Mobile Ad-hoc Network Simulators, a Survey and Comparisons

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Abstract: Wireless communication technologies have been making growing interest in the past years, which has resulted in many proposals of their new applications. From indoor wireless local area networks to outdoor cellular mobile networks, wireless networks have gained billions of users around the world. A Mobile Ad-hoc Network (MANET) is the active research topic in wireless communications; it is a collection of two or more nodes in which the communication links are wireless; without the service of any fixed infrastructure or centralized administrator. Research on MANET depends on the following techniques - Analytical model, Emulation, Testbed and Simulation to evaluate the behavior and the performance of its communications protocol. The simulator assists the network developer to check whether the network is able to work in the real time. So when beginning to work with MANET, it is significant to select a simulation environment that will be up to requirements and will grant the researchers to conduct experiments in a given area. There are many different MANET simulators available; it is extremely complicated to choose an appropriate tool for performance testing without the complete analysis of existing tools. In this paper, we introduce the main characteristics of different simulator and look at their advantages and disadvantages. We hope this survey be a well reference source for those researchers who feel difficult to select the appropriate network simulators for their research.

Keywords: *MANET, Simulator, Emulator, Comparison, Performance evaluation.*

I. Introduction

During the last ten years, Mobile Ad-hoc Networks (MANET's) have become more and more popular.This still growing interest requires adjusting solutions from the traditional wired networks to the wireless environment. Performance evaluation of algorithms and protocols becomes challenging at different stages of design, deployment and implementation. Performance analysis of newly designed algorithms and proposed protocols are extremely attractive for efficient MANET's deployment. For the performance analysis of MANETs the follow techniques that can be applied are Analytical Modeling, Testbeds, Emulation and Simulation.

- ***Analytical*** methods require certain simplification to model and expect the performance. Therefore, they are incompatible due to difficulty and different nature of MANETs.
- ***Testbed*** could include software, actual hardware, and networking components. In MANET protocol design and development, the specified hardware and software environment should be set up as a testbed for the design under test. As testbeds might afford the most exact results, there are several retreats, such as: the need to obtain hardware, the hard limited monitoring and debugging possibilities, as well as, high effort needed to construct an artificial environment representing the real application assumption. Therefore, testbed implementations will usually be achoice only for smaller numbers of nodes and during the later phases of the implementation level.
- ***Emulation*** is hybrid model that combines hardware and software where some components are implemented on actual hardware and some are simulated.
- ***Simulation*** is economical and flexible; it can implement experiments without the real hardware, any can study lot of factors with many measures, for example, simulate a connection with any bandwidth and propagation delay or a virtual router with any queue size and queue management scheme. A network simulator is a software program that imitates the working of a computer network. In simulators, the computer network is typically modeled with devices, traffic etc. and the performance is analyzed. Typically, users can then customize the simulator to fulfill their specific analysis needs. Simulators generally come with support for the most popular networks protocols in use nowadays.

The aim of this study is to find out a MANET simulator that provides a good balance between features, efficiency, and easiness of use. Such a simulator will allow researchers to take the steps described their researches without much worry, and allow them to focus on their research rather than the simulator. Therefore, this survey covers information about features, advantages and weakness of different MANET simulators and

comparison based on a collection of criteria. The reminder of this paper is organized as follows. In Section II, we explain the MANET Simulators Classification Criteria. In Section III, we introduce previous work related to our study. In Section IV is the main section of our paper where four Network Simulators are described in detail. The paper is concluded in Section V.

II. MANET Simulators Classification Criteria

Different types of network simulators can be categorized and explained based on some criteria such as:

- ***Complexity***: Simply, a network simulator is supposed to enable users to represent a network topology, assigning the nodes and the traffic connections between those nodes, determine the used protocols in a network, defining the scenarios.More complicated systems may allow the user to determine everything about the protocols used to process network traffic in a network, and allow users to do more advanced forms of customization
- ***GUI*** (Graphical User Interface): GUI simulator tools it provide a simple and intuitive set of icons to represent the components of a network which allow users to easily visualize the workings of their simulated environment.Others may be programming-oriented tools which providing a programming framework that customizes to create an application that simulates the networking environment for testing.
- ***Open Source***: Some of the MANET simulators are commercial which means that they would not provide the source code of its software or the full packages to the all users for free. All the users have to pay to beauthorized to use that software. In general the commercial simulator has up-to-date documentations and full technical support. On other side, the open source simulator is free software and everything is open for new recent developments of new technologies in a faster way than commercial network simulators, but with lack of enough specialized people in documentation and support.

III. Related works

There are several surveys of wireless network simulators, dealing either only a number of currently available simulators, or including commercial products. Some contribute useful contribution, such as the demonstration of main simulation methodologies, a comparison of simulation Features and results.

In [1] the author reported a case study in which four popular network simulators, JSim, OMNeT++, NS-2 and ShoX, were implemented to evaluate a topology control protocol. The paperreported the outstandingcharacteristics and also compared the effect needed for the installation familiarization, implementation visualization and usability point of view.

In [2] the author contributes features that MANETs Simulation tools should have and current support of these gives the description of a GloMoSim, GTNets, JSim, Jane, NAB, NS-2, OMNeT++, OPNET Modeler, QualNet, and SWANS Simulators. And presents the estimation popularity, and feeds some suggests on which simulator to use for what requirements.

In [3] the author simply introduces a comparative study of two common network simulators, OPNET and NS-2, and provides a guide to researchers undertaking packet-level network simulations. While the author in [4] describes a comparative study by considering the installation, familiarization, implementation and visualization of popular Network Simulators NS-2, JSim, and OMNET++ and ShoX. Also the author of [5] describes a comparative study compared strengths and weakness of NS-2, GloMoSim, JSim, OMNeT++, OPNET, QualNet.

In [6] author contributes an overview about different matters in wireless sensor networks on a common basis. Only at the end a table is demonstrated comparing the considered simulators according to their programing language, the available components, and whether they have GUI support or not.

IV. Network Simulations Tools

There are many different possible platforms for simulation and testing of routing protocols for MANET. Below is a list of some of the most popularly used simulators for MANET. Different aspects like simulation Environment, Simulation language, resources, features, simulation scenarios and limitations have been compared.

1- Network Simulator 2 (NS-2)

Summary: NS-2 is one of the most popular open source network simulators. The original NS is a discrete event simulator targeted at networking research. NS-2 is the second version of NS (Network Simulator). The first version of NS was developed in 1989 and evolved a lot over the past few years. NS-2 has a modular approach and hence is effectively extensible [7].

Environment: It provides substantial support for simulation of TCP, routing, and multicast protocols over wired and wireless networks. So it is support to simulate wireless LAN protocols, MANET and wireless sensor networks. The simulator focuses on the ISO/OSI model.

Simulation language: Simulations are based on a combination of C++ and OTcl. The usage of these two programming language is due to the internal characteristics of these two languages. C++ is efficient to implement a design but it is not very easy to be visual and graphically shown. It's not easy to modify and assembly different components and to change different parameters without a very visual and easy-to-use descriptive

language. OTcl happens to have the feature that C++ lacks. So the combination of these two languages proves to be very effective. C++ is used to implement the detailed protocol and OTcl is used for users to control the simulation scenario and schedule the events.

Features: NS-2 has advantages of large number of available models, supports deterministic or probabilistic packet loss in queues attached to network nodes as well as it supports deterministic and stochastic modeling of traffic distribution. NS-2 includes an energy model and it allows user to easily generate traffic and movement patterns. Also it provides a set of randomized mobility model and there are several projects to bring advanced mobility models to the simulators. The simulator can generate personalized trace files by allowing users to select parameters to be traced, therefore saves CPU resource.

Limitations: NS-2 has a long learning curve and requires advanced skills to perform meaningful and repeatable simulations. NS-2 lacks an application model. In many network environments this is not a problem, but MANET networks often contain interactions between the application level and the network protocol level. Simulation running will be very slow especially when the network simulated contains many nodes.

Availability (site): Free for use,
http://www.isi.edu/nsnam/ns/ns-build.html

2- Network Simulator 3 (NS-3)

Summary: NS-3 is discrete network simulator, which is mainly used in teaching and research. NS-3 is free software, and it is available under the GNU GPLv2 license for use, study, and modify. NS-3 is the third version of NS which is released in June 2008. NS-3 is designed to replace the current popular NS-2. However, NS-3 is not an updated version of NS-2 because that NS-3 is a new simulator and it is not backward-compatible with NS-2. NS-3comes to try to solve the problems present in NS-2 [8].

Environment: NS-3 depends on ISO/ OSI model to simulate various environments in different layers. NS-3, for example, can simulate the asynchronous sockets API, UDP/ TCP. It can also support the unicast and multicast routing according to the network layer. MANET is one of NS-3 simulated environment. In link layer, NS-3 can represent the point-to-point protocol. In general, NS-3 is suitable to simulate wired and wireless networks [9].

Simulation language: NS-3 is written in C++ language with Python language as optional to represent the interface. NS3 can be developed with C++ entirely which simulation script can be written as a C++ program, which is not possible in NS-2. Depending NS-3 on one programming Language makes debugging easier than NS-2, which is bi-language (C++/Tcl) system which makes debugging complex, but for NS3 only knowledge of C++ is enough. One-language architecture is more robust in the long term. According to the contributed codes, NS-3 has very limited number of contributed codes made with it compared to NS-2 contributions [9].

Features: In the discrete simulator, the points in simulation time represent each event. Computing these events in real time is an advantage especially during the system running. NS-3 presents satisfied computing power for the simulated network does not exceed the laws of physics. NS-3 provides simulations for the main components of a network which are nodes, channels, net devices, and applications. The node in a NS-3 simulation represents a communication point, like router or an end system which it is the base for any event or interaction. By connecting these nodes by different type of channels NS-3 can represent different forms and media of data transmission. NS-3 can represent a simple wired connection (point-to-point); also it can represent a Wi-Fi connection. According to the net devices, NS-3 can attach them to nodes and channels to represent a network interfaces like in real world. The application is main concept in all NS-3 simulation. NS-3 provides different applications for any kind of network functionality. The main functionality of the applications is the creation, processing and transmission of data. The configuration and creation of nodes, channels, net devices and applications is one of the responsibilities of the simulation designer. But in NS-3 this can be done by using the powerful Helper-API which does this configuration in the simulated network with relatively low effort [10].

Limitations: As any simulator NS-3 has some limitations which its designers try to overcome them. One of these limitations is the credibility [11]. Simulation credibility is a challenge in the field of network simulation as in any other fields. Actually, NS-3 designer cannot be sure by one-hundred percent if the behavior of the network simulation shows and delivers results just like a real network. Another limitation comes from the fact that when NS-3 simulator was built, the designer didn't build it from scratch; rather, they depended on available models and made a needed modification according to the requested characters. The used models may have malfunctions which will affect on the results of the simulated network. In addition, the Scalability [12] (the possibility of adding and removing components, channels, and nodes to the network) Limitation is important one. The memory usage and the required computation time are the main factors which limit the scalability concept. NS-3 as all discrete simulators, events are processed in a certain time controlled by the assumed maximum time, Also, the amount of events which can be processed is limited to the available memory.

Availability (site): free for use under GNU GPLv2 license: http://www.nsnam.org

3- GloMoSim

Summary: Global Mobile Information System Simulator (GloMoSim) is a network protocol simulation software that simulates wireless and wired network systems.[13] GloMoSim is designed using the parallel discrete event simulation capability provided by Parsec, a parallel programming language. In GloMoSim we are building a scalable simulation environment for wireless and wired network systems. Most network systems are currently built using a layered approach that is similar to the OSI seven layers network model. The plan is to build GloMoSim using a similar layered approach. Standard APIs will be used between the different simulation layers. This will allow the rapid integration of models developed at different layers by different people.

Environment: GloMoSim has several choices for radio propagation, CSMA MAC protocols (including 802.11), mobile wireless routing protocols, and implementations of UDP and TCP. GloMoSim is good at simulating mobile IP networks [14].

Simulation language: Parsec is a library for the C-based simulation language, developed by the Parallel Computing Laboratory at UCLA, for sequential and parallel execution of discrete-event simulation models.

Features: GloMoSim permits the simulation Scalability to simulate networks with a huge number of wireless nodes. GloMoSim supports the Random Waypointmobility model and other kinds of mobility models, which may not be suitable for all types of simulations. GloMoSim can be executed using a variety of synchronization protocols and was successfully implemented on both shared memory and distributed memory computers.

Limitations: GloMoSim currently supports protocols for a purely wireless network. GloMoSim is effectively limited to IP networks because of low level design assumptions. Therefore, it suffers some problem as the packet formats, energy models, and MAC protocols are not representative of those used in Mobile ad-hoc networks.

Availability (site): Free for use,
http://pcl.cs.ucla.edu/projects/glomosim

4- OMNeT++

Summary: The OMNeT++ discrete event simulation environment has been publicly available since 1997. It has been created with the simulation of communication networks, multiprocessors and other distributed systems in mind as application area, but instead of building a specialized simulator, OMNeT++ was designed to be as general as possible. Since then, the idea has proven to work, and OMNeT++ has been used in numerous domains from queuingnetwork simulations to wireless and ad-hoc network simulations, from business process simulation to peer-to-peer network, optical switch and storage area network simulations. OMNeT++ attempts to fill the gap between open-source, research-oriented simulation software such as NS-2 and expensive commercial alternatives like OPNET.

Environment: OMNeT++ is actually a general-purpose simulator capable of simulating any system composed of devices interacting with each others. It can then perfectly be used for MANETs simulation.

Simulation language: is a well-designed simulation package written in C++.

Features: OMNeT++ is a great and powerful GUI simulation tool. OMNeT++ has extension tools that allow it to offer support for simulation of wireless networks. Two most famous and applied extensions are INET Framework and Mobility Framework for MANET networks. OMNeT++ GUI makes the tracing and debugging much easier than using other simulator. OMNeT++ accurately simulations most hardware and contains the modeling of physical phenomena.

A future development is that simulation executables created by the simulator are actually standalone programs that can be run on other machines without the simulators

Limitations: It does not extend a wide variety of wireless network protocols, and very limited have been implemented, leaving user with significant background work if they want to implement his own protocol in different environments. Poor documentation and analysis of typical performance measures [15]. The mobility features of the simulator fairly incomplete [16].

Availability (site): Free for academic and educational use

V. Conclusion

We hope that the introduced classification will speed up the decision process and assist researchers to focus their attention on the software that meets specific requirements.

Simulators have the lots its features, but none of them extend the good support for all features for MANET simulation. NS-3 is the best choices for the MANETs; it supports wide range of protocols in all range of protocols in all layers.

GloMoSim is a strong scalability power when the wireless network contains the large number of nodes. OMNET++ also a worthy simulator and supports the powerful GUI.

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