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A SURVEY ON THE USE OF GNS3 FOR VIRTUALIZING COMPUTER NETWORKS

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ABSTRACT

The development of virtualization technology has moved beyond its primary application for storage area network and server resources; today it encompasses simulation of entire computer network components. Network virtualization composes an intelligent layer of abstraction that offers flexible deploying and managing network services and its underlying resources. The network virtualization and simulation tools, like GNS3, is an alternative that allows network designer and developer to implement multiple networked computers, hosts and routers in virtualized environment in a cost effective manner to validate and test new networking protocols and verify a specific network algorithm. Thus Computer network simulation is an important modern technology that provides easy and economic method of testing and validation of network feasibility. In this survey paper, we discuss about main features of GNS3 simulator and consider its advantage for network virtualization and its enhancement.

KEYWORDS: GNS3, Virtualization, Cisco IOS, Topology Automatic Configuration, Network Simulator

I. INTRODUCTION

Network virtualization refers to the process of simulating network infrastructure and their functionality into a single, logical software-based administrative entity, a "*Virtual Network*" [5]. Virtualized network can be set up either by using virtual devices(such as a virtual machine inside a hypervisor)or creating protocol based virtual networks (such as VLANs, VPNs and etc.) [4].

Computer simulation is technique of imitation of imaginary and actual objects on a computer such that system functions and its behavior can be studied [2], [1]. The network simulation, particularly means that the computer aided simulation techniques model the network functionality and its behavior by determining the interaction between the different network elements (hosts/routers, etc.) using mathematical formulas, or actually monitoring and imitating experimental observations from a real network [1]. The data from simulation experiments, could be used to analyze in a series of offline test experiments to test the protocols that are supported by the network and network behavior [2]. lately, application of simulation technology has been widely developed for simulating computer networks traffic.

Network simulator is an integrated and versatile package of tools that emulates network's behavior like creating network topology, log events that occurs under any load, parsing the events and understanding the network. It supports application of various kinds of protocols in diverse types of network with different elements and traffic models [3].

Recently, network simulators are being used extensively in different areas such as, conducting research and

teaching, designing different network topologies, Quality Assurance of industrial developments for simulating, verifying, and analyzing the performance of new networking topologies and evaluating effects of the different parameters on the communication protocols that are being studied [2].

Network simulators can be categorized based on their futures and functionality, to very simple or complex, commercial or open source simulators [2]. A simple simulator can imitate a small network topology by specifying the nodes, data links between those nodes and network traffic but a complex one possibly emulates many different types of network devices and communication protocols to handle network traffic. They are designed to model massive network performance with variety of vendor's equipment to provide facility for designing and optimization of large and complex networks. Moreover a powerful network simulator enhances capability of network performance optimization [6]. Graphical network simulators enable users to simply visualize the operation of their emulated computer network and serve them possible customization options.

The value of a simulator based on emulation of router hardware enabling the use of actual router software cannot be underestimated. Furthermore, emulation enables router virtualization such that multiple virtual machines can be implemented on a single host. The benefits of virtualization in server farms and for users desiring to run multiple operating systems on their computers are resulting in the growth of virtualization applications such as various kind of simulators, Virtual Box and VMware [12].

Currently, there are various simulators that are available to provide virtualized networks such as: GNS3 (Graphical Network Simulator 3), NS2 (Network Simulator version2), NS3 (Network Simulator version3), M5 Simulator, OPNET (Optimized Network Engineering Tools), OMNET++ (Optical Micro-Networks Plus), NETSIM (Network Based Simulation and Modeling Environment), REAL (Realistic And Large), J-SIM (Java-based simulation) and QUALNET(a high-fidelity network simulator based upon GloMoSim) where some of them are widely acknowledged in academia researches and some of them have commercial use[7].

In this paper, we intend to discuss about GNS3 which is very powerful graphical simulators and easy to use. It helps us to create a heterogeneous and quiet complex network, as close as a real network without any expense.GNS3 offers following features [9]:

- Design of very complex and high quality network topologies

- Emulation of several Cisco router platforms and PIX firewalls

- Simulation of common network switches such as Ethernet, Frame Relay and ATM switches

- Ability to connect virtualized network to the real live network

- Ability to capture and analyze packets with aid of Wire shark

II. GNS3 CAPABILITIES

GNS3 (Graphical Network Simulator 3), is an open-source graphical network simulator written in python that allows emulation of complex networks, it is freely available online under the GNU General Public License (GPL License) [11]. However, the users have to supply a real router Internetwork Operating System (IOS) image, which means that it has to be gained directly through Cisco or from an actual router [12]. GNS3 is promoted by user- friendly

Graphical User Interface (GUI) that enables users to configure a network component in a virtual machine that runs the OS same as the original network component [12] [7]. GNS3 is much flexible than the other vendor-specific network simulators which is suitable for distance-learning applications as well as preparation for network certifications such as CCNA, CCNP and CCIE [11].

GNS3 is a virtualization platform consisting of three software programs that runs on common PC hardware and could be installed on Microsoft Windows, Linux and MAC operating systems [9]. In order to accomplish faultless and complete network emulation, GNS3 uses the following emulators, illustrated in Figure1, to run the exact OS as in actual networks [8]:

- Dynamips, the famous Cisco IOS emulator

- Virtual Box, which runs server and desktop OS as well as Juniper Jun OS

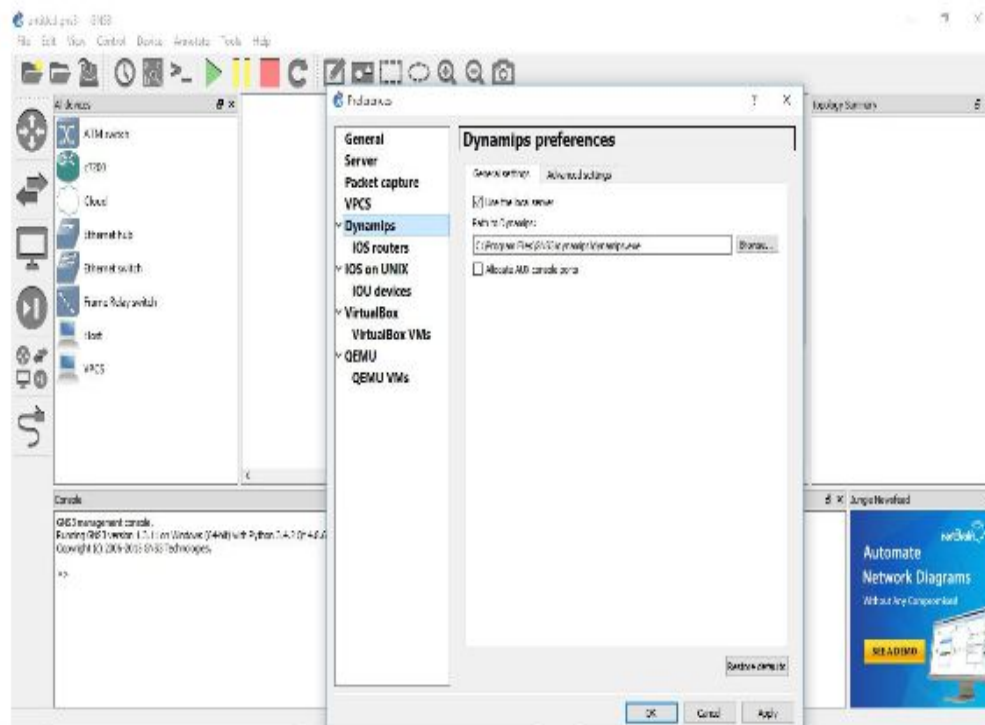- QEMU, a comprehensive open- sourced machine emulator, it runs Cisco ASA, PIX and IPS

Figure 1: GNS3 Software Component

The GNS3 interface, is quiet straightforward and relatively simple to use, very simpler than the text-based Dynagen interface [12]. However, at first time of using GNS3 a good background and experience in configuring Cisco routers is very helpful; there for simulation awkwardness can be simply identified as being associated with the simulator or the router(s). Figure 2 illustrates GNS3 version 1.3.11 on Windows (64-bit) interface. This figure shows an example of a simple network, consisting of two Cisco7200 routers and two Ethernet switches that interconnecting 3 PCs.
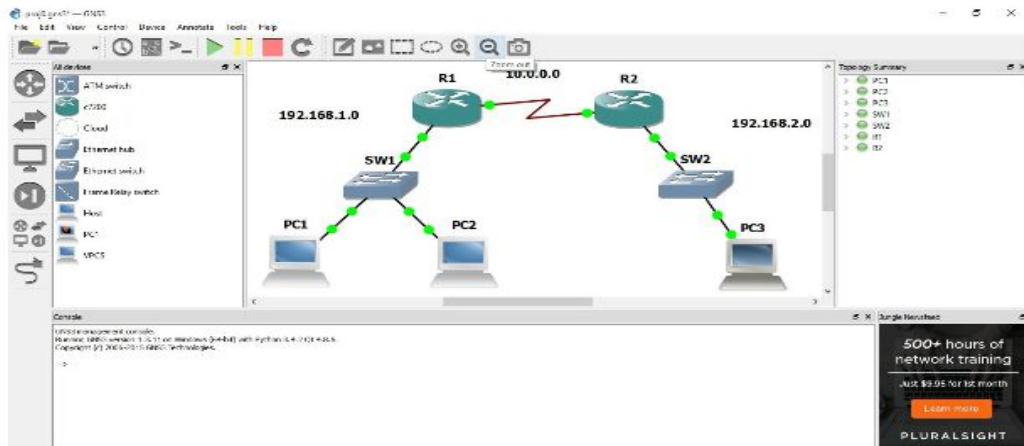
Figure 2: GNS3 User Interface

Since GNS3 is essentially interdependent on Dynagen, and Dynamips so recognition of simulation-software related problems is difficult task.

GNS3 hypervisor, Dynamips is the core software of virtualization engine that simulates Cisco routers through IOS emulation. *"IOS is a package of routing, switching, internetworking and telecommunications functions integrated into a multitasking operating system"* [10]

GNS3 operates on the top of Dynamips to create a more user friendly, graphical environment than other simulators [8] [9]. Dynamips conducts an internetworked topology of Cisco equipment and enables access to a virtual console port and appropriately to the Cisco IOS command line [12]. The topology setting of virtualized network could possibly be adjusted compatible with memory and CPU configuration of the host system [12].

Dynamips provides emulation of multiple instances of router devices as a virtualization hypervisor. As result every emulated router operates actual IOS software image, so it is able to emulate most of the commands and functions available in the IOS image [9] [6].The limited processor and memory capacity of single computer creates a barrier for implementing simulation over greater networks; to overcome this restriction a TCP/IP connection could be established between Dynamips as a dominant hypervisor and other computers hypervisors to extend network simulation over serval computers. Moreover, Fast-Ethernet connections link external computers as a host in the simulated network through simulated router network [6]. Dynagen is front- end for Dynamips and provides a text based environment to create an easy and simplified control of the simulation parameters for Dynamips through a management console [8]. To perform network virtualization, the Dynamips hypervisor dedicates the host computer's RAM space according to each router's RAM and ROM space and emulates a separate virtual machine for each router so the more routers are added to the simulation, the more RAM on host computer is required [6].

GNS3 allows user to select the values of NVRAM and flash memory contents to be saved on the computer's hard disk for each router and these values must be the particular values for a given router's IOS. To create virtual network the hypervisor creates an instance of a router virtual machine; in this stage it will use processor power of simulation computer as much as possible.

Several virtual machines will struggle for processor power and none of them has priority in this regard. As a result

the hypervisor uses complete capacity of the simulation computer's processor resource even if hypervisor attempts to virtualized a single router because it is emulating the router's processor on the virtual machine [6].

The emulated router's idle routines employs great amount of the simulation computer's processor resources. This idle process can be pinpointed when it is entered by an Idle PC utility available in GNS3 [6]. After recognition, the user can considerably reduce consumption of the simulation computer's processor by imposing termination of the direct emulation of the idle process of each router in virtual machines.

However, emulation of the idle processes is eliminated but adding more routers to a simulation, still results in great processor consumption [6]. Several experimented scenarios proved that having adequate host computer resources is important for a successful simulations. Therefore, a fast processor and adequate memory space are vital requirement for simulation [6].

Emulated devices in GNS3 are capable of interacting with real networks devices connected to the host system such as live routers that provides full incorporation between emulated and real world networks and thus expanding the entire topology. In GNS3 Configuration files for virtual and real routers are in the form of identical plain texts. Therefore, users are able to learn networking techniques and test actual network configurations without requirement of having actual networking equipment [12].

Another very handy feature of GNS3 is the capability of capturing packets on serial interfaces as well as virtual Ethernet by using Wire shark packet analyzer to monitor traffic of network [8] [6]. Figure 3 illustrates captured traffic at the serial interface s1/0 of router R1 as per scenario shown in the Figure 2. The router serial interfaces are given 10.a.b.c IP addresses and the Fast Ethernet interfaces of routers and all PCs having 192.168.y.z IP addresses. The captured traffic shows RIP routing protocol packets, Cisco Discovery Protocol (CDP) packets as well as ICMP protocol packets generated by pinging a Fast Ethernet interface on the R2 from the R1 router.
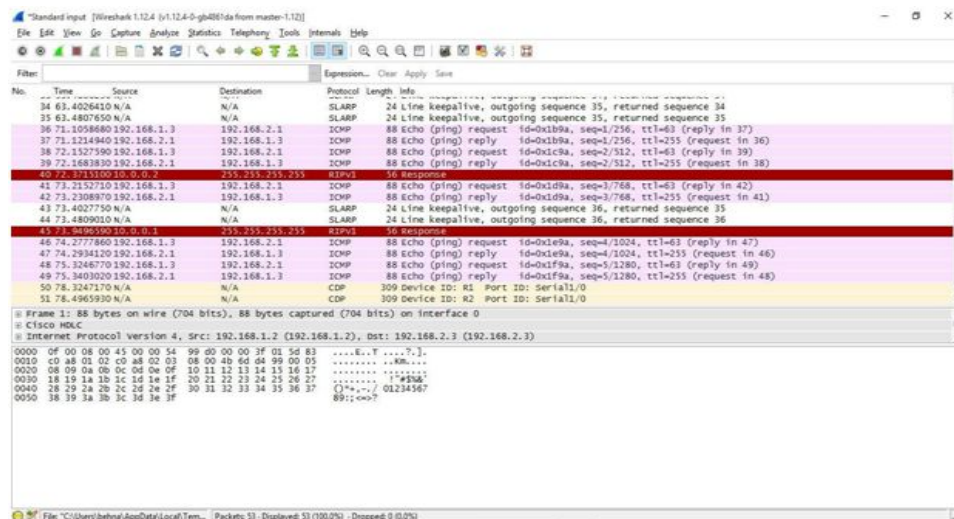

Figure 3: Captured Traffic on Serial Link between R1and R2 in Wireshark

GNS3 provides the capability of observing and capturing traffic on simulated router and other network devices links, hence this feature is not provided in most of other simulators.

The downside of using GNS3 for network simulation can be considered as its limitations in emulating network devices. in fact, it only correctly emulates routers, and provides basic simulation of network switches such as ATM switches, generic LAN switches and frame relay switches [6]. Furthermore it cannot perform routers emulation at real-time speeds which limits accuracy of simulation for network loading issues [6].

To summarize this section, GNS3 was developed as a complementary GUI to Dynagen and Dynamips, and can be considered as an overlay of Dynagen to create user friendly environment to simulate computer networks.

III. AUTO-CONFIGURATION OF VIRTUALIZED NETWORK IN GNS3

In order to create a complex network in GNS3, we have to employ primarily and repetitive logical IP configuration several time for attached interfaces cards of all connected network components. In the next step routing protocol configuration must be done, using for instance EIGRP or OSPF, RIP, etc. In the next stage the manual configurations used for route advertisement and node neighborhood establishment have to be compatible with the logical IP configuration that is done in last steps [12].

Hence in the complex networks the topology expands; the more network equipment the more configuration steps must be done which is the error prone process. To overcome this problem the Authors in [12] have proposed an enhancement on GNS3 to automatically generate primary IP and routing configuration of all the Cisco network equipment that are part of a simulated topology.

The Authors get benefit of the topology **setup configuration files** generated by GNS3 to auto-generate the network nodes (e.g. routers and switches) configuration files, without the need to access their corresponding consoles [12]. This application offers the customized settings, like what routing protocol to be employed and which standard configuration must be done [12].

GNS3's GUI enables users to simply design their network topology, and then it produces a specification text file for each object with appropriate information accordingly. This implementation [12] scans GNS3's configuration file and produces the Cisco IOS configuration file relevant to each equipment. The application will generate an authentic and operational configuration set of files, based on some common settings, such as the method of choosing IP addresses and what routing protocol must be employed [12].

The proposed architecture for this [12] application has been illustrated in Figure 4 After creating the topology on GNS3, the emerged JSON project file (.gns3) consists of the network topology blueprint that includes the details of all network nodes and the relations between them. Enhanced GNS3 application [12] is developed by writing scripts in Perl; considers two input files as framework: the first file is .gns3 blueprint file that is already generated by GNS3 and the second file is a setting specification file that specifies the way configuration has to be implemented.

After analyzing the GNS3 file, the application will automatically produce the primary configuration files for all network equipment, such that the network topology and IP configuration are authentic and operative. Pre-defined templates will generate the network configuration, in which Authors specify the required commands for each operation, such as IP configuration in a network interface card (NIC) or arranging a particular routing protocol.

After the file generation step has been completed and since GNS3 stores the configuration files for each node in a network project, the newly generated configuration files produced by application will replace the primary (and empty)

ones. Finally, since the Cisco IOS virtual machines starts through GNS3, the newly created configuration files will be loaded for each corresponding device, represented by a separated virtual machine [12].

The way this application employs the correct Cisco IOS commands for each configuration line is through the use of templates. For instance, to give an IP configuration on a NIC, one must have to use the Cisco IOS command **IP address m. n. o. p. w. x. y. z** that are **"m. n. o. p"** and **"w. x. y. z"** the IP address and subnet mask respectively. There would be a template for each particular function such as the template for routing protocol configuration which is different from the template specified for NIC configuration. Any command in the template having a mask that would be substitute by values produced by script or user values [12]
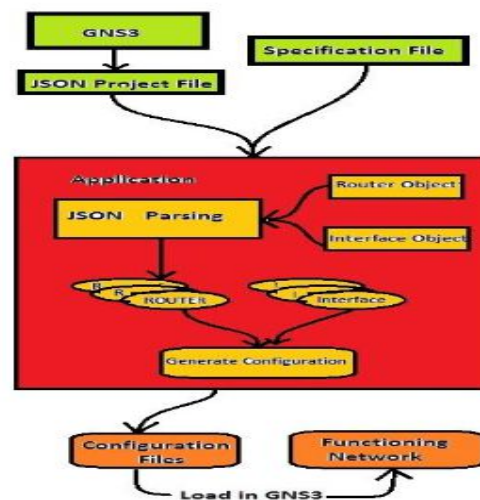

Figure 4: Advanced GNS3 Architecture

There are some benefits of employing this approach while configuring computer networks on GNS3 as follow. First, in the learning environments, mini networking lab scenarios are commonly being created, this solution can help armature users to learn better by comparing their own created configuration with Auto- generated configuration. By this approach intermediate learners can learn the most frequent configuration errors and troubleshoot their own configurations [12].

Second, in very advanced networks that are having complex topologies which consist of many number of routers, this application can solve difficulty in another manner. For instance, in a network that aim is to create a Multi-Protocol Label Switching (MPLS); the topology consists of 20 routers, and professional users require an operative network to configure this protocol. Whereas applying the primary configuration in the 20 routers is time consuming, repetitive and error susceptible process; this approach could possibly help users to skip this stage, preparing all the important initial configurations of this scenario and providing it for the setting up MPLS. GNS3 would provide great advantage by integrating with auto-configuration feature, without considering the size of the created topology [12].

IV. CONCLUSIONS

The simple and unique virtualization capability of GNS3 provides a precise and flexible simulation platform that can be used as an efficient tool for emulating computer networks. It can be used to easily simulate a more complex network, which operates as close as possible from of real network, than those possible using the hardware in many real

world scenarios. The GNS3 software is open-source and free of cost simulation software that can be easily downloaded online, but router IOS images must be provided by user.

In this paper we overviewed main features of GNS3.In the first section; we discussed about network simulation and available simulation tools. In section II, we reviewed GNS3 capabilities and in section III, we discussed a proposed extension of GNS3 that could be provided as a set of Perl scripts. It Auto- creates the IOS initial configuration files for each device in the network topology. Using this application offers following two main advantages in computer network area.

First, In Academic environment small network scenarios must be setup, so the intermediate users can get benefit of this solution to compare their own configurations with automatically created configuration. This helps them to learn the most common configuration errors and troubleshoot their own configurations. Second, in very complex topologies that are composed of many devices, this solution can help professional users differently. This solution allows users to skip basic configuration steps, and save their time by creating all the compulsory configurations as per scenario and provide it for advanced configuration. This application takes advantage of the GNS3 specification files produced for each device at the time of designing network topology. Integrating GNS3 with this extension gives a simpler and quicker approach of automatically creating more complex networks.

REFERENCES

1. "Network Simulator." [Online].Available: https://en.wikipedia.org/wiki/Network_simulation [Retrieved: October 2015]

2. Jianli Pan, Prof. Raj Jain, Project, "A Survey of Network Simulation Tools: Current Status and Future Developments", report.

3. [3]" Basics of Network Simulation." [Online]. Available:

    http://iitkgp.vlab.co.in/?sub=38&brch=121&sim=561&cnt=1 [Retrieved: October 2015]

4. "Virtual Network."[Online]. Available: https://en.wikipedia.org/wiki/Virtual_network [Retrieved: October 2015]

5. "Network Virtualization."[Online]. Available: https://en.wikipedia.org/wiki/Network_virtualization. [Retrieved: October 2015]

6. Tianyi Li, Walter E, Thomas Fallon, "On the Use of Virtualization for Router Network Simulation", published in American Society for Engineering Education, Pages 15.925.1-15.925.11, 2010.

7. Saba Siraj, Ajay Kumar Gupta, Rinku Badgujar," Network Simulation Tools Survey" International Journal of Advanced Research in Computer and Communication Engineering, vol. 1, no. 4, pp. 199–206, 2012.

8. Mike Fuszner, "GNS3 Tutorial ", [Online].Available: https://www.csd.uoc.gr/~hy435/material/GNS3-0.5-tutorial.pdf [Retrieved: October 2015]

9. "GNS3."[Online].Available: http://www.gns3.com [Retrieved: October 2015]

10. "Cisco IOS." [Online].Available: https://en.wikipedia.org/wiki/Cisco_IOS [Retrieved: October 2015]

11. "Graphical Network Simulator 3."[Online].Available:

    https://en.wikipedia.org/wiki/Graphical_Network_Simulator-3 [Retrieved: October 2015]

12. Rodrigo Emiliano, Mário Antunes" Automatic network configuration in virtualized environment using GNS3", in proc 10th International Conference on Computer Science & Education ,July 2015,published in IEEE Journal, pages 25-30, 2015.

13. Pablo Gil, Gabriel J. Garcia, Angel Delgado, Rosa M. Medina, Antonio Calderon, Patricia Marti," Computer Networks Virtualization with GNS3" in proc IEEE Frontiers in Education Conference, pages 2141-2144,Oct 2014.