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A Study on Large Scale Network Simulators

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***Abstract*— Simulation of network is a very complex task. Network simulation is a modern technique used to analyze the behavior of the network. Simulation method analyzes the behavior of large, complex and highly volatile system. Network simulator software predicts the behavior of a network. It allows the designer to test new networking protocol and change the existing protocol. Through network simulator a program controls the behavior of the network by calculating the interactions of different network entities using various mathematical formulae. The behavior of the network and the various applications and services it supports can then be observed in a test lab. Under different conditions the attributes of the environment can be modified in a controlled manner to assess how the network would behave. In simulators, the computer network is typically modeled with devices, links, applications, etc. and the performance is then analyzed. Simulators usually support the most popular protocols and networks in use today, such as WLAN, Wi-Max, TCP etc. perform. In this paper, we study some standard network simulators and recent developments of network simulators.**

***Keywords*— Network simulation, simulation techniques, NS2, NS3, OPNET, NetSim ,OMNeT++, QualNet etc**

I. INTRODUCTION

Network simulation is a technique to analyze the behavior of network. In order to understand the dynamics of various networking protocol there is a need to understand large scale network simulation. Simulation technique is also widely recognized as a primary tool for analyzing such large networks. Simulation can be applied to various application fields such as science, engineering and research for various purposes. Typical application areas include physics, chemistry, biology, and human-involved systems in economics, finance or even social science. Application of simulation technology into networking area such as network traffic simulation, however, is relatively new. Most studies performed today use packet level simulations that are limited to experiments modeling hundreds to thousands of network nodes (e.g. routers and end host computers).

Few advantages of simulation include:

1. A simulation model helps us to gain the knowledge about the improvement of the system.
2. It can help in understanding how the system works.
3. It helps in evaluating new protocol design.

Simulation is also used to predict the behavior of a particular protocol and the mechanisms of various conditions of network. In other case simulation is also used to understand the true effects of a new protocol, mechanism, application, and network services when it is widely used effectively on a large scale of networks.

There are many both free/open source and proprietary network simulators and some are discrete event software. Network simulators are used by people from different areas such as academic researchers, industrial developers, and Quality Assurance (QA) to design, simulate, verify, and analyze the performance of different networks protocols. Some examples of famous network simulation software are ns NS (open source), OPNET (proprietary software), and NetSim (proprietary software).

Packet level simulation model the transmission and queuing of individual packets as they travel through the network. Packet level simulation is used extensively for protocol design and evaluation. It is widely used by various simulation tools such as ns2, GloMoSim and its commercial Version Qualnet and Opnet and many more.[1]

The rest of the paper is organized as follows. Section 2 discusses the basic standard network simulators that are often for network simulation. Section3 discusses the recent developments of various network simulators. We conclude the paper in Section 4.

II. DISCUSSION ON STANDARD NETWORK SIMULATORS

Simulation of large scale network can be done by using some existing network simulation techniques which are as follows:

- Discrete event simulation
- Parallel discrete event simulation
- USSF

In the field of simulation, a discrete-event simulation (DES), models the operation of a system as a discrete sequence of events in time. Each event occurs at a particular instant in time and marks a change of state in the system.[1] Between consecutive events, no change in the system is assumed to occur; thus the simulation can directly jump in time from one event to the next.

In [2] R. M. Fujimoto et al. had discussed parallel discrete event methods which utilize a space parallel approach where a large network is partitioned and the nodes of each partition are mapped to a different processor, offering the potential for both network size and execution speed to scale in proportion to the number of processors. Several parallel discrete event simulation systems have been developed to improve the scalability of network simulations. Examples of parallel network simulators using this approach include GloMoSim (Global Mobile Information System Simulator), TeD, SSFNet (Scalable Simulation Framework Network), DaSSF (Dartmouth

implementation of the Scalable Simulation Framework), TeleSim, and the ATM simulator described in among others.

USSF is a simulation technology based on Time Warp and built on top of the WARPED parallel discrete event simulator that claims to simulate large-scale target systems of over 100,000 nodes. USSF is complicated to use and develop for, requiring the creation of topology models and then generation from application model to application code. Developers then tailor their application to the simulator, which may be unacceptable for existing code, particularly complex code that interfaces with undocumented legacy systems [1].

Much of the current simulators follow discrete event simulation technique. Hence, here we only focus on this technique. In [3] J. Pan et al. had discussed the current network simulators which have different features in different aspects. The list of such network simulators include OPNET, NS2, NS3, OMNeT++, REAL, SSFNet(Scalable Simulation Framework Network), J-Sim ,NetSim and QualNet. Here we discuss some of the most famous network simulators which follow discrete event simulation such as OPNET, NS2, NS3, OMNeT++ and NetSim.

A. *Optimized Network Engineering Tools (OPNET)*

The OPNET is considered as one of the most famous and commercial network simulators because of its wide uses in the industry and the name of product presented by OPNET Technologies incorporation. OPNET's software environment is specialized for network research and development. OPNET offers powerful visual or graphical support for the users. Object-oriented programming technique is used to create the mapping from the graphical design to the implementation of the real systems. It has the wide variety of possibilities to simulate heterogeneous networks with various protocols.

OPNET is based on a mechanism called discrete event system. We can see all the topology configuration and simulation results can be presented very intuitively and visually. Through the GUI the parameters can be adjusted and the experiments can be repeated easily. Hierarchical structure is used to organize the networks. OPNET provides programming tools for users to define the packet format of the protocol.

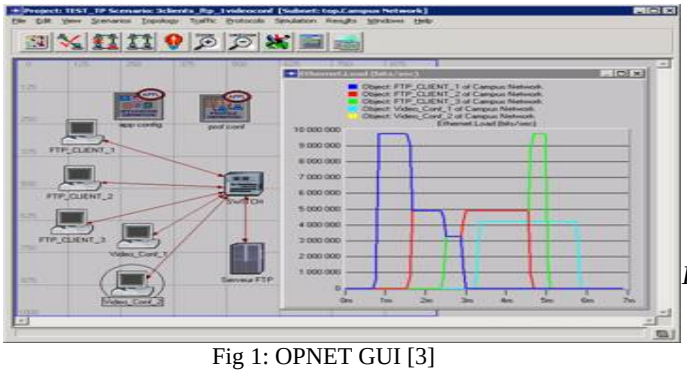

Fig 1: OPNET GUI [3]

B. *Network Simulator 2 (NS2)*

NS2 is an open source network simulator. NS2 is mostly used in academia because of its open-source and plenty of components library. NS is based on REAL network simulator. NS2 is widely used because of the lot of packages contributed by different non-benefit groups that can be widely used for network simulation.

NS2 is an object-oriented, discrete event driven network simulator NS2 uses C++ and OTcl programming language. NS2 separates control path implementations from the data path implementation. The event scheduler and the basic network component objects in the data path are written and compiled using C++ to reduce packet and event processing time. C++ is used to implement the detailed protocol and OTcl is used for users to control the simulation scenario and schedule the events. A simplified user's view of NS2 is shown in figure 2.

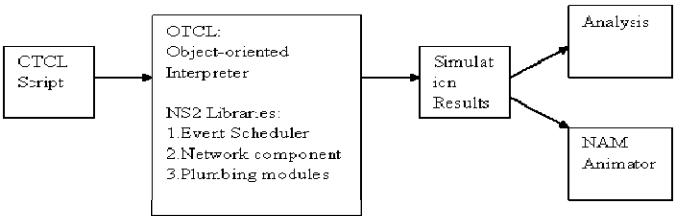

Fig 2: Simplified User's View of NS2 [3]

Another feature of NS2 is the event scheduler. In NS2, the event scheduler keeps track of simulation time and release all the events in the event queue by invoking appropriate network components.

C. *Network Simulator 3 (NS3)*

Like NS2, NS3 is also an open sourced discrete-event network simulator which targets primarily for research and educational use. NS3 put more emphasis on the documentation works and some specialized people are volunteered to manage different components. NS3 redesigns a lot of mechanisms based on the successful and unsuccessful experiences of NS2.

The main features of Network Simulator 3 (NS3) include:

a) **Different software core**: The core of NS3 is written in C++ and with Python scripting interface.
b) **Attention to realism**: protocol entities are designed to be closer to real computers.
c) **Software integration**: support the incorporation of more open-source networking software and reduce the need to rewrite models for simulation

D. *Optical Micro-Networks Plus Plus (OMNeT++)*

OMNet++ is open source, component-based network simulator with GUI support and widely acknowledged in academia. Its primary application area is communication networks.OMNeT++ is a discrete

event simulator. It is a component-based architecture and is programmed in C++. The components are then assembled into larger components and models by using a high-level language. OMNeT++ provides GUI support, and due to its modular architecture, the simulation kernel can be embedded into all kinds of different user s' applications. Figure 3 is an OMNeT++ GUI screenshot.

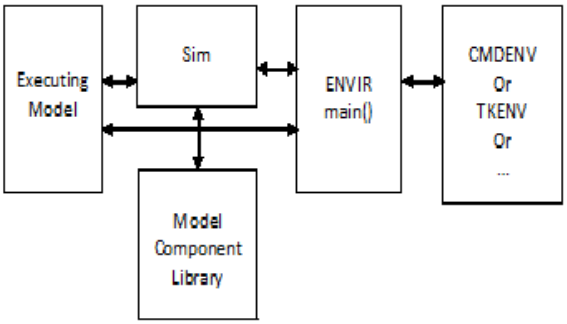

Fig 3: Architecture of OMNET++ [4]

The main features of OMNeT++ include:

a) Simulation kernel library
b) Compiler for the NED topology description language (nedc)
c) Graphical network editor for NED files (GNED)
d) GUI for simulation execution, links into simulation executable (Tkenv)
e) Command-line user interface for simulation execution (Cmdenv)

E. Network Based Environment for Modeling and Simulation (NetSim)

NetSim is a discrete event simulator developed by Tetcos in 1997. It has an object-oriented system modeling and simulation (M&S) environment to support simulation and analysis of voice and data communication scenarios for High Frequency Global Communication Systems (HFGCS) [4]. The advanced features that are included with Boson NetSim are:

a) Supports 42 routers, 6 switches
b) Simulates network traffic with virtual packet technology
c) Provides two different viewing styles: Telnet mode or Console mode
d) Supports up to 200 devices on one network topology

III. RECENT DEVELOPMENTS OF NETWORK SIMULATORS

In this section we are discussing the recent developments of some most famous network simulators. The recent development of the network simulators are as follows:

A. *OPNET*

OPNET technologies announced the addition of two major application performance management capabilities. These capabilities include end-to-end visibility into application performance for organizations using WAN optimization solutions and the ability to capture and analyze NetFlow data.

OPNET recently upgrades its ACE Analyst software includes functionality and it is announced to allow end-user organizations using Riverbed, Cisco, or Juniper WAN optimization appliances to maintain end-to-end visibility into application performance while deploying WAN acceleration solutions. OPNET also provides a module to collect and analyze NetFlow data. Because of the consistent endeavor and operation of OPNET Inc., OPNET is becoming mature and its product maintains a high recognition in the industry. Moreover, OPNET always keeps an eye on the most recent users' requirements and keeps improving their product which make it very competitive compared with other commercial network simulators in the near expectable future.

B. *Network simulator*

The general purpose Network Simulator (NS) developed at University of California, Berkeley, is a discrete event simulator targeted at networking research. It provides substantial support for simulation of Transmission Control Protocol (TCP), routing, and multicast protocols over wired and wireless (local and satellite) networks. The simulator takes as an input a scenario, which is a description of the network topology, protocols, workload and control parameters. After simulation, it produces statistics such as the number of packets sent by each source of data, the queuing delay at each queuing point, and the number of dropped and retransmitted packets. With the recent emphasis on IT and the use of high speed networking across the nation, the interest in general networking as well as research in networking has increased tremendously in recent times. This has motivated this research to develop a network simulator which is meant to be user-friendly for undergraduate teaching as well as for research. While there are commercial products which allow general purpose simulation with an intuitive GUI interface, the price for a single license is usually very high. The work on this project has resulted in the development of SWAN (Simulator Without a Name) for general purpose process- oriented simulation.

C. *NS2*

The most recent version of NS2 is NS 2.33 version which was released on Mar 31, 2008. Compared with the previous version, this newest version [NS2] has integrated the most recent extension on new 802.11 models which include the Ilango Purushothaman's infrastructure mode extensions, the 802.11Ext models from a Mercedes-Benz R&D, NA and University of Karlsruhe team, and the dynamic libraries patch and multirate 802.11 library from Nicola Baldo and Federico Maguolo of the SIGNET group, University of Padova. NS is now developed in collaboration

between some different researchers and institutions, including SAMAN (supported by DARPA), CONSER (through the NSF), and ICIR (formerly ACIRI). Contributions have also come from Sun Microsystems and the UCB and Carnegie Mellon Monarch projects. Generation 3 of NS (NS3) has begun development as of July 1, 2006 and is projected to take four years. It is deemed as the future of NS2.

D. *NS3*

NS3 is still in the process and some major challenges still remain for NS3 to solve. The biggest challenge is that NS3 needs participation from the research community. Firstly, the simulation credibility needs to be improved. We know that one of the limitations of simulations, in general, is that it often suffers from lack of credibility. Generally there are four points that are important for NS3 to solve this problem. These are:

a) Hosting NS3 code and scripts for published work
b) Tutorials on how to do things right
c) Flexible means to configure and record values
d) Support for ported code should make model validation easier and more credible

Secondly, NS3 is intended to replicate the successful mode of NS 2 in which a lot of different organizations contributed to the models and components based on the framework of NS2. Currently, OMNeT++ is popular in academia for its extensibility since it is also open sourced and there are plentiful online documentations.

E. *OMNET++*

OMNeT++ is being used in the academia as well as in industry. Several open source simulation models have been published in the field of network simulations such as IP, IPv6, MPLS, mobility and ad-hoc simulations. For the future of OMNeT++, we need to note that OMNeT++ is not a network simulator itself. Actually it is currently popular as a network simulation platform in the academia as well as in industry, and build up a large user community. So we have the reason to believe that using OMNeT++ as a basic platform but not an overall single solution. OMNeT++ can have greater development if it could persuade more organizations to participate in and to contribute.

At the Swedish Defence Research Agency (FOI) there is ongoing research, targeting the role of network/web based technologies in M&S, to support defence communities in their work. Our vision comprises an environment supporting the entire M&S-process, including conceptualization, scenario definition, design, development and execution. All these tasks should be maintained by a framework for collaboration, which lets users; developers, analysts, administrators etc, jointly work on a project. During the first phase of this research focus has been on efficient resource sharing and means of collaboration. Through experimental research and implementation of a prototype (NetSim), methods and techniques have been identified to form a framework for collaborative work, resource management and distributed execution

F. *QualNet*

SCALABLE Network Technologies, Inc. (SCALABLE), a leader in wireless network design and optimization tools, announced that it will be developing network simulation-based solutions for evaluating critical infrastructure environments for resiliency to cyber-attacks.

The QualNet® communications simulation platform (QualNet) is a planning, testing and training tool that "mimics" the behavior of a real communications network. Simulation is a cost-effective method for developing, deploying and managing network-centric systems throughout their entire lifecycle. Users can evaluate the basic behavior of a network, and test combinations of network features that are likely to work. QualNet provides a comprehensive environment for designing protocols, creating and animating network scenarios, and analyzing their performance. QualNet is composed of the following components:

- **QualNet Architect** — A graphical scenario design and visualization tool. In Design mode, you can set up terrain, network connections, subnets, mobility patterns of wireless users, and other functional parameters of network nodes. You can create network models by using intuitive, click and drag operations. You can also customize the protocol stack of any of the nodes. You can also specify the application layer traffic and services that run on the network. In Visualize mode, you can perform in-depth visualization and analysis of a network scenario designed in Design mode. As simulations are running, users can watch packets at various layers flow through the network and view dynamic graphs of critical performance metrics. Real-time statistics are also an option, where you can view dynamic graphs while a network scenario simulation is running.

- **QualNet Analyzer** — A statistical graphing tool that displays hundreds of metrics collected during simulation of a network scenario. You can choose to see pre-designed reports or customize graphs with their own statistics. Multi-experiment reports are also available. All statistics are exportable to spreadsheets in CSV format.
- **QualNet Packet Tracer** — A graphical tool that provides a visual representation of packet trace files generated during the simulation of a network scenario. Trace files are text files in XML format that contain information about packets as they move up and down the protocol stack.
- **QualNet File Editor** — A text editing tool
- **QualNet Command Line Interface** — Command line access to the simulator

A neural network simulator for Unix workstations, SNNS, under development at the University of Stuttgart, Germany, is described. The network simulation environment is a tool to generate, train, test, and visualize artificial neural networks. The simulator consists of three major components: a simulator kernel that operates on the internal representation of the neural networks, a graphical user interface based on X-Windows to interactively construct and change small neural nets, and a compiler to generate the internal representation of large neural networks from a high-level network description language.

IV. CONCLUSIONS

This paper contains a general overview of the different types of network simulators used for standard network simulation. This paper also contains a brief discussion about the network simulation techniques namely discrete event simulation, parallel discrete event simulation and USSF. Here we discussed the five types of network simulators namely OPNET, NS2, NS3, OMNet++ and Netsim which are very popular and are often used for research work. The paper also contains an overview of the network simulators and their important features. The development status of the network simulators and one more simulator Qualnet are also analyzed and discussed. Causal Productions permits the distribution and revision of these templates on the condition that Causal Productions is credited in the revised template as follows: "original version of this template was provided by courtesy of Causal Productions (www.causalproductions.com)".

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