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REVIEWING REAL WORLD IMPLEMENTATION OF MANETS THROUGH TEST BEDS

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Abstract:
Mobile Adhoc Networks- MANETs are Infrastructure-less Networks which do not employ any Central Access Point for communication. Each node of the network acts as Host and Router and has a Multi hop Routing Capability. It is observed that MANET is not as popular as Wi-fi Networks even though they are more cost effective than regular wi-fi networks and easier to set up. In most of the cases observed, MANETs have been developed for specific applications like Military, Rescue Operations etc but their general purpose use is not seen frequently. Very less literature exists on Real World Implementations of MANET. Most of the literature is based on simulating MANETs Routing Protocols. This paper is an attempt to understand the Real World Implementation of MANETs in terms of Test Beds, their Hardware-Software Requirements, Operating Systems used, applications tested under established MANET Environment, Routing Protocols, Wireless Standard used etc. The purpose of this study is to understand existing MANET Test beds to develop a Real World General Purpose Application for Mobile Adhoc Networks in future.
Index terms: Adhoc Network, MANET Test beds, Adhoc Routing Protocols

I. INTRODUCTION

MANET stands for Mobile Adhoc Network which consists of set of mobile nodes connected wirelessly without a central access point or a fixed infrastructure. The topology of the network changes frequently due to the mobile nature of the nodes. Each node in MANET acts as both host and a router and directs network traffic to the required destination. It is a Peer to Peer Network which communicates over Radio Frequencies in Multi Hop Manner. It is basically used in environments where building infrastructure is not possible, like Military Applications, Forest Fire Rescue Operations, Natural Disasters, and short ranged Personal Area Networks etc.

Most of the research work carried out in the field of MANETs has been implemented on Simulators like Network Simulator NS2, NS3 and OPNET etc. Simulation offers a controlled environment for verification of theories. But when it comes to real world implementation, the actual implantation results differ with the theoretical results obtained on simulators. The multi hop nature of the routing protocols, unrestrained radio propagation, mobile nature of the devices in MANET must be examined in Real Wireless Network.

Due to a large range of a typical network card, the real world testing environment would be spread over a wide geographical area. The researchers who have tried for real world testing of MANET have employed a Test Bed Environment where a small physical network of MANET Nodes is created and examined for various features. This work is an attempt to analyze some of these MANET Test beds.

Figure-1: Mobile Adhoc Network (MANET)

II. IMPORTANT FACTORS FOR MANET TEST BEDS

Careful selection of following factors is important for MANET Test Bed Implementation:

- Routing Protocol
- Operating System
- Wireless LAN Standard

Selection of Routing Protocol

Selection of Routing Protocol is an important factor of MANET Set up. MANET topology is highly dynamic, this means that the nodes are continuously moving. Also there is no central access point to coordinate the routing process. Each node acts as a host as well as a router. Hence an effective routing protocol is required to direct the packets to the destination using Optimal Path Selection by creating less routing overhead. The exchange of data in MANET is highly dependent of the efficiency of routing protocols to maintain the routing information and to adapt to the continuously changing topology.

There are three types of Routing Protocols in MANET:

(i) Proactive Routing Protocols (Table Driven):

In these protocols, each node maintains Routing Information about all other nodes in the network in the form of a table by exchanging Hello Messages. Hence it takes little time to perform route discovery and route establishment. The proactive protocol assigns pre-computed shortest route to a pair of source destination nodes. This protocol was designed to reduce the amount of time spent in route discovery and route establishment processes [38]. But it creates routing overhead due to periodic exchange of routing information.

Example: OLSR, DSDV, BATMAN

(ii) Reactive Routing Protocols (On-Demand):

In these protocols, each node discovers route to the destination as and when required by flooding Route Request Packets. They start finding the route when a packet needs to be sent [37]. The reactive routing protocol generates the shortest route on demand of the source node.

Updating of Routing Table is not involved in Reactive Protocols. Hence it creates little network overhead but it increases the end-to-end delay in the process of finding route from source to destination.
Example: AODV, DSR, TORA, ABR

(iii) Hybrid Routing Protocols:
These protocols combine the functionality of both the proactive and Reactive protocols. Initial Routing information is gathered from the Routing Tables and additional routing information is obtained by initiating the Route Discovery Process.
Example: ZRP, ZHLS

A lot of research has been carried out to assess the performance of MANET Protocols in terms of Packet Delivery Ratio, Throughput, and End to End Delay etc. For Ex Marwan Hamid et al. in 2021[37] evaluated the performance of AODV, DSDV and AOMDV and discovered that AOMDV is the best protocol for time critical rescue and search operations.

Valmik Tilwari et al. in 2020[38] proposed a new routing strategy called the mobility, contention window, and link quality-aware multipath (MCLMR) routing protocol for load balancing and network stability in MANETs. The proposed MCLMR scheme identifies multiple paths and selects the intermediate nodes on the basis of the best mobility, contention window size, and link quality status to construct the optimal route from source to destination nodes for reliable transmission of data.

Selection of Operating System

Selection of Operating System is another important criteria to set up MANETs. General purpose operating systems don't have direct provisions to support special requirements of adhoc on demand routing protocols. Employing the support for adhoc routing protocols requires modifications in Kernel Programming which is a tedious task. Most of the researchers working in MANET Test Bed Implementations prefer to use Linux Operating System as it is Open Source Operating System and supports extensible kernel functionalities.

Most of the implementations of adhoc routing protocols are found for Linux Operating System only but still limited research work exists for implementation on other platforms like Windows CE, Android etc.

Selection of Wireless LAN Standard

The purpose of MAC Protocols is to increase channel utilization, decrease delay, and protect the network. A shared channel is used by MANET nodes for information exchange. Collision may occur among the transmitting nodes due to the shared channel. Hence MANET requires some dynamic MAC protocols that can easily avoid and handle collisions [39]. A single radio channel is shared by all nodes with the help of a contention based protocols and is allocated on demand. Mostly MANETs use the IEEE 802.11b CSMA/CA MAC Protocol (Carrier Sense Multiple Access with Collision Avoidance Medium Access Control) to share a common medium among the nodes to communicate simultaneously.

802.11, 802.11x are the specifications developed by the IEEE for wireless LAN-WLAN technology. The 802.11 standard specifies over-air interface between a wireless client and a base station or between two wireless clients. 802.11b-an extension to 802.11 is the most popular choice of Wireless Standard for MANET implementation. 802.11b provides approximately 11 Mbps transmission in the 2.4 GHz band. The 802.11b standard provides a wireless range of roughly 35 meters in indoor environment and 140 meters in outdoor environment.

III. OVERVIEW OF MANET TESTBEDS

Salem Satia et al. in 2018[2] created a testing environment of Raspberian Linux Computers to implement MANET. The network card used in these systems was WLAN 802.11 which uses a static private IP address for creating an adhoc mode network. To make these nodes mobile, power batteries were added to them. In addition to installation of Raspberian Operating System, additional packages are required to be installed to set up MANET. Through Package Manager, Babel and OLSR Packages are installed and other required configuration was done. BABEL is a distance vector routing protocol for mesh networks and OLSR is a proactive routing protocol for MANET. For testing purpose, the authors placed these computers at various floors of their University building and observed the impact of obstacles. The authors tested downloading of files of various sizes in multi hop scenario under Babel and OLSR protocols and presented a comparative analysis of the two protocols.

Eduardo Soares et al. in 2017[1] have developed an Android based application- AdHocDroid to achieve IP Level Mobile Adhoc Network functionality in smartphones. IEEE 802.11 standard of wireless communications provides IBSS mode for employing adhoc networking where the nodes can communicate with each other without the help of central access point. But this mode cannot support multi hop functionality so they require additional routing protocol for network layer. Authors have added OLSR protocol to achieve multihop functionality. Due to this protocol the devices working on operating systems other than android are able to connect with this network. The authors tested the Adhocdroid application for networking between linux based laptop and android smartphones. They tested the performance of the created MANET for two multiplayer games Battle and Spaceteam. The authors claim that Adhocdroid is a MANET based application as it justifies all the requirements of establishing a MANET like no need of internet, no central access point, multi hop communication, working with diverse OS etc.

E. Kulla et al. in 2015[4] implemented a real test environment for MANET to check the performance of OLSR Protocol in terms of mobility and throughput. Nine Ubantu Laptops were placed at different floors in the University building to visualize a scenario of rescue operation by a Robot. IEEE 802.11b was used as a MAC Protocol with Distributed Internet Traffic Generator (D-ITG) Software to inject data flow in the network and analyze the results using decoding tools. Static (STA) and Moving (MOV) Scenarios of the devices were created for the experiment to check the effect on throughput.

S. Hou et al. in 2015 [5] implemented MANET Test bed for IOT Applications. The test bed

incorporated one controlling laptop with Java Based Network Management Software and more than twenty PDAs with QT based GUI. This GUI supported various functionalities like Video/Voice Transmission, RFID Reading, Sensing Temperature, Humidity etc required for IOT based Business Applications. This test bed was developed to compare performance of AODV and DSR Protocols under Outdoor and Indore Multi hop Scenarios. For the indoor testing, the devices were arranged in Chain Topology and for the outdoor testing, Ribbon Topology of the devices was used. The authors have given a very detailed explanation on the Comparative Analysis of DSR and AODV Protocols for the mentioned business parameters like Audio-Video Transmission, RFID Data Transmission, and Temperature Data Transmission etc.

M. Aloqaily et al. in 2013[3] developed an Audio/Video Conferencing based application which will help the Fire Fighters to communicate with each other effectively in emergency situation under standalone MANET environment. The authors identified the drawbacks of the current Walkie-talkies based system and overcome its limitations in their application by providing audio-video communications at various user levels in cluster based manner. The system is implemented in Windows Adhoc Networking Environment and developed using Java Programming Language. It is called a Standalone MANET System and specification about multi hop capabilities and routing is not mentioned. The authors used SIP (Session Initiation Protocol) for establishing multimedia sessions and for media transportation and mixing, they used RTP Protocol (Real Time Protocol).

Jie Liu et al. in 2013[21] implemented AODV Protocol in a real mobile network environment based on Windows CE Operating System. The Windows CE Operating System is not Open Source, so the authors could not modify the core protocol stack. The AODV Protocol Driver was added by extending the functionality of Windows CE which supported middle layer driver NDIS (Network Driver Interface Specification). For the test bed environment, the authors used two mobile nodes with PXA270 chambers connected by WiFi module and two fixed computers with USB Wireless Network Card with AODV Services added. The IEEE 802.llb wireless network interface was used. To test the multi hop scenario, the authors lowered the transmission power of wifi module to the minimum value and they removed the antennas of USB Card. The set up was tested using a Ping Command. The Source node sent a ping command for the destination which was not in the coverage of the source node. The destination successfully replied to the ping command of the source node through intermediate nodes following AODV protocol's RREQ, RREP mechanism.

E. Kulla et at. in 2012[6] developed a MANET Test bed to investigate performance of Batman Protocol in terms of Throughput, Delay and Packet Loss under Indoor Environment. The test bed consisted of network of five Fedora-14 Laptops with Lynksys Wireless Network Cards. The mac protocol used was IEEE 802.11b. The Distributed Internet Traffic Generator (D-ITG) Software was used to inject traffic in the network which also provides decoding tools to measure various parameters during the transmission process. The wxWidgets GUI Tool was used to set and edit network parameters. The experiments were conducted in Indoor environment – on the fifth floor of their University Building and tested under two topologies-

Linear and Mesh. Performance of Batman Protocol was tested for transmission of data with different packet rates under multi hop scenario.

Prinima Gupta et al in 2012[20] implemented AODV Protocol for Windows CE Operating System. The implementation was tested in two stages through Platform Builder Emulator. In the first stage with two nodes with the installation of Microsoft Loopback Adapter, the exchange of Hello Messages was tested. The second stage of testing the user level application under emulation was carried out for three nodes. The route was successfully discovered from the source node to the destination node through the intermediate node. This implementation was suitable for embedded and mobile devices such as PDAs and palm tops. The authors elaborated that there are two approaches of implementing AODV in Windows CE- first by implementing it as NDIS Intermediate Driver (Network Driver Interface Specification) and second by modifying the Filter Hook Mechanism. The authors implemented the first approach as it is easy to install and can be easily ported other Windows versions like Windows XP. But as the protocol gets tightly coupled with data link layer, it gets limited to 802.3 and 802.11 transmission mechanism.

Nicola et al. in 2011[22] created a MANET Test bed of Android Smartphones. The Authors selected Android OS as it is Open Source Operating System based on Linux Kernel. They made use of FB-AODV Protocol (Flow-Based Ad-I On-demand Distance Vector), developed by the Univesitat Politecnica de Catalunya (UPC). In the test bed, the authors used two Smartphones- HTC Polaris and Ideos Huawei and one Notebook PC- Asus EeePC. On the testbed devices the Authors installed Linux Kernel 2.6.32, configured with FB-AODV protocol module. The authors explained the complete process of configuring the MANET named “whixos”. The authors developed an Android Application- “hfbaodv.apk” having two buttons. “Start/Restart AODV” started the adhoc mode for the network. The button “List neighboring nodes” displayed the list of nodes in the MANET- whixos. The other Android Application “SMSoS” was developed to send free short text messages to nodes in the network. The network was tested under two scenarios. In the first scenario, all the three nodes were in coverage of each other. In the second scenario, two nodes which were not in coverage of each other, communicated through intermediate node.

L. Li et al. in 2009[7] explained in detail, what are the requirements of establishing a MANET Test bed, how the process should be carried out, and what are the possible challenges. They developed their MANET Test bed called “E2WMANT- Enhanced Experimental Wireless Mobile Ad hoc Networks Test bed” made up of 20 systems out of that 5 were Notebook PCs and 15 systems were Embedded Modules with Motorolla Controller. This test bed used all the software packages bundled in Red Hat Linux version 9.0 OS Packages. The test bed used 802.11b Wireless Cards Technology to construct the Multi hop Adhoc Network which can transmit up to about 150 feets using the 2.4GHz spectrum. As routing protocols, the authors used AODV and OLSR Protocols. Iperf Networking Tool was used to measure various network parameters. The information given in the paper is very valuable to the researchers who want to develop MANET Test beds as proper guidance is given on the test bed development process.

Ricardo in 2006[8] developed a MANET Emulation System called MANET Test bed Manager (MTM). The test bed consisted of five Linux based systems with one desktop computer having a wireless card and other systems were four PDAs. The desktop computer was also connected to internet and acted as Network Address Translation Gateway. The test bed implemented AHCPN Routing Protocol of MANET. The test bed was demonstrated around a college building to observe the effect of several obstacles. The main purpose of MTM system is to recreate simulation by accepting NS2 Files.

James T. Kaba et al. in 2001[9] developed a MANET Test bed that is easy for re-configuration and re-use due to its small size, low cost and independent of any specific operating system. The authors in detail explained the basic hardware components required to build the test bed like NICs, NIC Shielding, Antennas, Fixed and Variable Attenuators, Resistive Splitter/Combiners, Cables and Connectors, Terminators etc. The authors investigated the performance of the test bed under Two Node Configuration, Multi Node Configuration and Advanced Multi Node Configuration. The laptops used in the experiment were equipped with Lucent WaveLAN Turbo Gold NICs supporting 802.11b Standard. The authors created multi hop scenario by intentionally attenuating the signal level at each node. Under this test bed, Maximum signal level transmitted between the NICs and minimum attenuation required was measured.

Kwan-Wu Chin et al. in 2002[10] implemented MANET Test bed for real world performance comparison of AODV and DSDV Protocols. The test bed consisted of two notebooks and three desktop computers, equipped with Lucent Wavelan IEEE 802.11b PCM-CIA cards and running Linux (Debian with 2.2.15 kernel). The MAC Protocol used was 802.11b. To create a small multi hop network, they wrapped each network card with a metallic anti-static bag to decrease their communication range from 250 meters to five meters. Thus the authors managed to create four hop network inside their lab and could avoid experimentation over a large area. The test bed examined FTP File Transmission Data under upstream and downstream migration path. Downstream stands for movement towards a particular node and upstream stands for movement away from the node. The authors developed an application called PowerWave which was a signal quality based neighbor selection program. The authors found that in real world implementation, the routing protocols did not behave in the same way as they are observed under Simulation Environment.

IV. BASIC REQUIREMENTS TO SET UP MANET TEST BEDS

Lixin Li and Huisheng Zhang in 2009[7] described the process of MANET Test Bed set up in detail. From that description and the literature review done, the basic requirements of setting MANET Test Bed are outlined as follows:

- Selection of basic hardware components like desktops, laptops, phones running a standard operating system
- Configuration of required Softwares, Applications, Routing Protocol Drivers
- Setting the Wireless Interface Card and its properties
- Technology to enable multi hop adhoc network (Like IEEE 802.11b)
- Selection of Node Topology
- Providing Mobility Support to the nodes

- A Remote Monitoring Tool for the Test bed if it is spread over a large geographical area
- Experiment Analysis Tools

V. PROPOSED GENERAL PURPOSE MANET APPLICATION FOR FUTURE IMPLEMENTATION

Mostly MANET Applications exist for specific needs like Military, Rescue Operations etc. Its general purpose applications are very limited. After studying the existing configuration for MANET Test bed, a Real World Application of MANET can be developed to suite a general purpose need.

Figure -2 : MANET General Purpose Application

A general purpose MANET application can be developed for above scenario, for exchanging of audio video files among various devices at home like laptops, smartphones, tablets etc without the need of internet. The devices can be spread in multiple rooms in the house but communication among them can be done due to the multi hop nature of MANET. To create such a scenario, understanding their configuration requirement was necessary which the main purpose of this study was.

CONCLUSION

Most of the existing Research Work in MANET is based on Simulations which does not give a true idea of their real world performance. This paper is an attempt to give contribution in understanding MANET Real World Implementations by studying existing test bed schemes. From this study, it is observed that most of the MANET Test beds are implemented under Open Source Operating System like Linux which gives the developer, a provision to alter the Kernel Functionalities to employ Adhoc Protocols. The wireless standard used by most of these test beds is IEEE 802.11b. Special attention was given to create and test Multi hop Scenario in most of these test beds. Some schemes have also performed Comparative Analysis of MANET Routing Protocols.

Various aspects of this study are mentioned in the Summary Table below which includes Routing Protocols, Hardware Configuration, Additional Softwares, Operating Systems, MAC Protocol Standard used for the Test Bed Environments.

Sr No	Paper Title, Ref No, Year	Routing Protocols and Softwares	Hardware Devices	Operating System	Application Tested	Wireless Standard	Remark

1	MANET Testbed using Raspberry PIs[2] 2018	Packages of OLSR and Babel Routing Protocols	Raspberry PI Computers	Raspbian Linux	Downloading different sized files in multihop manner	Adhoc Mode of WLAN 802.11 Network Card	(i) Studied Obstacle Impact (ii) Applicable for proactive protocols only
2	Experimentation with MANETs of Smartphones[1] 2017	AdhocDroid- Android based Application to enable MANET , OLSR Protocol	Android Smartphones, Linux Laptop	Android	Multiplayer Games- Battle and Spaceteam	IBSS Mode of IEEE 802.11	Allows easy way to import & run different routing protocols
3	Real World Emergency Scenario with MANET in Indoor Environment- Experimental Data[4] 2015	DTIG-Distributed Internet Traffic Generator Software, OLSR Routing Protocol	Laptops with external USB Wireless Cards	Ubantu 14.04 LTS	Data Flows created by D-ITG Software	IEEE 802.11b MAC Protocol	Studied mobility and multi hop effect
4	Performance Comparison of AODV & DSR in MANET Test-Bed Based on Internet of Things[5] 2015	AODV, DSR Protocols, Network Management Software(Java based)for laptops, QT based GUI for PDAs	Laptop and PDAS	Embedded Arm-Linux	Voice Communication, RFID, Temperature Monitoring	IEEE 802.11b Standard	Indoor Outdoor Effect studied
5	A Novel Communication System For Firefighters Using Audio or Video Conferencing or Sub Conferencing In Standalone MANETs[3] 2013	JAIN SIP (Java API for Integrated Networks), JMF (Java Media Framework), RTP Protocol for Media Transportation and mixing	Windows Computers	Windows	Audio/Video Conferencing	Windows Adhoc Network	(i) Multi hop not mentioned (ii)Mobility not tested
6	An implementation study of the AODV routing protocol in Windows CE[41] 2013	AODV Protocol	Two mobile PCs and two fixed PCs with AODV Services added	Windows CE	Ping Command	IEEE 802.11b	Good Universality to employ other Routing Protocols like DSR, TORA
7	Multimedia Transmissions over a MANET Test bed- Problems & Issues[6] 2012	Batman Protocol, DTIG- Distributed Internet Traffic Generator ,wxWidgets GUI Tool	Laptops with The Lynksys wireless network cards	Fedora 14	Audio Video Data	IEEE 802.11b Standard	(i)Mobility not tested (ii)Multi hop nature studied
8	An approach to use FB-AODV with Android[42] 2011	FB-AODV Protocol	Two Smartphones- HTC Polaris and Ideos Huawei and one Notebook PC- Asus EeePC	Android OS	Android Application to display nodes in the network and to send sms	IEEE 802.11 Family	Useful for General Purpose Use, User friendly
9	Implementation study of AODV for Microsoft Windows CE platform[40] 2012	AODV Protocol, Platform Builder Emulator for Windows CE	Two Nodes, Three Nodes Configuration	Windows CE	Exchange of Hello Messages through User Level Application	IEEE 802.3 / 11	Suitable for Embedded and Mobile Devices

10	Research on Designing & Implementing an Experimental MANET Test bed[7] 2009	Iperf Application, AODV and OLSR Protocols	Notebook Computers & Embedded Module systems with IEEE 802.11b Wireless Cards	Red Hat Linux version 9.0	A simple testing application	IEEE 802.11b Standard	Integration of one Reactive and one Proactive Protocol
11	Design of a MANET Test bed Management System[8] 2006	AHCPN MANET Protocol, NS2	One Desktop Computer with wireless card, and PDAs	Linux 2.4.x	Packet Forwarding	Not Mentioned	Provides a standard validation framework for MANET protocol implementation
12	Implementation Experience with MANET Routing Protocols[10] 2002	PowerWave Program, AODV, DSDV Protocols	Desktop & Notebooks Computers with Lucent Wavelan IEEE 802.11b PCM-CIA cards	Linux Debian with 2.2.15 Kernel	FTP File Transfer	IEEE 802.11b cards	MANET Handoff discussed
13	Test bed on Desktop-Strategies and Techniques to Support Multi-hop MANET Routing Protocol Development[9] 2001	Applicable to any Adhoc Routing Protocol supporting multihop transmission	Laptops with Lucent WaveLAN Turbo Gold NIC	Any OS	Maximum signal level transmitted between the NICs, minimum attenuation required	802.11b wireless NICs	A small test bed under controlled environment

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