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A Comparative Study of B.A.T.M.A.N. and OLSR Routing Protocols for MANETs

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Abstract— Mobile ad Hoc networks are capable of making dynamic changes in any topology. The characteristic which differentiates MANETs from other networks is that it is capable of changing its location. The results of the surveys over the last 5 years have shown that it can overcome congestion and communication barrier between two nodes. This study compares the performance of two different multi hop ad hoc network routing protocols, Better Approach to Mobile Ad hoc Networks and Optimized Link State Routing Algorithm. These protocols have been devised to maximize packet delivery ratio, throughput and to minimize end to end delay, routing load to improve the performance. This paper studies link state, distance vector and biologically inspired approaches to routing using OLSR and BATMAN routing protocols as discussed in various papers. The paper concludes by showing that BATMAN outperforms OLSR in terms of better throughput, less delay, lower CPU load and lower routing overhead when experimental evaluation is considered. But, when other approaches are considered, they are found to be similar in their performances.

Keywords— Routing Protocol, MANET, B.A.T.M.A.N., OLSR, Reactive, Proactive

INTRODUCTION

Routing is the central and one of the most important areas of wireless multi hop ad hoc network architecture. But only a few real world experimental studies have investigated routing, despite its importance and the hundreds of different routing protocols proposed over the past decade. Different routing protocols have been proposed to improve the performance. All routing protocols have different behavior than others for improving and maintaining the routing performance. The two types of routing protocols are reactive (e.g. DSR) and proactive routing protocols (e.g. OLSR, BATMAN).
This paper studies an experimental comparison between Optimized Link State Routing (OLSR) and Better Approach to Mobile Ad hoc Networking (BATMAN) carried out by other researchers. These protocols represent different approaches to routing in multi hop ad hoc networks. OLSR is a link state routing protocol and the BATMAN routing protocol does not fit neatly into pre-existing routing taxonomies. It can be loosely described as a biologically inspired routing.

ROUTING PROTOCOLS

Two types of routing protocols are:

1. On Demand Routing Protocol (Reactive)
   The protocol finds the route as it is required. First of all, protocol sends the route request packet to all the forwarding nodes. This is done till the destination is not found. Destination sends the route reply packet to the source node. Only response route is maintained, rest is deleted. After that all the routes are maintain in the table. Dynamic Source Routing (DSR) is used. The connection is made between the source and the destination when source node sends requests.

2. Table Driven Routing Protocol (Proactive)
   This type of routing protocol makes the fresh list of destinations before the result is required. The route is maintained by routing table. The source sends the packet to the next node thereby making changes in the routing table. Various proactive routing protocols are:

   Better Approach to Mobile Ad Hoc Network (BATMAN): [1], [2], [3] First of all, it sends the OriGinator Message (OGM). The size of OGM is 52 bytes. This contains the information of the IP address of the forwarding node and sequence number is also increased. Then it takes the best node by using its rank. If the sequence number of the node varies within the range then connection is bidirectional.

Optimized Link State Routing algorithm (OLSR): [4], [5], [6], [7] OLSR produces the different links between the nodes as given by the source to destination. First, it sends the HELLO message to check its neighbor. It makes the changes in the route table after every node, when the packet transmission is possible. The routing table is managed by the information of Topology control (TC) Packets. Control packet is sent to the network, by the special nodes called multipoint relays. Due to this control traffic is reduced; the path is selected by using the shortest path algorithm.

CHALLENGES IN MULTI HOP AD HOC NETWORK PROTOCOLS

The challenges in multi hop ad hoc network protocols are as follows:

1. In hierarchical routing if one node fails, a new IP address and network mask would be required to form the link again with a different router. That is the reason why hierarchical addressing schemes will not work in multi hop ad hoc networks. Thus the addressing structure should be flat.

2. Multi hop ad hoc nodes are often low powered and low cost embedded machines because they must deal with a variety of environmental conditions. Thus, the CPU power of these devices will be constrained.

3. There are constant changes occurring in multi hop ad hoc networks [8] thus, traditional routing protocols such as RIP and OSPF cannot be used as they update too infrequently. A frequent stream of hellos and topology exchanges is required to track the constantly changing link conditions.

4. Since the conditions are constantly changing in an ad hoc network, routing information must be unreliably broadcasted in order to maintain efficiency in the shared medium. Overheads will therefore be higher in ad hoc routing protocols.

5. According to Split Horizon rule, if an interface receives a route then the same route should never be re-advertised through the same interface. This rule is used to avoid count-to-infinity routing loops in wired networks. In multi hop ad hoc networks, nodes must be able to rebroadcast routing information over the same interface which means that split horizon may not be used. RIP and EIGRP are therefore inapplicable.

6. The self forming, self healing properties are a way of not able to manually create variables such as bandwidth and delay. Since, such characteristics persist in multi hop ad hoc networks; they cannot manually enter changes as they can be entered in OSPF or EIGRP. As a result, designing routing metrics for multi hop ad hoc networks becomes a difficult task. The hop count metric is used for simplifying the process and the limitations are well known. The traditional problems worsen in multi hop ad hoc networks because paths with fewer hops are likely to be routes between distant, lower data rate links. In many cases this will lead to the utilization of longer distance, lower speed paths. These unintentional cross layer interactions led to performance degradations [9]. Hop count performs poorly in multi hop ad hoc networks [10].

METHODS OF OVERCOMING THE CHALLENGES

The different ways of overcoming the challenges faced by multi hop ad hoc networks are:

1. Limited Dissemination
   A popular approach to reduce routing overheads, in both proactive and reactive protocols, is to limit the dissemination of routing information. The application of this concept to link state routing is known as Fish-eye State Routing (FSR) [11]. These techniques have shown to reduce the overheads noticeably [12]. The reason why some of the imprecise or slightly inaccurate information can be tolerated is that the routing decisions are made on a hop-by-hop basis. This means that if a node is many hops away, a route in the general direction will often suffice.
   FSR modifies the Time to Live (TTL) in routing messages to update nearby and distant nodes at different intervals. Studies have shown that FSR provides greater optimization in large networks with a large diameter [13]. While FSR can reduce the generation of link state messages, it can lead to suboptimal routes. This trade-off requires consideration [14]. The inclusion of FSR into OLSR [15] is a testament to its effectiveness.

2. Routing Metrics
   ETX (or Expected Transmission Count) [16] is a reliability metric designed to find paths requiring the fewest transmissions. In spite of all packets being acknowledged using Automatic Repeat Request (ARQ) in 802.11, retransmissions result in a loss of airtime and hence, bandwidth. ETX calculates the probability of successful transmissions in both directions over a wireless link. In order to determine these statistics, there is periodic broadcasting of a configured number of probes by every node. Receivers calculate the number of probes received;

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against the number expected. As links are asymmetric, it is important to measure the success rate of probes in both directions. To obtain this information, each node will place its own ETX values in the probes sent. The formula for calculating the ETX of a link is shown in equation 1. There are well documented problems with ETX [17]. ETX does not incorporate bandwidth and this turns out to be the biggest problem. This may cause ETX to favor fewer slow long distance links over a larger number of high speed links. Despite these problems, ETX [18] [19] is used by numerous routing protocols such as OLSR [10].

$$ETX\ (\text{of a link}) = N/P = 1/(LQ \times NLQ) \qquad (1)$$

Where N = Total number of Transmissions without error required to transmit P packets and, P = Total number of Packets, LQ = fraction of successful packets that were received from a neighbor within a window period and, NLQ = fraction of successful packets that were received by a neighbor node within a window period.

The Expected Transmission Time (ETT) metric [20] adds the ability to measure bandwidth thereby improving ETX. ETT implementations are limited because they require a standardized way to obtain the data rate from the wireless driver. Until such mechanisms are widespread, ETT implementations will be problematic and suffer from interoperability problems. ETT is a significant improvement over ETX, but, it is difficult to practically implement.

PERFORMANCE EVALUATION

To evaluate the efficiency of the performances of routing protocols, following parameters are considered:

A. Packet delivery ratio (PDR): It is the ratio of the packet sent from source to the number of packet received at the destination. PDR is determined as:
   $PDR = Pr / Ps$
   Where Pr is the total packets received and Ps is the total packets sent. The greater value of packet delivery ratio means the better performance of the protocol.

B. End to end delay (D_{avg}): This is the average time required by a data packet to arrive in the destination. It includes possible delay caused by the buffering during route discovery. This is the delay packet send from source to the destination. The average delay is computed as:
   $(D_{avg}) = \Sigma\ (t_r - t_s) / \sum$ Number of connections
   Where t_s is the packet sent time and t_r is the packet receive time. The lower value of end to end delay means the better performance of the protocol.

C. Routing Load: Routing load is the number of routing control packet transmitted for each data packet delivered at the destination. Routing load is determined as:
   $RL = P_c / P_d$
   Where P_c is the total control packets sent and P_d is the total packets sent.

D. Throughput: The total successfully received packet to the destination.

SURVEY ANALYSIS

After considering the overall survey [21], by comparing the two different protocols result can be stated as follows:

When 100 nodes with packet length of 50,000 bytes are sent over BATMAN and OLSR, the packet delivery ratio (PDR), end to end delay, routing load and throughput was best for OLSR as compared to BATMAN. Also, when the mobility factor was included (Mobility = 30m/s), again OLSR outperformed BATMAN.

It is very difficult to design a routing protocol which satisfies all the parameters and taken as best from all point of view. But here, based on the analysis of the survey results, we have compared the two routing protocols.

EXPERIMENTAL STUDY

In the experimental study of BATMAN and OLSR [22], attempts were made to use Ad hoc On demand Distance Vector (AODV) routing, however similar to recent studies [23], implementation problems made this infeasible.

The BATMAN routing protocol is being developed as both a user-space routing protocol, that operates at the network layer, as well as a kernel-space implementation running at the data link layer. This study has been done on the experiments [22] conducted with both routing protocols, referring to them as BATMAN L3 and BATMAN L2. Only a couple of real world experimental evaluations of these protocols exist [18], [23].

The Linux implementation of OLSR developed by Tonnesen [24] was used for comparisons in the study [18]. This implementation is referred as olsr.org. It is now a part of the largest open source ad hoc networking development initiative. Version 0.5.5, which is RFC3626 compliant, is used and is capable of using the new ETX metric for calculating optimal routes as well as using an optimized version of the Dijkstra algorithm.

In the experiment proposed in [18], the wireless nodes were ALIX 500MHz x86 embedded PCs with 256 MB of RAM and Atheros CM9 wireless cards. The platform and routing protocol versions can be found in Table 1. All routing protocols were tested with their default configuration.

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Table 1 : Platform and Routing Configurations (Courtesy [18])

Platform	Version	Routing Protocols	Version
Voyage Linux	0.6	OLSR	0.5.6-rc7
Linux Kernel	2.6.30-486-voyage	BAT L3	0.3
MadWiFi	0.9.4	BAT L2	0.2

Comparative tests were performed in [24] over four different topologies. The first topology was set up by placing all the nodes in direct communication range of the gateway. In this topology no routing was taking place hence, it was used as a control.

The remaining three topologies featured random placement of nodes throughout a building in which the nodes were kept far apart to ensure a multi hopping topology. In the proposed experimental setup in [22], the transmission power was reduced and all wireless nodes were placed in different rooms. The parameters measured were, packet delivery ratio, bandwidth and routing protocol overhead.

In the bandwidth tests in [22], one gateway node was connected to a dedicated server which was running the lighthttpd web server. Wireless nodes were issued instructions to download a large 158MB file simultaneously from the lighthttpd server and the downloading was timed. The elapsed time between when the download command was issued and the final node completed the file transfer was recorded. These tests were performed multiple times for each routing protocol in each topology. And, to reach the final conclusion, these results were averaged.

In this study, routing protocol overheads were also captured. When routing thousands of packets per second, the nodes were not powerful enough to capture the traffic travelling through their interfaces. This led to the difficulty in determining the exact routing overhead. Routing protocol overheads were measured by placing all wireless nodes within the range of an external capturing device. Wireshark was used which captured the packets over 60 second intervals.

RESULTS AND FINAL ANALYSIS

Different protocols perform differently on various parameters. Different types of variations are done with nodes such as varying number of nodes, packet length and mobility. Based on survey analysis, following results have been obtained. When maximum number of nodes with maximum packet length scenario is taken, OLSR performed better than BATMAN. Also, when the same scenario was added with maximum mobility factor, again OLSR outperformed BATMAN.

The effect of nodes (N=100) and the packet length (50,000 bytes) on performance is discussed in the survey analysis. OLSR performs best because OLSR has shorter delay. Being a proactive protocol, OLSR maintains a fresh list of nodes. During its arrival, either it forwards or drops the packet.

The effect of nodes (N=100) and the mobility (30 (m/s)) on performance is also discussed in survey analysis. OLSR performs best when mobility is high. BATMAN has good performance when the mobility increases, but less than OLSR.

Based on experimental study in [22], all routing protocols were equally reliable and TCP dropouts were very rare. Consistent Packet delivery ratios were observed for the three routing protocols. Although all packet delivery ratios were between 99.6% and 99.98%, results varied for different topologies. These results differ from other experimental studies [18], [23] which found significantly lower packet delivery ratios as those studies were conducted on a grid, which was chosen as the logical topology of the wireless testbed. It was selected due to its ability to create a fully connected dense mesh network and the possibility of creating a large variety of other topologies by selectively switching on particular nodes and to make repeatability of the experiment possible.

The bandwidth test gave the following graph:

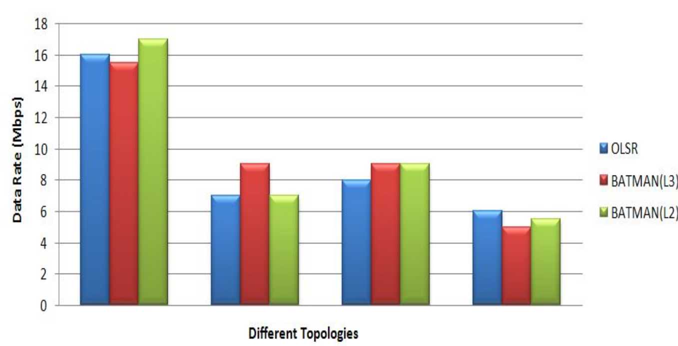

Fig. 1: Performance of different Algorithms for various Topologies (Courtesy [22])

Fig 1 shows that BATMAN L2 outperformed BATMAN L3 and OLSR in three of the four topologies. But, the performance differences are too small to reach any definitive conclusions. The study [18] comparing OLSR and BATMAN found that BATMANs throughput was approximately 15% better than OLSR. Another peer study [22] challenges this fact based on their selection of network variables. It says by default, OLSR has a hello interval of 2 seconds and an interval of 5seconds for topology exchange. Comparatively, BATMAN transmits an entirely different message known as an OGM every 1 second. In the previous study [18], for fairness reasons, OLSR's hello and topology exchange intervals are kept same as that of BATMAN's OGM intervals of 1 second. But, in the peer study [22], this is unfair because BATMAN and OLSR are completely different protocols. BATMAN's OGMs are very small because they carry very little routing information and are required to be sent more often than OLSR hellos and topology exchanges. I completely agree to the challenge made by them but the study [18] conducted compares both the protocols very efficiently, and hence, its significance cannot be denied.

CONCLUSION

In this review paper, BATMAN and OLSR protocols were compared based on the experimental studies conducted [18], [22], [23]. These protocols are analysed under the effect of nodes (network), packet length (traffic) and mobility to check the performance. The overall result of survey analysis show that OLSR perform well in large network (Nodes=100) and also when the factor of mobility is considered. Thus, in all the scenarios, OLSR shows best result than BATMAN. The experimental results [22] confirm that the overhead of OLSR is higher than BATMAN [18], [23], but contradict other studies that claim large throughput differences between OLSR and BATMAN [18], [23]. The results of study [22] suggest that the performance of OLSR and BATMAN is similar. Thus, no specific conclusion based on any of the research studies [18] [22] [23] can be reached and hence, scope of further experimentation is a must.

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