Performance of Routing Protocol OLSR and BATMAN in Multi-hop and Mesh Ad Hoc Network on Raspberry Pi

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Abstract. Ad hoc network is a network where each node can act as a terminal and also as a router. Ad hoc technology does not require infrastructure that controls communication systems centrally. Therefore, each node on the ad hoc network can manage itself. This study aims to design nodes that can be used for communication on wireless ad hoc networks then compare the networks performance on OLSR and BATMAN routing protocols. There are four performance parameters used, namely Throughput, Round Trip Delay (RTD), Packet Delivery Ratio (PDR), and Convergence Time. The topology used includes P2P communication and multi-hop communication. Network performance testing is done both for P2P and multi-hop communication on MESH networks. Convergence Time Testing is done only for multi-hop communication to find out the time needed by the protocol to repair the path when a path fail occurs. The test results show that OLSR gives a better average value of throughput compared to BATMAN. Whereas RTD shows that the BATMAN routing protocol is better compared to OLSR. Both protocols, OLSR and BATMAN, successfully received all data packets sent by the source node on P2P communications. Failure to send data packets occurs in multi-hop communication as indicated by a PDR value of 98% for the OLSR protocol and 95% for the BATMAN protocol.

1. Introduction

Ad hoc network is a wireless network technology without infrastructure consisting of a group of nodes that are interconnected. Nodes in the network not only working as terminals but also function can as routers. The ad hoc network technology is very easy to install. Therefore, it is suitable for use in emergencies or only for temporary networks such as in disaster areas or used for interconnection at meetings [1].

Ad hoc nodes can be static or dynamic, move randomly, and can change topology quickly. Therefore, changes in ad hoc network topology are difficult to predict. Some routing protocols are made specifically for ad hoc networks to cope with topological changes or to find the best path. Ad hoc network protocols are divided into 3 classifications: proactive, reactive, and hybrid protocols [2, 3].

Proactive routing protocol updates its routing table by spreading information about the existence of each node to all nodes in the network periodically. Examples of proactive routing protocols are OLSR, DSDV, and BATMAN. While reactive routing protocols do not broadcast information about the presence of nodes in the network periodically. The protocol creates a route to the destination node at the time of communication (on demand operation). AODV, MAODV, and DSR are examples of types...
of reactive protocols. Hybrid routing protocol is a combination of the characteristics of the proactive and reactive protocols. Examples of hybrid protocols are ZRP and TORA [4].

Routing is one of the most important things of an ad hoc wireless network. Several studies on the performance of routing protocols on wireless ad hoc networks have been conducted, but only a few of these studies have been carried out in real tests. Testing with real tests gives real environmental conditions [5-7]. This research designs ad hoc nodes that can be used for wireless ad hoc network communication and compares the network performance on OLSR and BATMAN routing protocols. There are four performance parameters used, namely Throughput, Round Trip Delay (RTD), Packet Delivery Ratio (PDR), and Convergence Time. The network performance testing is done both for point to point (P2P) communication and multi-hop on MESH networks. Convergence Time Testing is carried out to determine the speed of the network system in repairing the path when a path failure.

2. Literature Review

2.1. Wireless Mesh Networks (WMN)

Wireless mesh network is one of wireless telecommunications network technology. The networks consist of a series of interconnected nodes where each node has two or more communication lines. The node in WMN topology can function as a mesh host or mesh router. The node as a mesh router functions to forward data transmission packets for other nodes that cannot communicate directly with the destination node. WMN has the ability to manage and configure its own network (self-configure/self-organize). Therefore, WMN can create and maintain its connectivity in the event of a trouble at another node. The ability of WMN makes the nodes in the network have a high level of robustness and reliability because they can always be connected to each other even though there are nodes that have been damaged [8, 9].

2.2. Raspberry Pi

Raspberry Pi is a single board small computer that operates on a Linux-based operating system or a Windows IoT-based operating system. The Raspberry Pi device was developed since 2006 by volunteers and technology academics in the UK who are members of the non-profit Raspberry Pi Foundation. The development of Raspberry Pi is very fast and already has several versions. Raspberry Pi 3 which can be seen in Figure 1 used in this study is the third generation that has the following specifications [10]:

- SoC: Broadcom BCM2837
- CPU: 1.2 GHz 64-bit Quad-Core ARMv8
- GPU: Broadcom VideoCore IV
- RAM: 1 GB LPDDR2 900 MHz
- Networking: 10/100 Ethernet, 2.4 GHz 802.11n Wireless LAN
- Bluetooth: Bluetooth 4.1 Classic, Bluetooth Low Energy (BLE)
- Storage: MicroSD
- GPIO: 40-pin header
- Ports: HDMI, 3.5mm analogue audio-video jack, 4x USB 2.0, Ethernet, Display Serial Interface (DSI)

2.3. Routing Protocol

Routing protocol is a protocol used to determine the communication path from the sender to the destination. There are 3 types of routing protocols on ad hoc network technology, namely proactive, reactive, and hybrid. This study will compare the performance of two proactive routing protocols, namely OLSR (Optimized Link State Routing) and BATMAN (Better Approach to Mobile Ad-hoc Network).
2.3.1. **OLSR.** The most popular link state protocol is OLSR which is standardized by the Internet Engineering Task Force (IETF) in document RFC3626. OLSR protocol is a proactive protocol that creates a route for sending data packets based on the routing table in each node. Routing tables are made based on topology information from each node at the time of the broadcasting of Topology Control (TC) packets. The TC packet is activated after each node has a list of identities of its neighboring nodes. These nodes are neighbors if and only if they can communicate directly with each other [11, 12].

OLSR selects MPR (Multi Point Relay) nodes which are used to forward messages from the source node. Only the MPR nodes can rebroadcast the messages. Therefore, not all nodes in the OLSR network can spread information sent by sending nodes. The MPR nodes are chosen so that each node in the network can reach all the nodes in the network. The MPR technique can reduce the number of TC packages.

To overcome the shortcomings of the shortest-path algorithm in the link state algorithm, OLSR has been equipped with LQ Extention. LQ Extention is the shortest path algorithm with an average packet error rate as a measurement parameter. This parameter is called ETX (Expected Transmission Count) which is defined as \( \text{ETX}(i) = 1 / (\text{NI}(i) \times \text{LQI}(i)) \). \( \text{NI}(i) \) is the packet arrival rate seen by a node on the \( i \)-th link. \( \text{LQI}(i) \) is the estimated arrival rate of packets seen by a neighbor node using the \( i \)-th link. When the network has a low packet error rate, ETX is higher. LQ extension can increase packet delivery ratios due to hysteresis-based techniques.

2.3.2. **BATMAN.** The BATMAN routing protocol does not have a broadcasting topology message. Each node runs the following algorithm [13].

A. Sending advertisement messages regularly called OriGinator message (OGM). OGM contains the sender's IP address, IP address of the forwarding node, TTL value and sequence number (SQ).

B. Check the best neighbouring node for each destination node in the network through the ranking procedure.

C. Rebroadcasting of the OGM received through the best neighbouring nodes.

If SQ and OGM received from a particular node are in a certain area, communication is considered two-way. For example, in the time interval \( T \), node A sends the message \( T_r \), \( r \) is the level of the OGM message. The nodes around node A will rebroadcast the OGM node \( \hat{A} \) messages and the other OGM nodes. If node A receives an OGM message from neighbouring nodes, node A checks the OGM message whether the SQ value of the most recently received message from that node is less or equal to the \( T_r \) message. If they are the same, then they have two-way communication. Otherwise, if they are not the same, then the nodes are simplex communication.
3. Research Method

Some hardware and software used in this study are presented in Table 1.

| Devices                          | Number | Types   |
|----------------------------------|--------|---------|
| Raspberry Pi 3 model B           | 4 pcs  | Hardware|
| Memory micro SD 8GB              | 4 pcs  | Hardware|
| USB wireless network adapter     | 8 pcs  | Hardware|
| Computer Windows                 | 1 pc   | Hardware|
| Raspbian 8 (Jessie) lite version | -      | Software|
| Command Prompt                   | -      | Software|
| HSMM-Pi                          | -      | Software|
| Mozilla Firefox                  | -      | Software|
| Hostapd                          | -      | Software|
| Dnsmasq                          | -      | Software|

3.1. System Design

An ad hoc wireless network system that was built using the BATMAN or OLSR routing protocols. Each system is composed of four wireless nodes that are interconnected in an ad hoc network. System performance testing is done using 2 topologies in three scenarios. The first topology, is a MESH topology which uses 4 nodes arranged in the range of each node to be connected directly (point to point). The topology can be seen in Figure 2. The second topology, the four test nodes are arranged so that multi-hop communication occurs. The second topology is illustrated in Figure 3. The test is carried out using three scenarios below:

A. The first scenario using the first topology is intended to determine the throughput for each routing protocol in point to point communication.

B. The second scenario uses the second topology, building multi-hop communication in order to determine the throughput of the routing protocol.

C. The third scenario uses the second topology to determine the self-healing ability of each protocol.

![Figure 2. The MESH network topology](image-url)
3.2. Node Configuration

The configuration process is done by headless process, namely with the SSH command at the command prompt or through the PuTTY application. Setting up the nodes in the BATMAN routing protocol is done starting from setting up the wireless node to testing the delivery of data packets. Following are the settings for node 1 configuration with the wlan0 interface which acts as an ad hoc interface and wlan1 as the hostapd (access point) interface.

### Wireless node settings and access point services

```bash
sudo nano /etc/network/interfaces
auto wlan0
iface inet wlan0 static
    address 172.168.137.21
    netmask 255.255.255.0
auto wlan1
iface inet wlan1 static
    address 152.168.1.1
    netmask 255.255.255.0
```

### Hostapd configuration for access point:

```bash
sudo apt-get update
sudo apt-get install hostapd
sudo apt-get purge dns-root-data
sudo nano /etc/hostapd/hostapd.conf
interface=wlan1
driver=nl80211
ssid=BATMAN HOST 1
hw_mode=g
channel=1
wmm_enabled=0
macaddr_acl=0
auth_algs=1
ignore_broadcast_ssid=0
wpa=2
wpa_passphrase=12345678
wpa_key_mgmt=WPA-PSK
wpa_pairwise=TKIP
rsn_pairwise=CCMP
```

**Figure 3.** The Multi-hop network topology
DHCP configuration in hostapd

```
sudo apt-get install dnsmasq
dsudo nano /etc/dnsmasq.conf
interface=wlan1
bogus-priv
domain-needed
dhcp-range=152.168.1.10,152.168.1.50,255.255.255.0,1h
```

do nano /etc/sysctl.conf

Ad hoc Networks configuration for wireless node

```
sudo apt-get install batctl
sudo nano /root/mesh.sh
#!/bin/bash
sudo modprobe batman-adv
sudo ip link set wlan0 down
sudo ifconfig wlan0 mtu 1500
sudo iwconfig wlan0 ap any
sudo iwconfig wlan0 mode ad-hoc
sudo iwconfig wlan0 essid BATMAN
sudo iwconfig wlan0 channel 8
sleep 1s
sudo ip link set wlan0 up
sleep 1s
sudo batctl if add wlan0
sleep 1s
sudo ifconfig bat0 up
sleep 1s
sudo ifconfig bat0 132.168.168.1
sudo route add default gw 132.168.168.1
sudo route add -net 152.168.2.0 netmask 255.255.255.0 gw 132.168.168.2
sudo route add -net 152.168.3.0 netmask 255.255.255.0 gw 132.168.168.3
```

Configuration for mesh.sh

```
sudo chmod 700 /root/mesh.sh
sudo crontab -e
@reboot /root/mesh.sh
```

All nodes perform the configuration steps with different IP address and SSID access point on each node.

### 3.3. System Testing

The performance of each routing protocol was evaluated using the Raspberry Pi 3 model B which is composed of four terminals. Each terminal uses the IEEE 802.11bgn protocol on the 2.4 GHz spectrum. Node 1 is specified as the origin terminal in all scenarios. The first and second scenarios perform bandwidth measurements using iperf which generates traffic in the form of TCP packets in a 10 second period. While iperf is running, the origin node also sends ICMP packets to the destination node using the fping command. This provides averaged round trip delay (RTD) and a packet delivery ratio (PDR).
The third scenario is done by turning off the node that is being passed by data from sender to receiver. Then observe the time needed (convergence time) to find a new path. The fping command is performed to send ICMP packets from the origin node (node 1) to the destination node (node 4) via one of the paths whether node 2 or node 3. Convergence time is calculated from the time from the loss of the main path until a new path appears as a maintenance for the damaged path. The convergence time value is obtained by calculating the difference in the ICMP sequence number between the last packet received through the old path and the first packet received through the new path then divided by the fping rate.

4. Result and Discussion

4.1. Throughput testing

Figure 4 shows the value of throughput for each protocol in each scenario. It appears that OLSR provides a higher average throughput when compared to BATMAN. The throughput has decreased significantly as the increasing the number of hops passed.

![Figure 4. Bandwidth](image)

4.2. Round Trip Delay (RTD) and Packet Delivery Ratio (PDR) Testing

The observation of round trip delay of the two scenarios for both the protocols can be seen in Figure 5. BATMAN compared to OLSR shows a better average time for both scenarios. Figure 6 shows the PDR of the two protocols does not show any packet drop in mesh network communication. The failure of sending data packets occurs in multi-hop communication. OLSR and BATMAN routing protocols experienced packet drops of 2% and 5%, respectively.

![Figure 5. Packet delivery ratio (PDR)](image)
4.3. Convergence Time Testing Results

The results of convergence time testing are shown in Table 2. The BATMAN protocol shows a faster convergence time when compared to OLSR. The average convergence time on the BATMAN protocol is 12.75 seconds while for the OLSR protocol is 18.5 seconds. This shows that the BATMAN routing protocol is faster in finding new pathways when connection link failure occurs.

| Protocol      | Convergence Time (second) | Minimum | Maximum | Average |
|---------------|--------------------------|---------|---------|---------|
| OLSR          |                          | 7       | 17      | 12.75   |
| BATMAN        |                          | 13      | 32      | 18.5    |

5. Conclusion

The OLSR routing protocol provides a better average value of throughput compared to the BATMAN protocol. However, the BATMAN routing protocol shows better RTD compared to the OLSR routing protocol. A 100% PDR for the two protocols is shown for MESH network communication. They indicate that all data sent arrives at the destination. The failure to send data packets occurs in multi-hop communication, where the PDR for the OLSR protocol is 98% while for the BATMAN protocol is 95%.

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