Optimised Link State Routing Protocol Testbed and Performance Evaluation

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Summary
This paper discusses the implementation of OLSR routing protocol on TL-MR3040 routers for MANET experiment. To date, many devices are equipped with wireless module; however most system is set to be in the form of structured communication. Indeed the current wireless devices such as WiFi router and access point has the ability to communicate in ad hoc fashion. However, a compatible protocol is required to enable such devices to operate effectively. Nevertheless, the heterogeneity of the wireless communication frequently poses a challenge for the device to route packet in the network. The OLSR is a proactive MANET routing protocol which may create mesh topology and operate effectively to assist wireless devices to self-configure routing path when topology changes. To see the feasibility of OLSR routing protocol on real-world environment, the paper presents the implementation and experiment conducted on TL-MR3040 routers equipped with the OLSR routing protocol. Results from experiment show that the OLSR communication between the routers is viable. In addition, the performances of the routers are evaluated in terms of bandwidth, ETX, and the self-healing mechanism ability.

Key words:
OLSR, MANET, TL-MR3040, Mesh Network, Wireless

1. Introduction

As the communication network continue to grow, the demand for flexibility and ease of use via wireless technology also increases. In light of this, an independent and pervasive communication which does not substantially rely on organised network infrastructure is the model for future communication. Typically, many users required autonomous Internet connectivity irrespective of location and time of access. To that end, the Mobile Ad Hoc Networks (MANET) offers such flexibility and ability to communicate on demand. The technology employs a non-structural collection of mobile users for communication establishments over wireless links. Basically, the technology is the alternative to the existing infrastructure-based communication networks.

MANET technology enables an end-to-end network connectivity. The communication path can be instantly formed requiring minimal human intervention during path establishment. Generally, data are transmitted over path that are based on cooperative mobile nodes, which carry the packets over multi-hop propagating through the network. The nodes may form a linked chain of data transmission as the nodes relay the information to the intended destination nodes. Figure 1 shows the mechanism where data is relayed over multiple nodes to the receiver machine.

Based on Figure 1, as a result of the high separation distance the radio range of the source node is unable to reach the destination node. Despite such limitation, the multi-hop mechanism of MANET enables each intermediate node to relay the packet from the source, which eventually forms a chain-link of path to the intended destination. Typically, many wireless devices can be configured to operate using MANET routing protocol such as Optimized Link State Routing (OSLR) routing protocol [1]. However, some proprietary devices prohibited changes to the firmware and as such; the devices may be only re-configured by the manufacturer. In most circumstances, devices that operate based on open source platform are readily available to be fitted with MANET routing protocol.

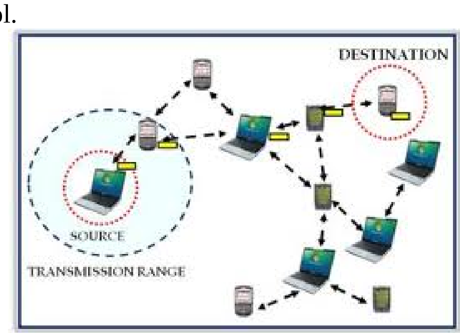

Figure 1 Data relayed to destination

In light of the feasibility of OLSR to operate in real-world environment, many research works employs such routing protocol in testbed implementation. The inherent nature of OLSR, which frequently maintains fresh lists of

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destinations and routes to every node, allows the system to offer a highly stable network connectivity However, such feature also may causes the battery to last for short period of time. It is one of the issues affecting many proactive routing protocols. On the flip side, the OLSR is capable of minimising the control traffic overhead, while concurrently able to rapidly compute fresh routes to adapt to links breakage due to node movements. The OLSR routing protocol works in a distributed manner and therefore, the nodes can cooperatively form self-organising and self-healing system. Based on the previously stated benefits, the OLSR routing protocol is proposed to be used as the routing algorithm for establishing the MANET system in this research work [2].

As a link-state protocol, the OLSR typically inherits the stability of the link state algorithm. Each node discovers every link with the neighbour nodes and periodically floods a message containing the entire links i.e. Link State Message. In addition, each node constructs a topology map of the network and independently calculates the next best hop pointing to the destination using the shortest-path algorithm. Basically, the OLSR routing protocol is an optimisation to the classical link-state algorithm. The key concept of OLSR lies in its capability of a multipoint relays (MPRs). The MPRs mechanism selects node which forward broadcast messages during the flooding process. It is also an algorithm to reduce propagation of control packet throughout the network because nodes declare only a subset of link with its neighbour that is MPR selectors. In other words, the packet flooding in the network is substantially reduced due to the fact that only selected MPRs generate the link state information and broadcasts the message. Subsequently, the MPR nodes may choose to advertise only links between itself and its MPR selectors, hence using partial link-state information for route calculation [2]. Figure 2 shows the MPR selection in OLSR.

2. Optimised Link State Routing Testbed

To date, the MANET technology has gained significant recognition in the communication and networking area for potential use in many industries. Much research works related to the evaluation of MANET performance and the routing protocols e.g. OLSR are conducted with using the real-world testbed. This project extends such methodology and quantifies the feasibility of a specific routing protocol performance with a pre-defined hardware.

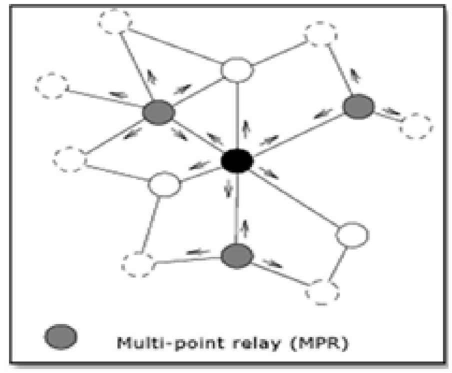

Figure 2. Data relayed to destination

In view of the emerging trends which measure the performance of MANET routing protocols, some research team have developed real-world testbed for such purpose. Kanchanasut [3] and his research team have developed an emergency network platform based on a hybrid combination of a MANET and the satellite IP network. The system operates with conventional terrestrial Internet known by DUMBONET. The system is a mesh network that enables a mobile ad hoc multimedia communication between the field team members and the headquarters. The aim of such system is to provide the rescue teams with multimedia internet capabilities for sending and receiving rich and crucial multimedia information while executing on-field operation.

Kulla et. al. [4], in the research work deal with the evaluation of MANET in a testbed of indoor stairs scenarios. Empirical data such as throughput and delay are collected and subsequently analysed. The routing protocol in the experiment is set to OLSR routing protocol, similar to the choice of protocol used in this paper. The experiment is classified into two scenarios, where static and shifting is employed. Several parameters are taken into account for the experiment i.e. transmission duration, number of trials, source address, destination address, packet rate, packet size and topology setting function. In addition, to evaluate the network performance, the performance metric set includes the effect of multi-hop to nodes mobility, throughput, and delay.

In other research work [5], the authors performed the evaluation of OLSR routing protocol with using a simple testbed. Three different set of evaluation are made. Firstly an experiment is conducted to investigate the availability of ad hoc wireless network at various distances. Secondly to assess the feasibility of the self-healing mechanism in which various scenarios were applied. And finally is to evaluate the performance of multi-hop ad hoc network. In the experiment, the ad hoc network nodes are constructed using Raspberry Pi, equipped with USB Wireless TP-Link WN722N.

3. OLSR Prototype Development

This section describes the development and implementation of the OLSR mobile devices. Four TL-MR3040 devices are used and in each node the firmware is replaced with OpenWRT operating system. Later the OLSR routing protocol is flashed on each device. The devices are then ready to be used to set up the testbed. In principal, the experiment conducted on the testbed typically emphasises on the OLSR performance study under dynamic topology. Several performance metrics are employed to quantify the routing protocol performance i.e. throughput, jitter, and the self-healing properties.

3.1 OLSR on OpenWRT

As previously stated, four identical wireless routers i.e. TL-MR3040 is used as mobile nodes. In addition to the requisite hardware, each router is also equipped with small flash memory that can be used to store the data collected from the experiment. Table 1 shows the items used in the testbed implementation.

Table 1. List of Equipment

Items	Remarks
TL-MR3040 Router	Acts as a mobile node in MANET testbed implementation
OpenWRT	Software to employ OLSR routing protocol
OLSR	Routing protocol for MANET testbed implementation
SD Card	Mount point storage for root file system and OLSR packages

The physical device of each mobile node is shown in Figure 3. The small form factor enables such device to be highly mobile while at the same time responsive to the changes of network topology.

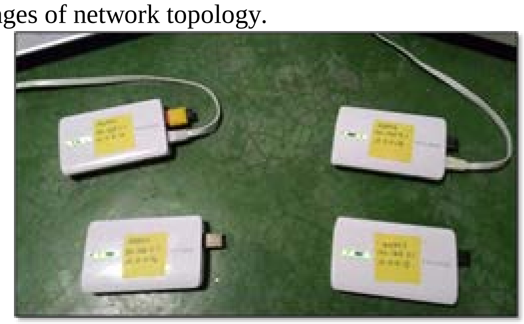

Figure 3. TL-MR3040 wireless route

To flash the devices with OLSR routing protocol, an open source platform is needed. The OpenWRT is used which provides support for such MANET routing protocol. However, the existing built-in memory of the mobile router is insufficient to accommodate the complex code of OLSR. As such, the devices are "exrooted", which facilitates memory expansion. The nodes then may utilise additional memory via the auxiliary storage i.e. flash card memory. Upon memory expansion, the OLSR routing protocol code is then uploaded into the flash card. Finally the mesh network can be created between the mobile routers, where each device communicate over the existing 802.11 wireless TCP/IP protocol stack.

4. Experiment Methodology

To measure the performance of the network, firstly each mobile router is set with OLSR and the mesh connection is formed. The point-to-point connectivity from one node to the other is measured for verification. In subsequent experiments, the testbed is separated into two different topologies i.e. single hop and multi-hop connection. Such configurations are essential, which can show the differences in terms of the OLSR performances with different scenarios.

Figure 4 shows the set up for a single hop connection, while Figure 5 shows the set up for multi-hop communication.

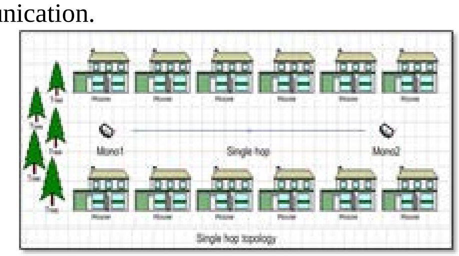

Figure 4. Single-hop communication

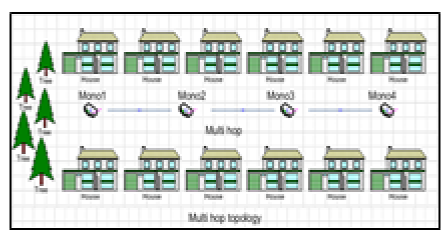

Figure 5. Multi-hop communication

In single hop transmission, only two mobile nodes are used. A mobile node is connected via LAN connection to Host A, while the other is connected via different LAN connection to Host B. The OLSR routing protocol then automatically computes the link and subsequently the routing path is created. On the contrary, in multi hop communication, all four mobile nodes are used. Similar set up is employed as with the single hop experiment. However, two intermediate mobile routers are placed at predetermined locations between the two LAN. The OLSR routing protocol computes the links and will utilise the intermediate routers to form a chained link between the two LANs.

Experiments are also conducted to measure the throughput and jitter from two different types of packet i.e. UDP and TCP. A comparison between UDP and TCP can provide a better insight on the ability of OLSR to perform with different application. UDP is a best effort delivery mechanism and therefore, in the event of route breakages some packet may not be delivered. In contrast, a TCP connection requires the handshake mechanism and OLSR performance may be severely affected when packets are retransmitted due to link disconnection. Additional experiment on the self-healing feature of OLSR is also investigated. It is to measure the response of OLSR when a routing path is disconnected.

5. Experiment Results

Table 2 and 3 show the summary of results tabulated for single hop and multi hop transmission TCP packets.

Table 2. Single-hop TCP Packet Transmission

Single-hop	Interval (sec)	Transfer (Mbyte)	Bandwidth (Mbps)
1	10.1	6.00	4.98
2	38.1	4.00	0.88
3	10.6	8.00	6.35

Table 3. Multi-hop TCP Packet Transmission

Multi-hop	Interval (sec)	Transfer (Mbyte)	Bandwidth (Mbps)
1	13	4.09	2.58
2	11.4	4.09	2.94
3	13.3	6.14	3.77

In this experiment, the transmission of TCP packets is iterated three times. Based on the results, it is observed that TCP packet transmission for a single hop communication is generally faster than the multi hop communication. The throughput for a single hop transmission is also higher than multi hop transmission. The bandwidth fluctuates in both transmissions with the single hop showing significant erratic rise and fall of throughput with the lowest only receiving 0.88 Mbps while highest reaching 6.35 Mbps.

Table 4 and Table 5 show the summary results tabulated for single hop and multi hop transmission UDP packets.

Table 4. Single-hop UDP Packet Transmission

Single hop	Int. (sec)	Transfer (Mbyte)	Bandwidth (Mbps)	jitter (ms)
1	10	1.19	0.98	15.809
2	10	1.19	1.00	7.654
3	10	1.19	1.00	1.051

Table 5. Multi-hop UDP Packet Transmission

Single hop	Int. (sec)	Transfer (Mbyte)	Bandwidth (Mbps)	jitter (ms)
1	10	1.22	1.00	3.895
2	10	1.22	0.99	6.102
3	10	1.22	0.99	5.745

Similar to the TCP experiments, the UDP packets transmission is iterated three times. It can be seen that the interval time for single hop and multi hop transmission for UDP packet has a very small variance. The achieved throughput is also nearly consistent and the difference is as small as 0.1 Mbps. However, the jitter value for single hop transmission shows a significant fluctuation. In the first experiment, the jitter is 15.809 ms whiles it is observed that the jitter is 1.051 ms in the final experiment. Nonetheless, the jitter for multi hop is quite consistent throughout the iteration.

Table 4 shows the average result tabulated for TCP and UDP packets for single hop and multi hop transmission.

Table 6. Average Results of TCP and UDP Transmission

	Throughput (average)		**Jitter (average)**
Single-hop	TCP Packet (Mbps)	UDP Packet (Mbps)	UDP Packet (ms)
1	4.07	0.99	5.9
2	4.67	1.0	4.1
Multi-hop	TCP Packet (Mbps)	UDP Packet (Mbps)	UDP Packet (ms)
1	3.09	0.98	5.2

Result shows that the average TCP packet throughput is low for the multi hop transmission as compared to the single hop transmission. On the other hand, the UDP packet throughput does not have any significant changes. This is due to the presence of an intermediate node in the multi hop topology, which decreases the throughput received at the destination. As for UDP packet, although the packet is propagated through an intermediate node in multi-hop fashion, the source has no information of receipt acknowledgment. Therefore the UDP source does not re-transmit packets that are dropped due to route breaks.

In the self-healing mechanism experiment, every node is initially placed in proximity to other node. The device is then gradually moved away from each other. While moving the nodes it is observed that the expected transmission count (ETX) is impacted. A node, which is outside the other node transmission range, shows a decrease in the ETX value. Figure 6 shows changes to the ETX when nodes are moving.

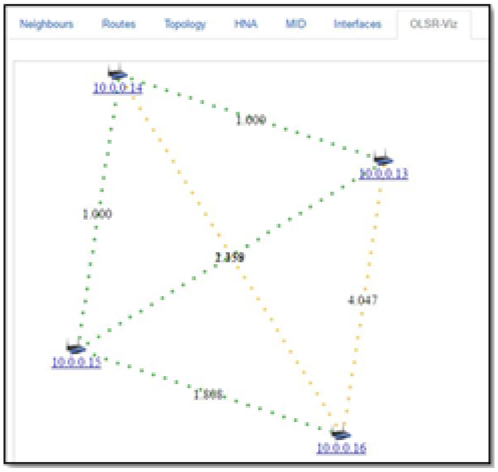

Figure 6. ETX value on each link

By simulation, it can be shown that the ETX value varies with respect to mobility. In the simulation, the links (represented by dotted line) changes from green to yellow, which indicates that the links are becoming non-reliable. The link is considered infinite, which indicates that links are on the verge of breaking. As shown by Figure 7, broken links between nodes is not represented by any lines connecting the nodes.

Later, the nodes are moved back to position so it will be in each other's range. It is observed that all the nodes slowly build the mesh link again. The ETX value of 1 for each link shows that each node is in optimum range towards each other.

6. Discussion

In addition to the results obtained from the conducted experiments, other observations were also made, which point out the shortcomings of the testbed.

It is imperative that to completely implement a wireless based mesh network, the end terminal has to be operated on a platform which supports the OLSR routing protocol Alternatively the end terminal may be connected to the mobile router via the typical link layer protocol in the TCP/IP stack i.e. Ethernet. Nevertheless, in the experiment conducted, attempts are made to connect via wireless connection. The end terminal is able to associate with SSID broadcast of the mobile routers; however authentication to such SSID were not successful. Wireless connection to various end terminal platform were investigated including machine that run on Windows, several Linux distribution and android operating system. Such shortcoming may be due to the reduced support for Ad hoc Wi-Fi networks. As a result, by default, the operating systems are unable to correctly detect and connect to ad hoc networks [6].

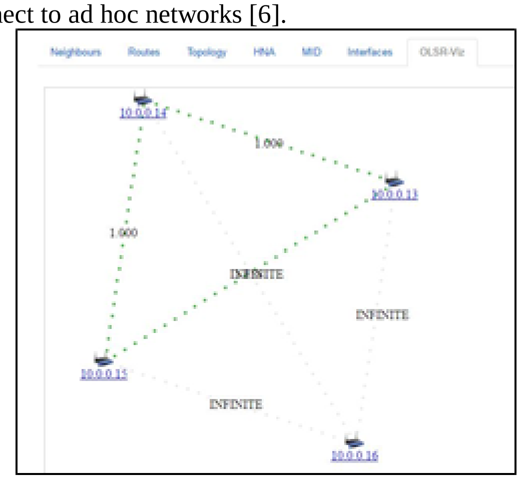

Figure 7. Infinite links

Despite the high transmitting power i.e. 20dbm as stated in the technical specification, the received signal power in indoor environment is quite poor. Consequently, the transmitting distance from a mobile router to the other is quite short. By default, the TL-MR3040 routers can go up to distance of 100 meters to 150 meters in a line of sight communication. However, in the experiment a significant portion of the signal is attenuated due to obstacles and the radio coverage for a mobile router is only 50 meters to 70 meters. When the receiver node move 70 meters away from the source the link is broken and JPerf connection between server and client is disconnected.

In wireless communication there are many elements which can affect the radio signal. In particular, indoor wireless communication can be severely impacted by obstruction such as solid wall and doors. Signal from the source is dampened, decreasing the radio range. The other factor which causes the transmission signal to be substantially reduced is the noise signal. Note that every mobile router in the experiment is set to the highest transmitting power i.e. 30 dBm (1000 mW). Theoretically, when the transmitting power is increased, the signal range transmission can be extended. However, with OpenWRT, tweaking the transmitting power to the maximum provides minimal benefits in extending the signal range transmission.

It is because when the transmitting power is high, the noise level of the signal also increases. A high level of noise significantly reduces the receiving sensitivity of the mobile nodes. As a result, it limits the distance for the signal range transmission [7]. Table VII shows the noise level reported from the experiment when the transmitting power is set to 13dbm.

Table 7. Noise Level

	TX-Power (dbm)	Signal (dbm)	Noise (dbm)
Mono1 (10.0.0.13)	13	-44	-87
Mono2 (10.0.0.14)	13	-46	-90
Mono3 (10.0.0.15)	13	-46	-95
Mono4 (10.0.0.16)	13	-48	-93

7. Conclusion

In conclusion, the OLSR routing protocol is possible to be implemented on TP-ML3040. Both the single-hop and multi-hop communication are tested and the routing protocol is able to perform as expected despite the poor performance. Nevertheless, the radio range for a mobile router in indoor environment is quite small. Therefore scalability will be an issue when the MANET networks need to be expanded. It will require several intermediate nodes to build a complete network. Such set up could degrade the network performance because the number of hops may increase. When the number of nodes in the network increases, each OLSR nodes will have to frequently update it database and subsequently battery power will be quickly drained. In addition the routing path which is built upon many hops is more susceptible to route breakage. Any single mobile nodes in the line of path may change location and a slight movement could break the connection. The OLSR system could end up frequently computing the routing path, leading to more resource needed for computation. It is also shown by experiment in this research work that as the number of mobile nodes increase in the network, the throughput decreases and the jitter increase over time.

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