Deployment and Evaluation of a Multi-Hop Wireless Network

Fakrulradzi Idris[#1], Norlezah Hashim[*2]

[#1]*Lecturer, Faculty of Electronics and Computer Engineering, Universiti Teknikal Malaysia Melaka (UTeM), Malaysia*
[*2]*Teaching Engineer, Faculty of Engineering Technology, Universiti Teknikal Malaysia Melaka (UTeM), Malaysia*

Abstract— **Multi-hop wireless network uses two or more wireless hops to send information from source to destination. This paper presents the design and deployment of multi-hop wireless network testbed in Universiti Teknikal Malaysia Melaka (UTeM). While using the testbed to provide additional WiFi coverage around the cafeteria area in UTeM Industrial Campus, real-time measurements of various key parameters are carried out. This paper also provides some technical details of the testbed implementation as well as performance evaluation of network coverage, signal strength and connectivity. Performance of network throughput and effect of difference channel allocations are also presented.**

Keywords— **Multi-hop wireless network, testbed, network performance.**

I. INTRODUCTION

Multi-hop wireless networks (MWN) utilize multiple wireless nodes to provide coverage to a large area by forwarding and receiving data wirelessly between the nodes. Multi-hop wireless networks offer an extremely cost effective and easily deployable access alternative. Potential examples of this is for municipal networks, building networks, in malls, hotels, and apartment blocks, where wireless links are used as relays between individual consumer devices and a wired point of presence, eliminating the need for expensive wiring and maintenance.

Research works on multi-hop wireless networks have been extensive whether using simulator such as Network Simulator 2 [1] and OPNET [2] or network testbed [3]-[7]. Although simulation is an important approach for network protocol design, multi-hop networks are more complicated in a real scenario. Real world test bed implementations for multi-hop wireless networks are very significant and will provide strong support applications such as VoIP and video streaming.

In this paper, the design, deployment and evaluation of multi-hop wireless network testbed in Universiti Teknikal Malaysia Melaka (UTeM) will be discussed. In this project, we focus on the deployment scenario which is specific to campus environment. Results on the network connectivity, coverage and effect of throughput with different frequencies for this network are presented.

The rest of the paper is organized as follows: Section 2 briefly describes multi-hop wireless networks, followed by testbed implementation for the MWN in section 3. Test methodologies are described in Section 4. The results obtained are discussed in Section 5. Finally, the conclusions of the study are given in Section 6.

II. MULTI-HOP WIRELESS NETWORKS

In multi-hop wireless networks, there are at least one or more intermediate nodes along the path that received and forward packets from source to destination. Multi-hop wireless networks have several benefits such as can extend the coverage and improve connectivity. Data transmission over multiple short links might require less transmission power and more energy efficient than that required over long links [8] Multi-hop wireless networks can be deployed in a cost effective way and required less deployment of network cables. For a dense multi-hop networks, there are many paths available in which can increase the robustness of the network.

In wireless multi-hop network, nodes do not need for common infrastructure and can communicate with each other using wireless channels. The communication between nodes can be achieved by forwarding or relaying each other's packets.

III. TESTBED IMPLEMENTATION

The testbed [9] location is at UTeM Industrial Campus cafeteria. Fig. 1 shows the layout of the cafeteria and the location of access points.
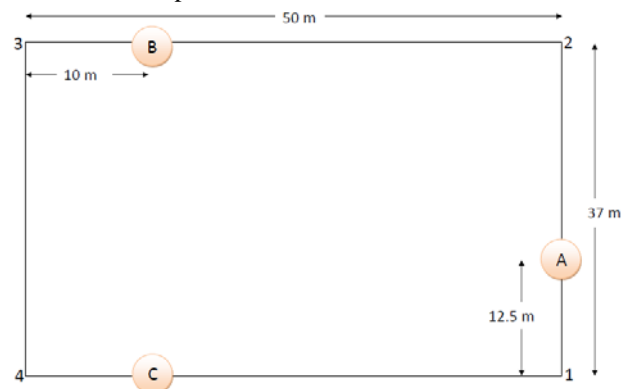

Fig. 1 Testbed layout

Three units of Multiradio Access Relay (MAR) [10] which provides both multi-hop relay and access point capability were installed at point A (MAR_A), B (MAR_B) and C (MAR_C) approximately 4m form the ground as shown in Fig.2 and Fig. 3.
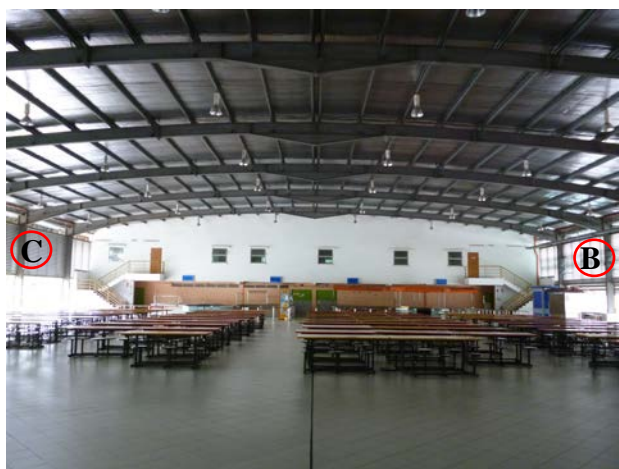
Fig. 2 Point A

Fig. 3 Point B and C

Each MAR is located at specific distance in order to widen the coverage of wireless network. The network configuration of the testbed is shown in Fig. 4.
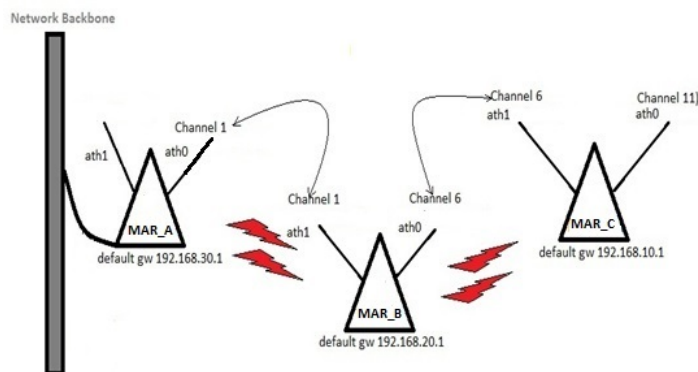

Fig. 4 Network configuration

Inside each MAR, there are two wireless radio interfaces which are designated as ath0 and ath1. MAR_A is connected to Internet via Ethernet interface and act as the gateway. In MAR_A, ath0 is assigned to use channel 1 so that it can be connected to the second network interface of MAR_B that is ath1 which is also using channel 1. Then, the first channel of

MAR_B is assigned to be in channel 6 and connected to the second network interface, ath1 of MAR_C that is also assigned to be in channel 6. The MAR_B will enable the connection between MAR_C and MAR_A thus creating the multi-hop network. The configuration of each access point is performed using telnet application in Ubuntu 11.04 operation system. Transmit power of each access point was set to maximum value of 16dBm.

IV. METHODOLOGY

Before making any measurement, several configurations for signal strength, connectivity, channel profile and throughput test need to be implemented in order to get desired result.

A. Coverage Test Setup

After all the MARs were deployed, coverage test are performed by walking around the testbed area and using laptop equipped with Ekahau HeatMapper [11]. Overall parameter for testbed area is 50m x 37m.

B. Signal Strength Measurement Setup

In order to measure the Received Signal Strength Indication (RSSI) for each deployed MAR, inSSIDer [12] is used. InSSIDer can be used to monitor the RSSI value for 2.4GHz or 5GHz channel. Using this software, we can observe the condition of the channel in the testbed area, whether overlapping or not. Based on Fig.1 there are 4 points for test location. The laptop installed with inSSIDer is left for a while at each of the location in order to get stable measurement of RSSI value.

C. Connectivity Test Setup

The easiest way to test the connectivity of the network is by using 2 laptops which one act as a client and the other as a server. For first test, the ping test between laptop and access point will be done to ensure there are connectivity in the multi-hop network. A Laptop is connected wirelessly to MAR_C and ping test to MAR_A and to MAR_B are performed. The multi-hop network will be successfully established if there are connectivity between MAR_A and MAR_C. Besides that, ping test from client to client and also from client to server will be done. The server is always stationary and connected to MAR_A.

D. Throughput Measurement Setup

The TCP throughput measurements are performed using the Iperf [13] traffic generator and measurement tool. Using a dedicated script, Iperf could be launched from Ubuntu terminal application. The results for throughput will be taken from the average value of throughput automatically measured by Iperf. The client node send TCP windows packet of 16Kbytes to the server node which is connected to MAR_A. The location for server node is fixed while the client node is positioned accordingly to create 1, 2 or 3 hops. In our definition, single hop configuration occur when a client node connected to MAR_A, 2 hops is when client node connected to MAR_B and while 3 hops occur when the client node connected to

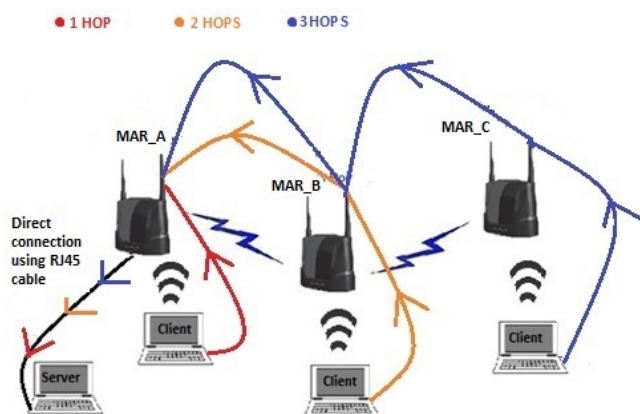MAR_C. The setup for this throughput measurement is shown in Fig. 5.

Fig. 5 Throughput test setup

V. RESULTS

A. Coverage

The deployed multi-hop network was able to provide coverage over the cafeteria area and it surrounding. The coverage map at the cafeteria was captured using Ekahau HeatMapper. The software indicates the signal coverage of the access point by heat color. The signal is excellent at area where dark green color is shown while the coverage is poor at area by indicated by red color. In the cafeteria, the minimum heat color shown by the software is in light green, approximately between -50dBm to -60dBm.

B. Signal Strength

The signal strength of each MAR was measured at four points as in Fig. 1. At point 1, the RSSI readings recorded were between -56dBm to -61dBm while at point 2, the reading were between -57dBm to -61dBm. Meanwhile at point 3 where the nearest MAR is MAR_B, the highest signal recorded was -34dBm while the signal strength of MAR_A and MAR_B were between -53dBm to -56dBm. At point 4, the RSSI value were between -50dBm to -60dBm. Overall, the measured RSSI were in the good magnitude which is sufficient to support the highest data rate (54Mbps) or modulation and coding scheme of WiFi (64QAM3/4).

C. Connectivity

We performed ping test between the MARs to ensure the packet can be routed from one to another. The average round trip time from MAR_A to MAR_B is 2.116ms, which is very small since both MARs only one hop distance. Meanwhile, the average round trip time from MAR_A to MAR_C is 4.226ms. The round trip time increased because MAR_A needs to forward the packets through MAR_B before reaching MAR_C. For both ping tests, there is no packet loss occurred.

Next we performed ping test from client to client. A fix client is connected to MAR_A and located about 3m away. Then, ping test is done from clients associated with MAR_B and MAR_C to the client associated with MAR_A. From the

observation, the time interval is slightly changed as the packet transmitted from client associated with different MARs to a fixed client. Similar to the previous test, there is no packet loss occurred.

D. Throughput Performance

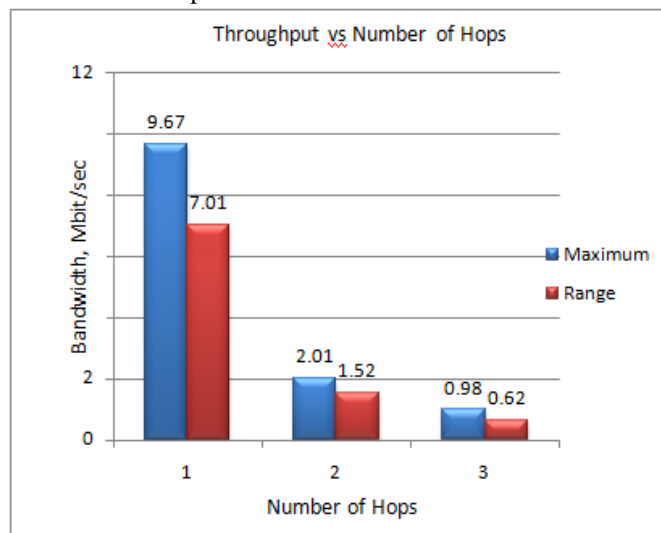Fig. 6 shows two types of throughput measurement for this wireless multi-hop network.

Fig. 6 Throughput performance

For maximum possible throughput, the client is located at close proximity to the MAR. The throughput is inversely proportional to the number of hops. The throughput value drops for more than 50% as the number of hops increased. For range throughput test, in which the client move 25m – 30m away from the MARs, the throughput value are decreasing due to the weaker signal strength received. Compared to maximum throughput test, the throughput value for first hop, two hops and three hops decreased approximately 27%, 24% and 37% respectively. From this percentage, it is indicated that the distance of a client from the MARs affected the throughput for this multi-hop network.

E. Effect of different channel allocation

Fig. 7 shows the throughput performance when different channels were assigned to the MARs as in Table I.

TABLE I
CHANNEL ASSIGNMENT

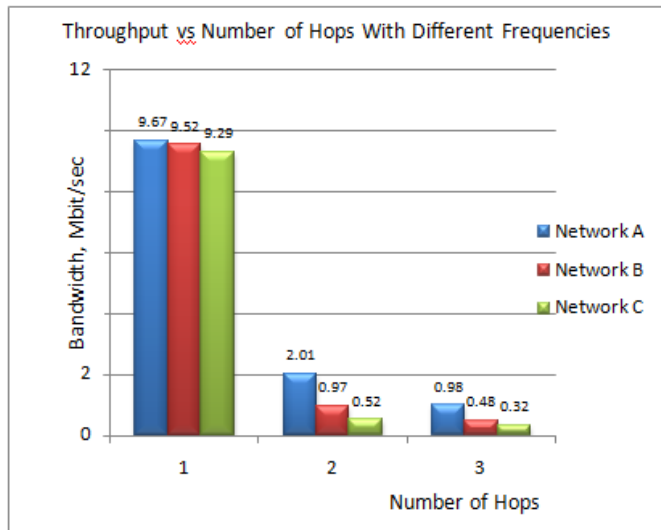| MARs / Network	Channel		
	A	B	C
MAR_A	1	2	7
MAR_B	6	5	8
MAR_C	11	10	9

Fig. 7 Throughput for different channel allocation

Similar with previous test, the throughput performance for the multi-hop network using different channel allocation experienced a significant decrease as the number of hop are increased.

For two hops configuration, the packet forwarding from MAR_A to MAR_B introduces additional delays which cause the throughput to decrease. It is also shows that the three hops configuration experience lower throughput because MAR_B need to relay the traffics to client associated with MAR_C.

The lowest throughput recoded for each number of hop configuration for Network C since adjacent frequencies are used. The larger overlapping channel gives a huge impact to the throughput value. The radio frequency (RF) overlapping between MARS affects the performance of the multi-hop network.

VI. CONCLUSIONS

In this work, we have deployed a multi-hop wireless network testbed and analyze its performance. The results show that three MARs are sufficient to provide the signal strength required for the highest data rate (54Mbps). However, the highest throughputs are obtained when non-overlapping channel 1, 6 and 11 are used. For future work, MARs equipped with two radio interfaces; 2.4GHz and 5GHz will be used to reduce the interference from channel overlapping as well as to increase the throughput of the network. The 5GHz radio can be used as backhaul connection between MARs while the 2.4GHz radio can be used for user access.

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