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A Survey on Emulation Testbeds for Mobile Ad-hoc Networks

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Abstract

Mobile Ad hoc Network (MANET) can be said as a collection of mobile nodes, which builds a dynamic topology and a A resource constrained network. In this paper, we present a survey of various testbeds for Mobile Ad hoc Networks. Emulator provides environment without modifications to the software and validates software solutions for ad hoc network. A field test will show rather the simulation work is going on right track or not and going from the simulator to the real thing directly to analyze the performance and compare the results of routing protocols and mobility models. Analyzing and choosing an appropriate emulator according to the given environment is a time-consuming process. We contribute a survey of emulation testbeds for the choice of appropriate research tools in the mobile ad hoc networks.

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Keywords: Mobilead hoc network, routing protocols, Emulation, Simulation, Testbeds.

1. Introduction

MANET (Mobile ad hoc networks) [5] is a self-configuring infrastructure less network in which the mobile devices are connected by wireless medium. In MANET devices are free to move independently in any direction, and can change its links to any other devices in the network frequently. The phenomenon of movement of the data packet from source to destination is known as routing which means that the process of selecting best paths in a network. A routing protocol uses routing algorithms as well as software to find an optimal path in network for transfer and communication between network nodes. Examining and evaluating protocols for MANET [33] is a guarantee success of a real world application.

Simulation [35] is the process of designing a model of a real system and conducting experiments on the node and understanding the behaviour of the node in the network and also evaluating various operations. Simulations are used to understand the behaviour of routing protocols, mobility models. There are many network simulators. Simulators can be categorized as: NetSim, OPNET, Network Simulator (NS2/NS3).

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This paper is organized as follows. Section-II highlights the Emulation. The testbed category and architecture in section-III. Section-IV includes issues addressed. Section-V discusses related work. The conclusion is presented in section-VI.

2. Emulation

Emulation [17] focuses on creating an original environment of computer, which can be time-consuming and difficult to achieve, and also it is very costly because of its ability to maintain a close connection to the legitimacy object.

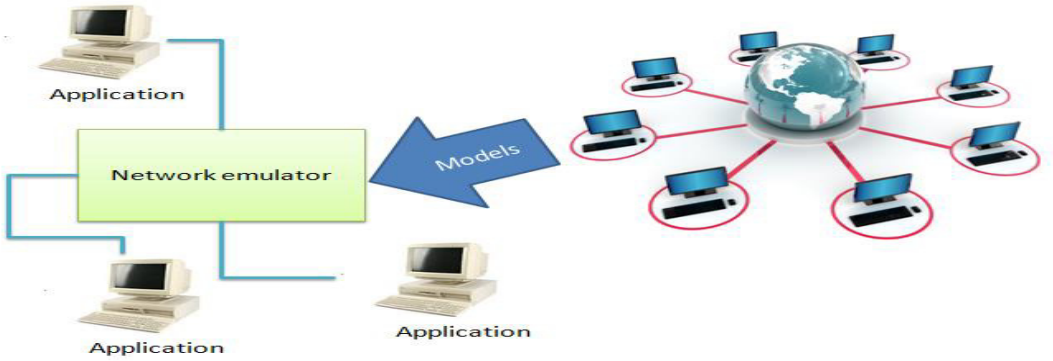


Fig.1. Network emulation [36]

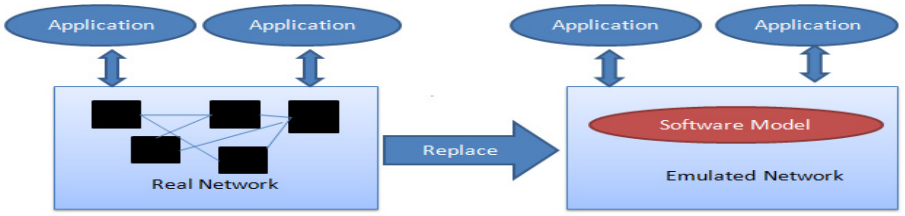
Emulation [29][31] provide fully controlled and reproducible environment and it shows realism. The most important thing in the emulation is protocols which are implemented will be tested without any modification. It is cost effective and scalable. It is not a simulator but necessity of hardware equipment. Each node is a device that has a wireless 802.11 interface, so that it can communicate with other ad-hoc nodes and run MANET protocols.

2.1 Simulation Vs Emulation[36]

1. A system represents by an off line software.	1. In emulation system is seems like other system.
2. Simulation can run at any speed compare to real world.	2. Emulation creates visions like real thing and used for testing without buying real things.

2.2 Why Emulation ?

Emulation [29] is required to introduce the simulator into a live network. In emulation object within the simulator are capable of introducing live traffic into the simulator and injecting traffic from the simulator into the live network.



1. Requires real deployed network.
2. Hard to reconFig real network.
3. Real network behaviour not easily or reliably reproducible.
4. Difficult to develop distributed applications in a single lab.

1. Only needs a software model.
2. Easy to vary emulated network configuration
3. Emulated network behaviour easily reproduced.
4. Enables applications to be co-located in a single local lab to develop/debug.

Fig.2.Emulation process [36]

3. Testbed Category and Architecture

A testbed [5]is a framework for testing protocols in the real world. The testbed consists of four elements: components (hardware and software), monitoring architecture, database and graphical user interface (GUI) for storing and analyzing results. Mobile ad hoc networks (MANETs)[2] testbeds is categorized as:

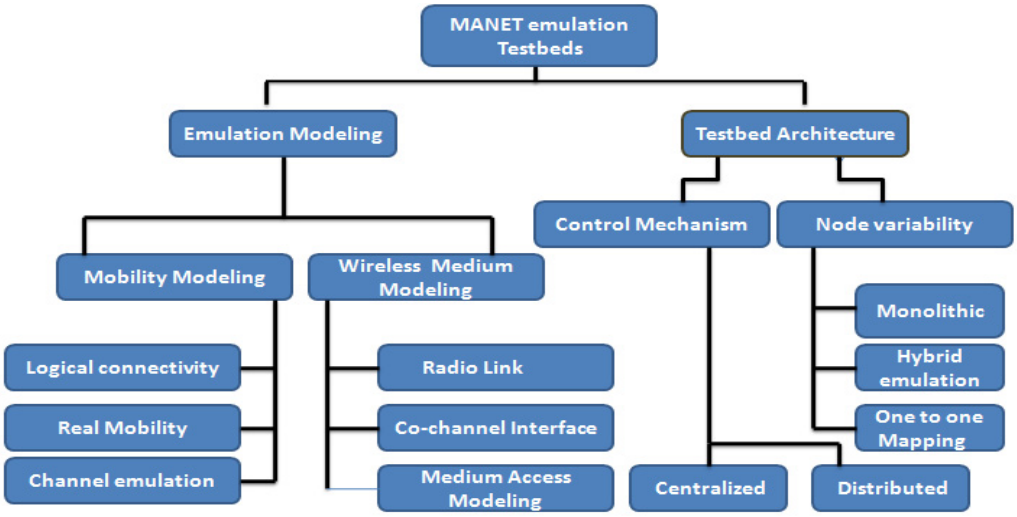


Fig.3.Categories of testbeds [2]

3.1 Mobility modeling

3.1.1 Real Mobility

To change the physical position of the node real mobility is used. It can be done using robots, or antenna. Testbeds are based on real mobility.

3.1.2 Channel Emulation

Channel emulation [2] is based on nodes which are stationary.

3.1.3 Logical Connectivity

The mobility modeling [2] approaches deals with physical radio signals.

3.2 Wireless Medium Modeling

3.2.1 Radio Channel

The radio channel or we can say radio link. The physical channel and pair of nodes depending on the node location and mobility.

3.2.2 Co-Channel Interference

Two different transmitters uses the same frequency, signal to noise and interference ratio is measured.

3.2.3 Modeling medium Access

Mostly emulation testbeds are IEEE 802.11. In ad hoc networks nodes compete for access to a shared wireless medium frequently resulting in collisions.

3.3 Node variability

3.3.1 Hybrid Emulation

Emulation [5] setup consisting of several physical machines, each host contain one or multiple virtual node instances.

3.3.2 One-to-One mapping

A physical machine that holds only a single node.

3.3.3 Monolithic Emulation

Setup for an emulation contains a single physical machine it holds all virtual nodes.

3.4 Control mechanism

Classification of testbeds according to control mechanism:

3.4.1 Centralized control

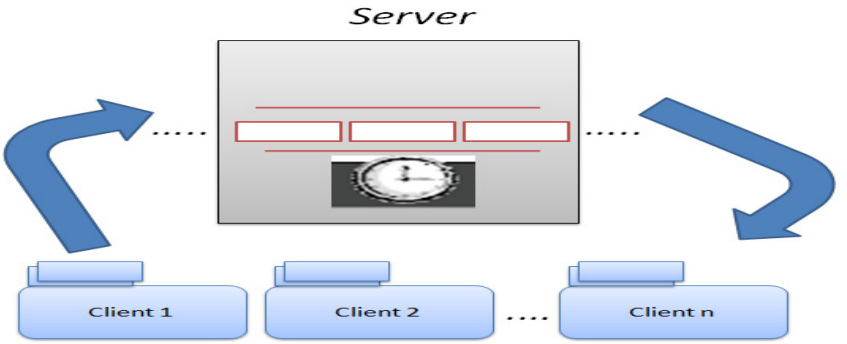


Fig. 4. Centralized control [19]

As expressed in Fig 4 centralized control [19] an emulation of the node movement is done by the central server. The nodes send their outgoing traffic to a main server, frames/packets that forwards, drops, or alters which is according to the network topology and wireless medium conditions.

3.4.2 Distributed control

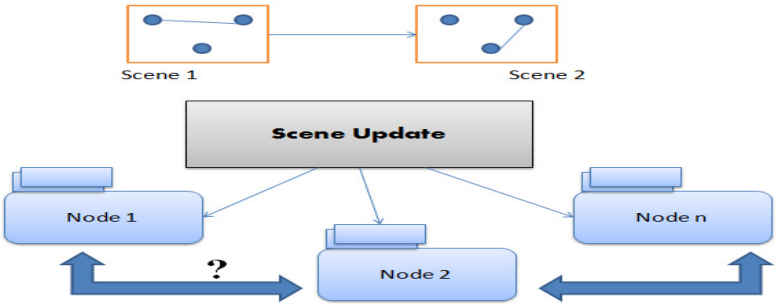


Fig.5.Distrubuted control [19]

As expressed in Fig 5 distributed control [19] approaches build on clients that are mutually connected via a cabled or wireless shared medium. Nodes in the network receive the entire communication automatically and also determine whether incoming packets are accepted or rejected. This conclusion is founded on logical connectivity, which can be made from topology and media information in a broadcast manner.

3.5 Scalability and Cost efficiency

3.5.1 Scalability

Addresses the number of nodes.

3.5.2 Cost efficiency

In terms of cost for the required hardware and software, as well as the required space for deployment.

4. Address Issues

Most of the work is done on the simulator. Simulation is an effective and feasible approach to design, develop and test network protocols. Simulators faces difficulty to model and predict the behavior of real environments. Models adopted by the simulator are not accurate, therefore simulation results may not be as accurate as real implementations. Work done on a simulator is just an experiment. We can't predict the experiment performed on the simulator will successfully implement in real environment. Simulators' results may not be same when it is implemented in real environment. To validate and proof of implementation of the experiment in real environment emulation is performed.

5. Related Work

Recently, a number of testbeds have been described in literature while only some of them are actually accessible. This section provides an overview of existing, publicly available testbeds and classifies their features with regard to the testbeds size and the features of the software used for operating, managing, and using the testbed. Table I summarizes the most well-known testbeds.

Flynn et al. [28] JEMU is a central controlled emulation testbed and its tested size is 12 physical nodes its mobility medium is wired and centralized collision detection on frame level it was developed by the Networks & Tele-communications Research Group. It is centralized so every packet is first sent to the emulation engine then engine decides rather certain nodes are able to receive it or there should be a collision.

Carreras et al. [12][32] WHY-NET is a scalable testbed for in Mobile Wireless Networking. The 12 interconnected multidisciplinary testbeds to test new wireless technologies. The WHYNET investigates different types of wireless technologies, one can look at them individually and together. The different wireless technologies include, Sensor Networks and Smart Antennas.

Zhang et al. [27] MobiEmu is a distributed controlled emulation testbed. There is no physical connectivity. It allows to run several virtual node on a single physical machine it consists of several slave nodes and one master node. Central server indicate the change in connectivity. The master node gives instructions on topology changes,

and the slaves node set local IP tables-rule. MobiEmu very impractical for us to use.

Raychaudhuri et al. [11] ORBIT consists of 400 radio nodes which are fixed and installed within one meter. Each physical node is logically connected to a virtual node in a network. The radio nodes are decked with two 802.11x interfaces and Bluetooth. Measurements can be performed on the physical level, MAC level, and network.

Zheng et al. [18][4] EMWIN is based on EMPOWER which has hybrid emulation testbed with distributed control mechanism based on a wired network . Its tested size is 48 virtual nodes on 8 physical machine. The connectivity matrix will provide input to all virtual nodes.

Puzar et al. [1] NEMAN is centralized controlled testbed and its tested size is one physical node. It can run hundreds of nodes on a single machine Also it is useful tool for developing protocols. Topology manager manages virtual network interfaces and performs packet switching.

Jorge Hortelano et al. [32][34] CASTADIVIA is a test-bed platform, It uses IEEE 802.11 interfaces. It is has two major elements: (1) The core (2) The nodes which can communicate among themselves. Communication between the core and the Nodes is performed over a typical Ethernet network. The graphical user interface takes mobility instructions and generates network topologies to put them to real devices and obtain the test result.

Matthes et al. [7] MASSIVE is distributed emulation testbed. It allows to emulate several virtual MANETs in real-time. To control the virtual network topology, drag and drop mechanism is used for the mobile devices. A group of nodes are assigned script based creation of movement patterns which emulates complex mobility scenarios and presence of attractive forces.

Ramanathan et al. [29] NET The Network Emulation Testbed (NET) is a Hybird Emulation, it is based on distributed control mechanism.. The degree of Node Virtualization is very high of up to 30 nodes per physical machine. Bandwidth adaptation and the insertion of artificial delay can be performed by shaping tool called Net-Shaper. The traffic for the emulation layer is called ”Net- Shaper.

Macker et al. [6] MNE (Mobile Network Emulator) is real world testbed and distributed control controlled emulation testbed and its tested size is ten physical node and its medium is 802.11. The main problem in MNE is requirement of separate device for each emulation.

Johnson et al. [14] TrueMobile is the wireless, mobile, which is extension to the Emulab testbed, it provide access to a variety of experimental environments. It is tested on 16 physical node. Localization can be achieved by a vision based tracking mechanism which supports collision free path planning for the robots.

Raniwala et al. [3] MiNT testbed apply 802.11 based radio nodes mounted on remote controlled robots. To avoid noise sources, the testbed is set up in a single laboratory room. MiNT supports full topology reconfiguration and unrestricted node mobility.

Ramanathan et al. [9] DAWN it is real world testbed emulation and its tested size is 10 physical node. It is based on the LR 4000 embedded router from Nokia Wireless Router. It measures different power control algorithms and QoS support within MANETs for voice communication.

Kotz et al. [15][21] Gray is a real world testbed and distributed controlled emulation testbed and its tested size is 33 physical nodes its mobility medium is IEEE 802.11. Real-World Testbed for evaluation of ad hoc routing protocols. Software architecture provides dual functionality as distributed controlled emulation.

Mahadevan et al. [26] MobiNet is centralized controlled and its tested size is 200 virtual nodes and it is wired medium. It consist of core nodes. It used to emulate topology, edge nodes and hop-by-hop.. It is built-in routing protocol (DSR) and specially emulates MAC layer. Its setup is complicated.

Hernandez et al. [16] RAMON can be classified as a channel emulator. For evaluation of Mobile-IP mechanisms the testbed consists of three 802.11b Access Point. Multi-hop communication is not possible in ramon. Its tested size is one physical node with a computer controlled RF attenuator as well as stationary node. This emulates the SNR(signal to noise ratio).

Weirong Jiang et al. [19] POEM is a software used for testing and evaluating MANET routing protocols. Poem is centralized architecture. It operates in a client/server structure and also it can run on several workstations. The server software and the client software can run on any hardware platform and also it is connected through

TCP/IP connections.. It can run several clients in one workstation to emulate MANET nodes.

Kang Yao et al. [23] ART-NET A Real-Time Testbed for Routing Network which supports the popular routing protocols for typical applications. ARTNet consists of a Web-based Interface (WBI). It is implemented on a multiprocessor server for creating and managing their routing networks for users.

Nordstrom et al. [20] APE is a real world testbed and distributed controlled emulation testbed and its tested size is 37 physical nodes mobility medium is IEEE 802.11. It is Linux based software environment, allowing to perform MANET experiments with various ad hoc routing protocols. The APE framework was designed to run experiments on laptops.

Ritter et al. [8] Ritter testbed is tested out so it is called ”Embedded Wireless Modules, which are based on a Motorola 68HC912 core controller quipped with Bluetooth and a 433 MHz RF-module. The tested size is 5 real nodes.

Judd et al. [13] This Testbed has digital baseband emulation which provides facility to emulate the small scale fading and different antenna patterns.

Kaba et al. [22] Kaba is a radio frequency emulation testbed**,** its tested size is four physical nodes and its mobility medium is IEEE 802.11**.** The RF signals are feed into coaxial cables which are connected by resistors, splitters and combiners to set up the network topology. In Kaba nodes are physically separated on signal level by fixed and variable value attenuators to decrease transmit and receive power

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Engel et al. [24] Engel it is distributed controlled testbed emulation and its tested size is 5-10 virtual node per physical node. It has properties of the wireless medium. The Engel testbed addresses optimizations and virtualization degree for Hybrid Emulation. The emulation architecture is based on a L4 Microkernel.

6. Conclusion

The ad hoc networks have dynamic topology. Most of the research work has been performed on the simulator. Sometimes there may be instability in the network performance and unexpected behaviour of the nodes due to external effects, but it is difficult to anticipate the behaviour of the nodes in real surroundings. Consequently testing the actual environment is required and it is very pricey and time consuming. We present a survey of testbeds for choosing an appropriate tool for testing mobile ad hoc networks. This paper presents testbeds with size and mobility modeling, scalability and price efficiency. Every emulator have its own limitations, some shows good results in specific setting while some may not perform in a similar context. We conclude that the selection of an emulator largely depends upon given environment.

Appendix A.

Table 1.A Survey on various Testbeds (See Table I)

Testbeds name	**Architecture**	**Tested Size**	**Mobility/ Medium modeling**	**Cost efficiency**	**Scalability**	**Protocol**	**Description**
JEMU[28]	Centralized	12 physical node	Logical connectivity/wired	low	medium	DSR	It was developed by the Networks & Tele-communications Research Group to emulate the radio components of their particular communication stack.

WHYNET [12]	Distributed	-	Real /wireless	medium	medium	-	It is a hybrid wireless testbed and realistic environment, flexible evaluation of wireless applications
MobiEmu [27]	Distributed	50 physical node	Logical connectivity/wired	high	medium	PROACTIVE ROUTING PROTOCOL	It allows to run several virtual node on a single physical machine it consists of several slave nodes and one master node and it also facilitates the use of User Mode Linux.
ORBIT[11]	Centralized	400 physical node	Antenna switching/Bluetooth and IEEE 802.11	high	low	AODV/ OLSR	It consists of 400 radio nodes which are fixed and installed inside within one meter. it uses 802.11 interfaces.
EMWIN[4] [18]	Distributed	45 virtual 8 physical node	Logical connectivity/wired and wireless	medium	medium	MAC LAYER PROTOCOL	It is hybrid emulation testbed with distributed control mechanism based on a wired network.
NAMEN[1]	Centralized	1 physical node	Logical connectivity/pointer passing	high	high	OLSR	Is a monolithic emulation.
Castadiva [32][34]	Centralized	-	Logical connectivity / IEEE 802.11	medium	high	OLSR	Castadiva carrying out realistic experiments. It is combination of wireless routers a Linux platform.
MASSIVE [7]	Distributed	13 physical node	Logical connectivity/wired	medium	low	AODV	It allows to emulate several virtual MANETs in real-time.
NET[29]	Distributed	64 physical 1920virtual node	Logical connectivity/wired	high	high	AODV	The degree of Node Virtualization is very high of up to 30 nodes per physical machine.
MNE[6]	Distributed	10 physical node	Real person/ IEEE 802.11	medium	low	OLSR	It uses a static network infrastructure to interconnect devices and it require separate device for emulation.
Truemobile [14][30]	Real world testbed	16 physical node	Real robots/IEEE 802.11	low	low	-	It is extension of mlab.
EWANT [10]	Radio Frequency emulation	4 real nodes	Antenna switching/IEEE 802.11	low	low	DSR	It is radio frequency emulation.
Mint[3]	Real world testbed	8 physical node	Robots/IEEE 802.11	low	low	AODV	Test is done single room due to the unwanted noise source.
Ne[17]	Distributed	-	Logical connectivity/wired	low	low	DSR	it is based on the wired Ethernet and matrix is used for broadcasting link state information by central server.
DAWN[9]	Real world testbed	10 physical node	Real person/2.4 GHZ RF	low	low	ZRP	It measures different power control algorithms and QoS support within MANETs for voice communication.

Gray[15] [21]	Distributed	33 physical node	Real person/IEEE 802.11	medium	low	AODV	It is based on laptops decked with 802.11 interfaces.
Mobi Net [26]	Centralized	200 virtual node	Logical connectivity/wired	high		DSR	Its setup is complicated and It is built-in routing protocol (DSR) and specially emulates MAC layer.
RAMON [16]	Radio Frequency emulation	1 physical node	Channel emulation/IEEE 802.11	-	low	-	It is computerized controlled RF attenuator it emulates the SNR values and multi hop communication is not possible.
PoEm[19]	Centralized	-	Channel emulation/real traffic	medium	high	MULTI RADIO ROUTING PROTOCOL	It operates in a client/server structure and also it can runs on several workstations.
ART-NET[23]	Distributed	-	real environment	low	medium	OSPF	It supports almost all routing protocols for typical applications and implemented on a multiprocessor server for creating and managing their routing networks.
APE[20]	Distributed	17 physical node	Real person/IEEE 802.11	medium	low	AODV/DSR/ OLSR	It is Linux based software environment, allowing performing MANET experiments with ad hoc routing protocols.
Ritter[8]	Real world testbed	5 real nodes node	Real person/bluetooth	low	low	MAC LAYER PROTOCOL	It is based on a Motorola 68HC912 core controller with Bluetooth.
Maltz [25]	Real world testbeds	8 physical node	Real person	low	low	DSR	it performs the experiments on Mobile-IP
Judd [13]	centralized control	channel emulation	IEEE 802.11	low	medium	MAC and physical layer	it facilities to emulate the fading and different antenna patterns.
Kaba[22]	Radio Frequency emulation	4 physical node	Channel emulation	low	low	DSR	It is a radio frequency emulation testbed. It also uses coaxial cables in which resistors, splitters is used.
Engel[24]	Distributed	5 virtual per physical node	Logical connectivity	medium	medium	MAC LAYER	The testbed shows optimizations and the virtualization degree for Hybrid Emulation.

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