9. It is found that Batman-adv has least latency as compared to OLSR. In OLSR, the latency is found to increase drastically with the increase in number of hops. PDR for the two protocols for the topology considered is shown in the figure 8. The PDR is excellent and almost 100% for first, second and third hops, but is found to deteriorate gradually for higher hops indicating the deterioration of link quality for higher hops.

6. CONCLUSION

This paper presents a real time WMN experimental test bed and novelty of this test bed is that it is highly customizable (using Open-WRT we can customize a router to accept any standard mesh protocol) to a user specifications. A detailed performance comparison of two mesh network protocols on this test bed is carried out. We have performed a comparative analysis of the mesh protocols Batman-adv, OLSR and demonstrated that in a real world setting. It can be concluded from the results that, Batman-adv has the highest bandwidth, throughput and a low latency for the topology considered. Hence it is a protocol suitable for a network that requires high data rate and speed. OLSR is found to be inefficient in the topology considered but it is suitable for dense networks with low data-rate and Higher LOS between the nodes.

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