A Practical Evaluation for Routing Performance of BATMAN-ADV and HWMN in a Wireless Mesh Network Test-bed

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Abstract— **Over the past few years, connections between the end devices or stations have been increasingly wireless. In 1997, 802.11 subcommittee had first approved its Wireless Local Area Network (WLAN) standard. Since then, many wireless networking standards have taken extra efforts in developing mesh architectures in which data is forwarded between multiple wireless hops to reach the desired destination. The main advantage of Wireless Mesh Network over the traditional WLAN is the fact that Wireless Mesh Networks are easy to deploy, flexible, have capability of self-forming, self-healing, and self-organization. In this Project, an implementation and development of wireless mesh network test bed is carried out on the layer 2 routing using Better Approach to Mobile Adhoc Network- advanced (BATMAN-adv) and Hybrid Wireless Mesh Network (HWMN) protocols. The main reason for the use of layer 2 protocol over layer 3 is the less processing overhead that helps in maximizing the throughput. Also, a protocol that runs on layer 2 is capable of supporting any protocol above layer 2. The major aspects of this project will cover setting up a real time wireless mesh test bed and performance analysis of BATMAN-adv and HWMN and their comparisons.**

Keywords— Wireless Mesh Network; BATMAN-adv; 802.11s; HWMN

I. INTRODUCTION

WLANs based on 802.11 have gained a tremendous growth due to its ease of deployment, support for mobility, robustness, economical access points and 'plug and play' architecture. They are extensively used in universities, homes, schools, and public wireless hotspots to provide different services. WLANs depend extensively on Access Points that are connected to the wired backbone networks. This infrastructure based network suffers from high network complexity and high cost of deployment. Therefore since the last few years, the network topology has been slowly migrating towards infrastructure less or Adhoc network. Wireless Mesh Network is based on Adhoc Network and can be established using Bluetooth, WIMAX, UWB or Wi-Fi standards [1]. But Wireless Sensor Networks using WIMAX as radio interface could be overkill.

In this experiment, Wi-Fi (802.11 Family) has been used to establish Wireless Mesh Network among 5 Nodes, dispersed across MSRIT campus. The 802.11 family consists of 802.11, 802.11a/b/g/n/ac. Other standards in the family (c–f, h, j) are used to extend the current scope of the existing standard. The most commonly used standards are 802.11a, 802.11b/g. 802.11b/g uses the 2.4 GHz ISM band, with underlying modulation schemes being DSSS and OFDM signaling methods, respectively. 802.11a uses 5GHz ISM band with speed of 54 Mbps. In this project, 802.11g is used that operates in 2.4 GHz ISM band; with a speed of 54 Mbps per channel (802.11g has four non-overlapping channels).

The protocols operate on layer 2. In layer 2 routing, the protocol not only transports the routing information using raw ethernet frames, but also handles the data traffic. The traffic is encapsulated and forwarded until it reaches its destination. The protocols are implemented as kernel drivers. This way, a negligible packet processing overhead can be introduced even under a high load.

The main contribution of this project is to provide a comparative analysis of the different routing protocols (BATMAN-adv and 802.11s) used for Wireless Mesh Network.

The remainder of this paper is described as follows. In section II, the architectures of Wireless Mesh Network (WMN) and 802.11s are defined. In section III, some recent Wireless Mesh Network projects with the objective of providing wireless mesh test-beds are presented. In section IV, Protocol operations for BATMAN-adv and HWMN (802.11s) are discussed. In section V, the details of the hardware and software requirements, along with the design and the implementation of the test-bed are presented. In section VI, the parameters used to verify the performance of the protocols along with the results are shown. The paper is concluded in section VII, that presents the conclusion and the future works.

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II. ARCHITECTURE OF WMN AND 802.11s

A. The architecture [2] of Wireless Mesh Network consists of three types of nodes:

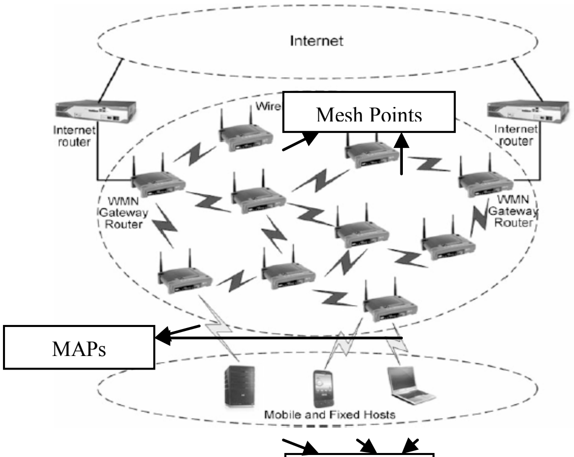

Figure 1: Architec Mesh Network

- Mesh Portal Points (MPPs): These nodes act as the gateway between the Mesh Environment and the external network. The gateway can give the Mesh Network access to the Internet. For optimal performance, number of Portal Points should be kept mesh network becomes more identical to WLANs.
- Mesh Points (MPs): The primary job of these nodes is to provide routing only. These nodes act as relay points.
- Mesh Access Points (MAPs): These are the nodes which act as an access point so that end devices (STAs) can connect to the mesh network.

Figure 1 below shows an example of such architecture [1].

The test-bed consists of some nodes which act both as gateway and router whereas some other nodes act as both access point and router.

B. The architecture of 802.11

Figure 2 below shows the architecture of 802.11 that allows the operation of Adhoc Modes [3][4].

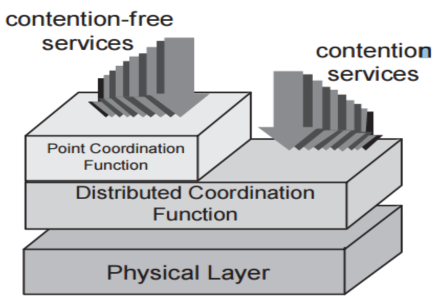

Figure 2: 802.11 architecture

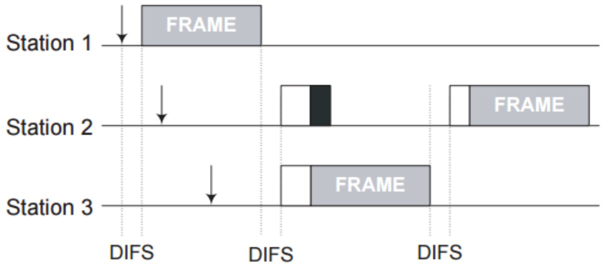

Figure 3: Basic MAC access Mechanism

In figure 2, the MAC layer offers two types of services: A Contention-free service and a contention based service. Distributed Coordination Function (DCF) is based on Carrier sense multiple access with collision avoidance (CSMA/CA) and provides the basic access method for the 802.11 MAC protocol. DCF can operate in both Infrastructure Mode- Basic Service Set (IM-BSS) mode and Infrastructure-less Basic Service Set (IBSS) mode, whereas Point Coordination Function (PCF) operates in IM-BSS mode only. Since we are dealing with the wireless mesh network, we will consider only the DCF mode.

The basic access Mechanism employed by DCF is explained in the figure [3] [4].

In the fig above, if a station wants to send a data, it must first sense the channel to check if any data transmission is going on between different stations. If the channel is idle for a period greater than DIFS (Distributed Inter-Frame Space), it will start sending the data else it will wait for a random back-off time. If the channel is found to be idle after the back-off time, it will again wait for a period of DIFS.

III. RECENT WIRELESS MESH PROJECTS

1. Google Project Loon: Project loon [5] is started on June, 2013, with an aim of providing Internet access around the globe, mainly to those areas that would be hard to reach with wired connection. The project uses solar-powered balloons that form a mesh network 20 kilometers above the ground. The balloons communicate with their neighbors and also with the ground stations that are connected to the Internet providers. Internet will then be provided by sending the signals to the antennas installed on the intended locations.

2. Microsoft Research Mesh Network: This project aims at establishing a community mesh network that connects the home networks of the community together. The core of the project is the Mesh Connectivity Layer (MCL) [6], which is an interface, added between the layer 2 and layer 3. The MCL layer is based on Dynamic Source Routing Protocol and nodes with the MCL interface can route the data for other nodes. Some nodes act as gateways between the mesh cloud and the external network to provide internet access.

3. Redhook Wi-Fi, Brooklyn: Red Hook became popular after the Hurricane Sandy struck in 2012 [7]. The cell phone networks were down and internet services were unavailable. The Federal Emergency Management Agency had to depend on Redhook Mesh Network, where the residents would connect to the mesh access points to communicate with each other and with the government officials.

4. Implementation of Partial Mesh Network in the Himalayan Region: The project was started in the year 2012 in an attempt to fill the digital gaps between rural and urban areas, particularly the Internet. The project employed a test-bed consisting of 8 nodes, placed at mountainous regions of Nepal [8]. The access points were placed at the rooftops, office and school buildings. The project was experimented jointly by Muroran Institute of Technology, Japan and Wakkanai Hokusei Gakuen University, Japan.

IV. PROTOCOL OPERATION

BATMAN-advanced: Better Approach to Mobile Adhoc Network-advanced (BATMAN-adv) is a layer 2 protocol that uses MAC address for finding paths to the destination [9]. It is a proactive protocol which uses the concept of Destination-Sequenced Distance Vector (DSDV) routing protocol (Perkins and Bhagwat 1994) [10] [11]. In DSDV, all the participating nodes will maintain a list of distances to all other nodes in the networks. A node will select the next hop based on the minimum distance. For example a node i will select node j as the next hop instead of node k if $\{d_{ij}$ to reach a destination x$\}$ < $\{d_{ik}$ to reach destination x$\}$,where d_{ij} represents the distance from node i to node j. Apart from the list of distances, a node will maintain a sequence number that is assigned by the destination node. This sequence number allows the nodes to differentiate between old routes and new routes. All the nodes will broadcast updates to the routing table periodically [10] [11].

In BATMAN-adv, every node broadcasts a hello message, OGM (Originator message) to all its neighboring nodes periodically and it uses Transmission Quality (TQ) metric [9]. The receiving node will measure a fraction of the OGM message, called the Receive Quality (RQ) and will rebroadcast to its neighbors. In this way, the entire network will be flooded by OGM messages [12] [13]. The nodes will then start measuring a fraction of the OGMs that are rebroadcasted by their neighbors. This fraction is denoted by echo quality (EQ). The TQ of OGMs that are received by a neighbor can then be calculated by dividing EQ by RQ. Among all the OGM messages received, a node will resend the OGM that has the best metric, TQ.

Hybrid Wireless Mesh Network (HWMN or 802.11s) protocol: IEEE 802.11s is a standard defined for Wireless Mesh Networking that uses Hybrid Wireless Mesh Network Protocol (HWMN) for its operation. Similar to BATMAN-adv, it operates on layer 2 by using MAC addresses for finding paths from source to destinations [14]. Every node in HWMN will be either Mesh Portal Point or Mesh Point or Mesh Access Point.

802.11s performs routing using MAC addresses and may use either four or six MAC addresses depending on the architecture [14] [15]. Four addresses will be used if both the source and destination are mesh points or nodes. For non mesh points or stations, six MAC addresses will be used. The additional two MAC addresses are used to track the MAC addresses of the source and the destination stations or clients that are outside the mesh network. The six MAC addresses include Destination MAC Address, Source MAC Address, Destination Proxy Address, Source Proxy Address, Final Destination Address and Originator Address. HWMN is a hybrid protocol that has the routing capability of both the reactive and proactive protocol [17].

The reactive and proactive routing in HWMN is described as follows.

1. Reactive routing: Reactive routing in HWMN performs similarly to Radio Metric-Adhoc On demand Distance Vector (RM-AODV) protocol, where a node broadcasts a Path Request (PREQ) message [15]. The PREQ message contains a unique sequence number that distinguishes it from other PREQ messages. An intermediate node receiving a PREQ message compares the sequence number in the message with the last locally stored sequence number and is processed only when received sequence number is greater than its stored sequence number. If the sequence numbers have the same value, then the one exhibiting a better route to the destination will be processed. The intermediate node will then update the PREQ message by including the weight of the last hop and its reverse path towards the sender. The updated PREQ message will then be rebroadcasted. A node receiving the PREQ message will the same principle until it reaches the destination. The destination node replies with a Route Reply (RREP) message to the intermediate node from which it received the PREQ message. The intermediate node will then update the PREQ message by adding the forward path towards the destination. The updated PREQ message will then be unicasted to the node from which the PREQ was sent. If a node failure is detected, the intermediate node replies with a Route Error (RERR) message towards the source so that the source can select a different route to reach the destination.

2. Proactive Routing: Proactive routing works similarly to the reactive routing in how the intermediate nodes process the RREQ, RREP and RERR messages. The difference is that in Reactive Routing, the messages are sent only when needed whereas in proactive routing, the messages are periodically.

V. EXPERIMENTAL SET-UP

Hardware Platform	TP-Link WR1043ND
Chipset	Qualcomm Atheros QCA 9558
RAM, Flash	64 MB, 8MB
WLAN driver	Ath9k

Firmware	OPENWRT
Performance measurement tool	IPERF
SSH and Telnet Client	Putty
BATMAN-adv debugging tool	Batctl

The experiment employed 5 tplink –WR1043ND routers.

BATMAN-adv set-up: The routers are upgraded with open-wrt firmware [12] [13] [18]. The packages kmod-batman-adv and batctl are installed in all the routers. The package batctl is used to configure the batman-adv kernel module and to display the debug information such as originator tables, translation table and debug logs. Out of the 5 routers, one router is employed as a Mesh Portal Pont (MPP), two routers are used as Mesh Points (MPs) and the remaining two routers are used as Mesh Access Points (MAPs).

The configuration of the MPP is done in such a way that two interfaces are provided for the MPP. One interface will communicate with the external network either through wireless or Ethernet cable, while the second interface will communicate wirelessly with other nodes, which can be MP or STA or a MAP. The MPs are configured to include only one interface, the wireless interface with other MPs or MAPs. The MAPs are configured similarly as MPPs except that one interface will be used for connecting the clients or STAs while the second interface is used to communicate among the nodes.

After the configuration of the network and wireless settings on these routers, they are rebooted and tested. After successful test, iperf is installed on two STAs.

The *batcl o* command is then given to generate the routing table. ICMP ping messages with an interval of 1 sec are sent continuously to each other nodes consecutively with record option set using the commands, *ping -R -c -i 1 <dest>* and *batctl ping -R -c -i 1 <dest>* for 10 minutes. In addition to this, TCP and UDP streams with unlimited bandwidth are sent to each other nodes consecutively for 1 minute. Based on these information, an average is taken and the below tables are generated.

HWMN set-up: The set up for HWMN is the same as BATMAN-adv in how the nodes are configured. The difference is that in HWMN , the package *authsae* is installed and package *wpad-mini* is removed. After the configuration, ICMP ping messages, TCP streams and UDP streams are sent from a node to all other nodes consecutively. An average is taken from the data and the below graphs are generated.

Details of Channelization used:

Wi-Fi Standard	802.11g
Band and Channel width used	2.4 GHz and 20MHz
Modulation Technique	OFDM
Number of channels	4 (1, 5,9,13)

VI. EXPERIMENT AND RESULT

Figure 4: Nodes location

Figure 4 above shows the various node positions that are kept on the rooftops. The performance metrics are recorded for one hop, two hops, three hops, four hops and five hops for both the protocols.

The results are shown below.

- Average TCP Throughput

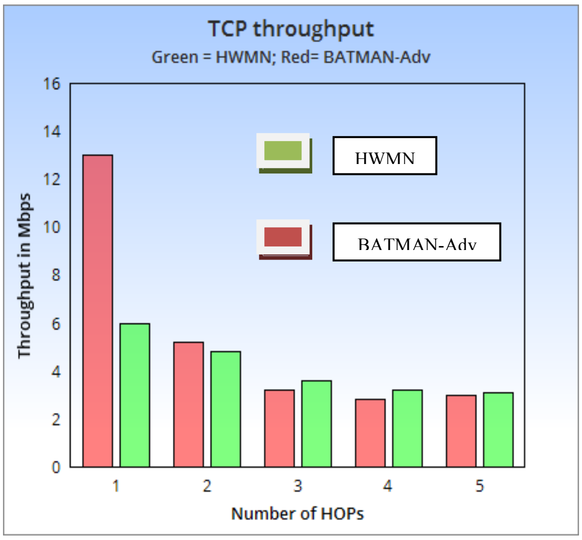

Figure 5: Average TCP Throughputs

- Average UDP Throughput

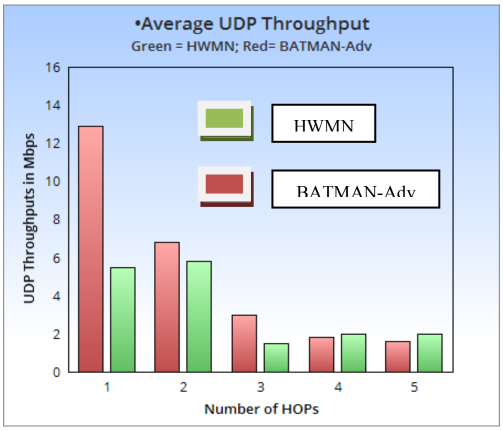

Figure 6: Average UDP throughput

- Average Jitter

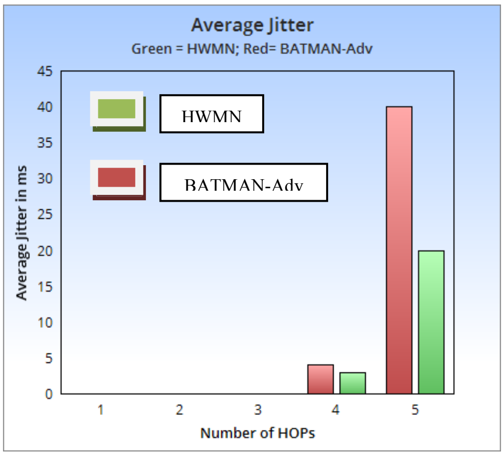

Figure 7: Average Jitter

- Packet Delivery Ratio

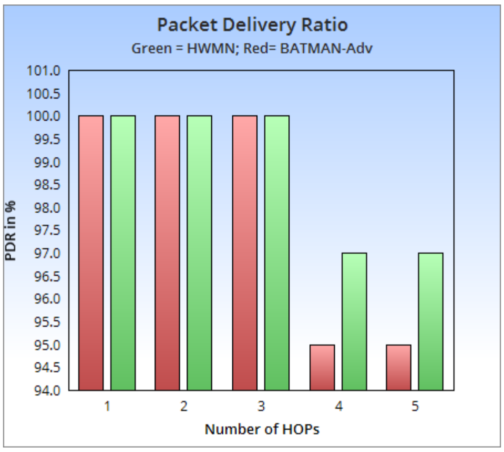

Figure 8 : Packet Delivery Ratio

Discussion:

Throughput: From the figure, we saw a steep decrease in the throughput from node1 to node2 in BATMAN-Adv as compared to the HWMN. This is because of higher routing overhead [19] incurred in proactive protocol (BATMAN-adv) as compared to HWMN. Routing overhead is the total cost involved when a packet is forwarded from one node to another, including the network resources, traffic forwarding and maintenance costs.

Jitter: The average delay from one node to a different node I, in a WMN is given by Diffusion Approximation Equation [20].The equations shows the increase in the delay with increase in the number of hops. The better performance in the HWMN in terms of Jitter is explained by the cross layer design system [21] employed in HWMN.

From the throughput graphs, it can be concluded that BATMAN-adv is efficient for networks with less number of nodes. The advantage of 802.11s or HWMN is the ability to recover quickly in case of failure of nodes, which gives a better scalability than BATMAN-adv. Since HWMN is a hybrid protocol, the routing overhead is less in HWMN compared to BATMAN-adv. Moreover the Packet Delivery Ratio (PDR) with increase in the number of hops is more in HWMN than in BATMAN-adv. Thus, it can be concluded that HWMN is more scalable than BATMAN-adv.

VII. CONCLUSION AND FUTURE WORKS

The implementation of Wireless Mesh Network is cost-effective as the hardware employed is cheap and it can be easily deployed at a very less time. From the experiment, it is found that the average TCP throughput and average UDP throughput decreases with increase in the number of hops. The decrease in the throughputs is steep from Hop 1 to Hop 2. However, a gradual decrease is seen subsequently.

BATMAN-adv provides better throughput than HWMN, however HWMN gives better performance in terms of latency and Jitter.

Future work can be done by increasing the number of nodes in the network and test it using a real time application like video surveillances or video chat over the mesh network. Work can be done by introducing security at the layer 2 level and introducing Directional Antennas instead of the Omni-directional antennas used in these routers.

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