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RvachovaNatalia, phD, senior lecturer
Acurcio Balao Cassongo, student
Poltava National Technical Yuri Kondratyuk University

THE COMPARISON OF NETWORK SIMULATORS FOR SDN

Network simulation is the most useful and common methodology used to evaluate different network topologies without real world implementation. The main focus of this paper is to compare the characteristics, open source network simulators based on the following parameters: CPU utilization, memory usage, computational time, and scalability.

Key words: *Soft-Defined Networks, network simulators, OpenFlow, Mininet, Estinet.*

Introduction

In this work we did a comparison between 4 networks simulators and/or emulators that are Mininet, Cisco Packet Tracer, GNS3 and EsitNet. Firstly, we must to understand the difference between simulator and emulator, an emulator will run an exact copy of an actual network operating system. A simulator is designed to have a resemblance to the actual network operating system, but only 'simulate' functions. A major challenge is how to analyse the obtained performance results of data transmission for these tools. These challenges include scaling to large networks, testing the correctness and evaluating the performance with the ability to easily migrate to a real system with minimal changes for deployment. GNS3 Ironically has 'simulator' in its acronym, but it simulates entire networks, not just network operating systems. Most users use GNS3 to emulate Cisco IOS as well as other vendors. But what sets GNS3 apart from other simulators, is its ability to emulate routing and switching as well as incorporate real virtual machines and connect them together via a logical tunneling system (overlay network). That is why it is

better to say where other software simulate, GNS3 has made advances to emulate your real production networks. Packet Tracer is a network simulator and embeds only limited real equipment features.

Currently, the demand for tools for evaluation of network scenarios is growing because of the need to test solutions to network before its use in the real world. Some factors such as: investment, cost, benefit, management complexity, and time required for implementation are some of the concerns associated with today's network assessment environments and emerging network technologies. For this reason, the study of the possible environments for the execution of experiments becomes important in the current context of the networks.

The main part

MiniNet creates an OpenFlow virtual network with a controller, switches, hosts, and links, and also allows you to develop custom topologies using Python scripts. MiniNet so far does not yet provide true performance and quality to a real network, although the code used in it serves a real network based on NetFPGAs, or commercial switches. This is due to the resources that are handled by the simulator kernel in real time, since the total bandwidth is limited by CPU and memory of the same, already the EstiNet is a proprietary simulator, already EstiNet is a proprietary simulator may be used for simulations with multiple controllers also allows the simulation mode and the emulation.

EstiNet presents some disadvantages, the fact that there is still not much material available on the Internet for study and research, still little known and used for simulations in networks in general, especially for SDNs, has a mid-level learning curve for difficult, mainly because it is a proprietary software. According to my research I can conclude that the EstiNet OpenFlow network simulator and emulator is the best OpenFlow network simulator and emulator in the world for doing Software Defined Networks research. In the simulation mode, a real-world open source OpenFlow controller such as NOX, POX, Floodlight, OpenDaylight and Ryu controllers can

directly run up on a controller node in the simulated network to control these simulated OpenFlow switches without any modification. Comparing other existing OpenFlow simulators and emulators, one will find that EstiNet OpenFlow network simulator and emulator is the most accurate, fast, scalable, and useful OpenFlow network simulator and emulator in the world. But now we are focused to future.

Network simulators are also particularly useful in allowing the network designers to test new networking protocols or to change the existing protocols in a controlled and reproducible manner. Most of the commercial simulators are GUI driven, while some network simulators are CLI driven. The network model, configuration describes the state of the network (nodes, routers, switches, links) and the events (data transmissions, packet error etc.). An important output of simulations are the trace files. Trace files log every packet, every event that occurred in the simulation and are used for analysis. Network simulators can also provide other tools to facilitate visual analysis of trends and potential trouble spots real devices and applications into a test network (simulated) that alters packet flow in such a way as to mimic the behavior of a live network. Live traffic can pass through the simulator and be affected by objects within the simulation. However, different simulators require variable time, memory and computation power for evaluating proposed protocols/techniques. This paper presents performance comparison of four network simulators, Mininet, Cisco Packet Tracer, GNS3. Packet Tracer 6.2 and GNS3 are two major network simulation software used for certification exam training (Cisco CCNA and CCNP for example) or network feature test without having to buy expensive real world equipment. The two software have been designed to address different needs.

Table 1

Mininet, Cisco Packet Tracer, GNS3 and EstiNet Feature Comparison

General	Mininet	Packet Tracer	GNS3	EstiNet
Free software	Yes	Yes	Yes	No
Open source	Yes	No	Yes	Yes
Publicly downloadable	Yes	No	Yes	No
Windows support	No	Yes	Yes	No
Linux support	Yes	Yes	Yes	Yes
Fully functional IOS	No	No	Yes	No
Simulation mode	No	Yes	Yes	Yes
Emulation mode	Yes	No	Yes	Yes
Compatible with real world controllers	Yes	No	No	Yes
Result repeatable	No	No	No	No
Scalability	Middle by multiple processes	No	No	High by single process
Performance result correctness	Depend of resources	No	Yes	Yes
Wifi	Yes	Yes	No	Yes
Gui support	Yes	Yes	No	No

Mininet was created by a group of professors at Stanford University to be used as a tool to research and to teach network technologies. The Mininet open-source network simulator is designed to support research and education in the field of Software Defined Networking systems.Mininet is designed to easily create virtual software-defined networks consisting of an OpenFlow controller, a flat Ethernet network of multiple OpenFlow-enabled Ethernet switches, and multiple hosts connected to those switches. It has built-in functions that support using different types of controllers and switches. We can create also complex custom scenarios using the Mininet Python API [1].

Mininet networks run *real code* including standard Unix/Linux network applications as well as the real Linux kernel and network stack (including any kernel extensions which you may have available, as long as they are compatible with network namespaces.) Because of this, the code you develop and test on Mininet, for an OpenFlow controller, modified switch, or host, *can move to a real system with minimal changes*, for real-world testing, performance evaluation, and deployment. Importantly this means that a design that works in Mininet can usually move directly to hardware switches for line-rate packet forwarding [2].

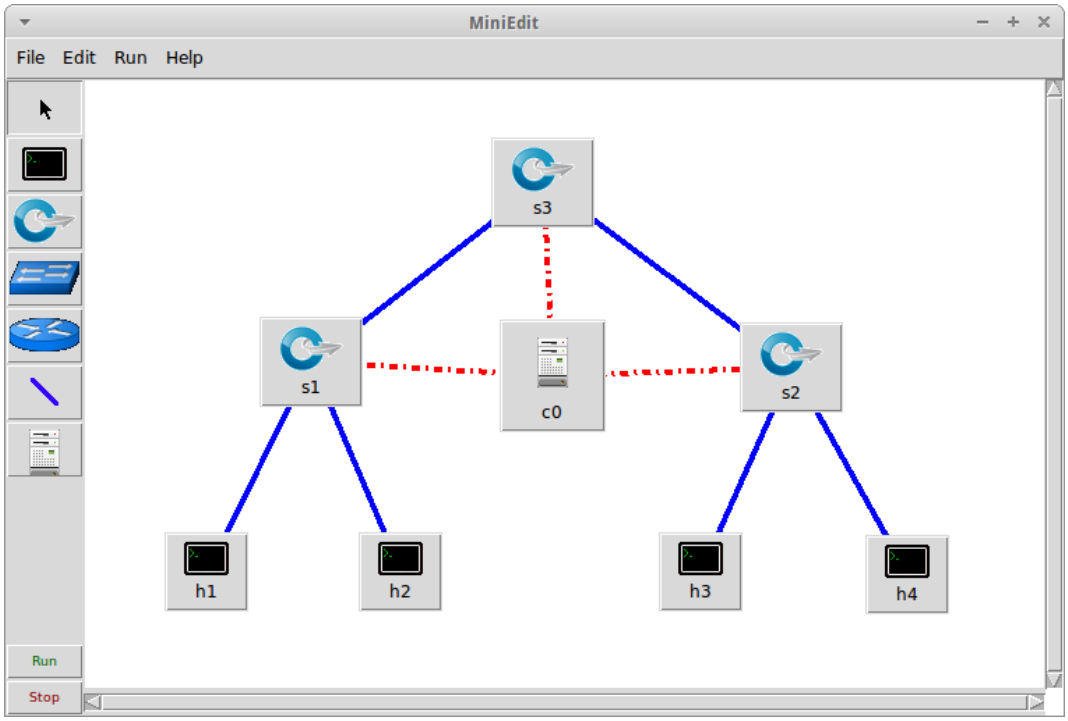

Fig. 1. Simulation Interface of Mininet

Packet Tracer is a cross-platform visual simulation program designed byCisco Systems that allows users to create network topologies and imitate modern computer networks. Cisco Packet Tracer is a powerful network simulation program that allows students to experiment with network behavior [4]. Packet Tracer provides simulation, visualization, authoring, assessment, and collaboration capabilities and facilitates the teaching and learning of complex technology concepts. The purpose of Packet Tracer is

to offer students a tool to learn the principles of networking as well as develop Cisco technology specific skills. However, it is not be used as a replacement for Routers or Switches [3].

It can be downloaded for free if you have a Netacad account. As Cisco says, the best way to learn about networking is to do it. Hands-on equipment gets students started, but is limited to the number of devices in the lab. Furthermore, Educators use Packet Tracer to demonstrate complex technical concepts and networking systems. Students use Packet Tracer to complete assignments, working on their own or in teams. As a network engineer, I used to simulate complex scenarios first on packet tracer and then deploy them on the real equipments. Please notice though, this course will not teach you networking, but rather let teach you how to simulate and apply your networking related knowledge. See the example in fig. 2.0.

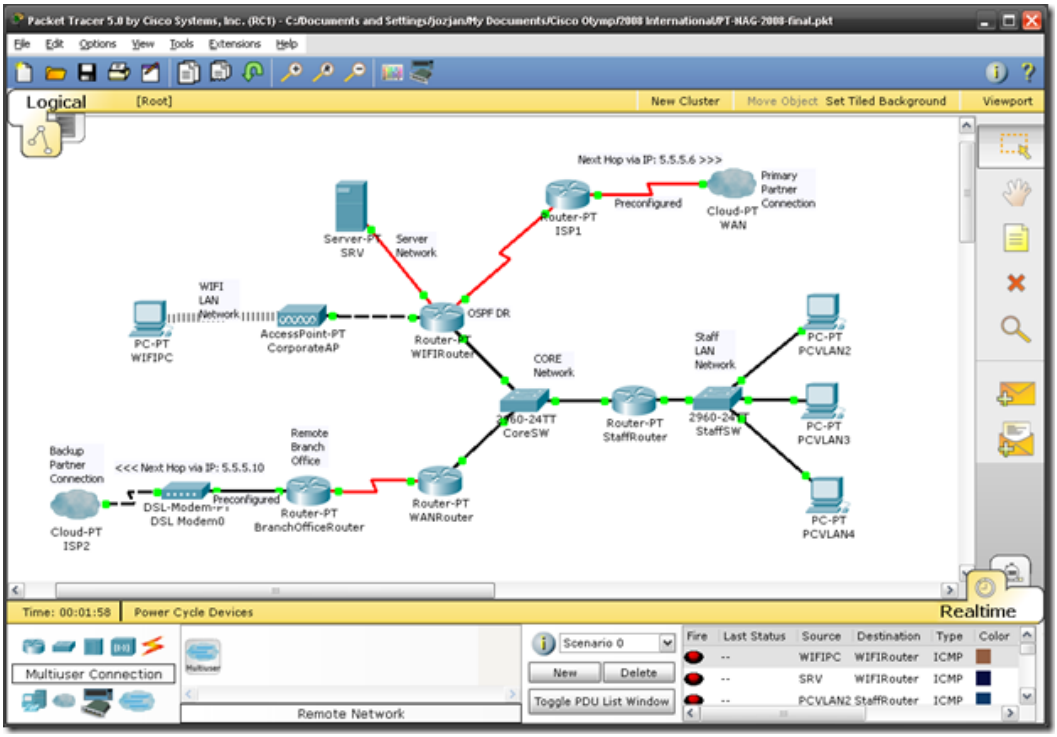

Fig.2. Simulation interface of Packet Tracer.

Packet tracer is cisco's simulator of Cisco IOS and is ideal for practice Labs, for beginners (like CCNA studies) Packet Tracer is good but for advanced labs I would

suggest GNS3, because most of the advanced labs and commands are not supported by Packet Tracer.

GNS3 is a Graphical Network Simulator that allows the user to run multiple emulated systems including Cisco routers, Juniper routers, Vyatta routers, Linux virtual machines, and Windows virtual machines. Getting GNS3 to actually do this simulation is not always an easy task, especially if you wish to venture beyond a simple network topology. GNS3 allows the same type of emulation using Cisco Internetwork Operating Systems. It allows you to run a Cisco IOS in a virtual environment on your computer. GNS3 is a graphical front end to a product called Dynagen. Dynamips is the core program that allows IOS emulation. Dynagen runs on top of Dynamips to create a more user friendly, text-based environment. A user may create network topologies using simple Windows ini-type files with Dynagen running on top of Dynamips. GNS3 takes this a step further by providing a graphical environment.

GNS3 allows the emulation of Cisco IOSs on your Windows or Linux based computer. Emulation is possible for a long list of router platforms and PIX firewalls. Using an EtherSwitch card in a router, switching platforms may also be emulated to the degree of the card's supported functionality. This means that GNS3 is an invaluable tool for preparing for Cisco certifications such as CCNA and CCNP. There are a number of router simulators on the market, but they are limited to the commands that the developer chooses to include. Almost always there are commands or parameters that are not supported when working on a practice lab. In these simulators you are only seeing a representation of the output of a simulated router.

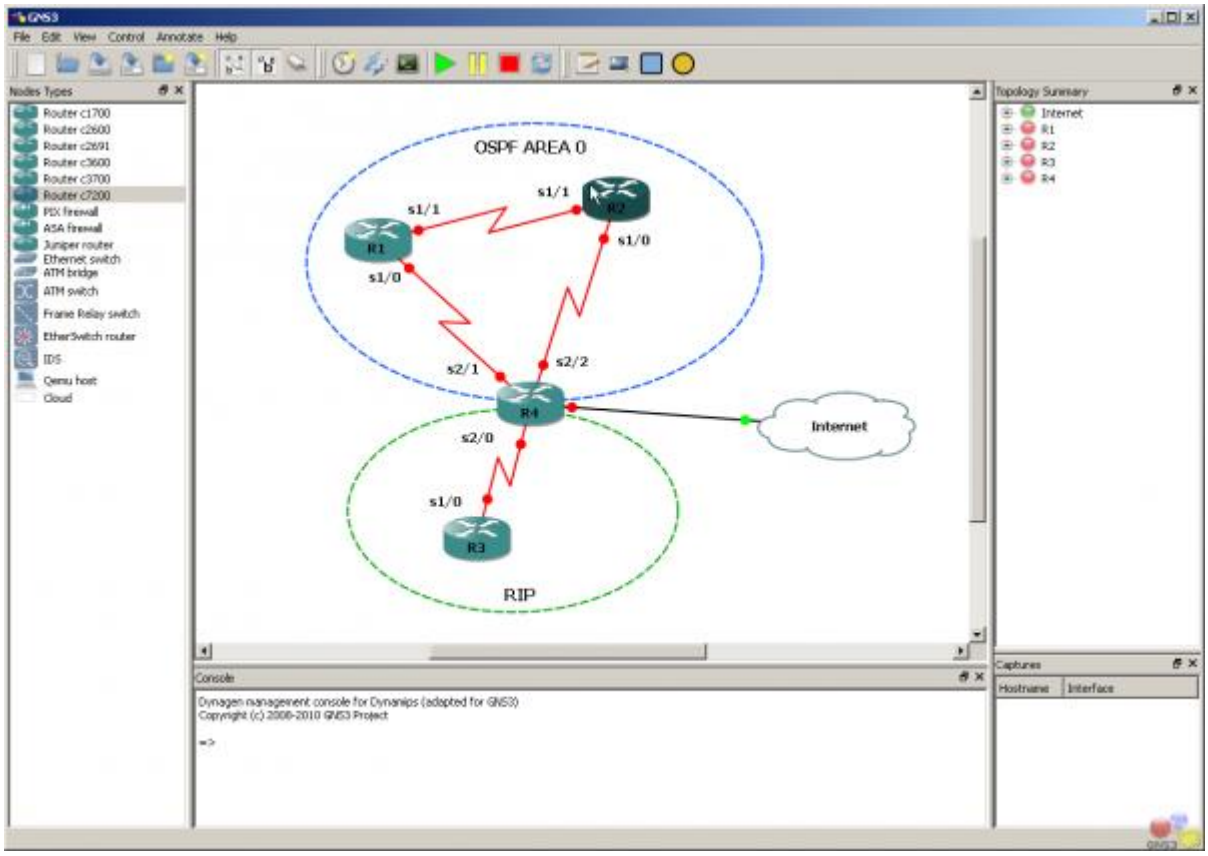

Fig.3 Simulation Interface of GNS3

Is great for emulating a physical network in a virtual manner because it's using the binary image you choose. That includes bugs but it does mean your access to multiple features is limited only by your access to an IOS images supported and the server or computers hardware limitations, through the table above of features comparison we can conclude that GNS3 is more complete than Cisco Packet Tracer,

EstiNet network simulator and emulator originates from NCTUns. NCTUns had been used for network-related research and publication from 2002 to 2011. It became a commercial software on 2011 and was renamed EstiNet. EstiNet's network simulation environment includes physical layer, media access control layer, network layer, transportation layer and application layer. In addition, EstiNet's user-friendly GUI provides users a convenient way to construct a simulated network and a visual display for simulation result observation and debugging. Linux kernel’s TCP/IP & UDP/IP

protocol stacks are directly integrated in simulated networks to provide real layer-3 and layer-4 protocol behavior for network applications, a Linux-based network application program, that can be run up on a real Linux network device, can be directly run up on a simulated network device. Running real programs reflects real network applications' behavior in simulated networks. This helps to develop and test applications' functionalities in simulated networks. It also helps to use real network applications to test newly-invented or modified lower-layer protocols and mechanisms.

When turning a simulator into an emulator, a simulated network/device can interact with a real-world network/device. An emulator builds a testing network field consisting of physical and virtual devices. The software functionalities of a physical device can be developed and tested in the testing field.

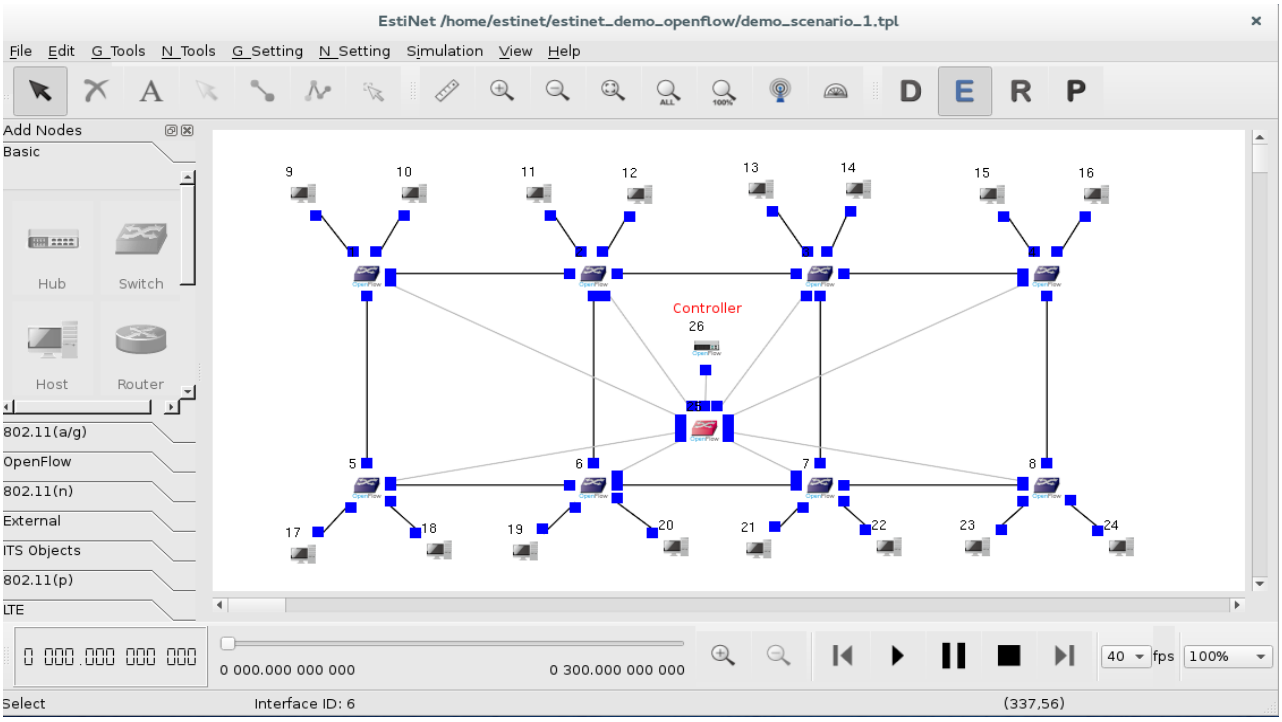

Fig.4. Simulation Interface of EstiNet

In this paper, we compare and evaluate the cor-rectness, performance and scalability of EstiNet OpenFlow simulator, EstiNet OpenFlow emulator, and Mininet OpenFlow emulator over a set of grid networks. The popular Floodlight OpenFlow

controller is used without any modification to control the simulated/emulated OpenFlow switches created in these tools.

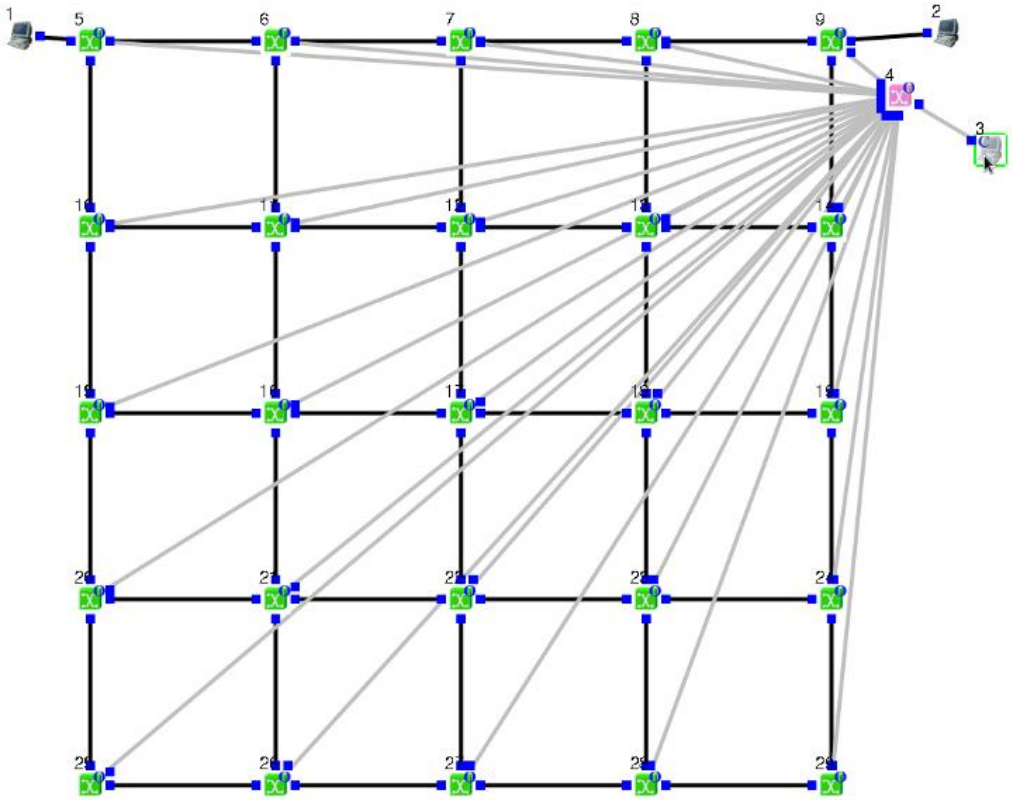

Fig. 5.0 NxN grid Network, where N=5

We performed experiments over a set of N x N grid networks, where N = 5, 6, ..., 31 and used the real-world ping program to observe whether the average RTTs reported by these ping packets are correct or not over these tools. We found that in EstiNet simulation, the simulated results of the average RTT are always correct and repeatable, but EstiNet simulator needs more time to finish the simulation when the network size becomes larger.

As for emulation, we found that Mininet emulator generated strange results that cannot be explained over some network sizes. In addition, Mininet emulator spends a huge amount of time on its program launch, network setup, and resource releasing when

the network size is large. As for EstiNet emulator, we found that it generated good performance and scalability and it used less time to obtain results.

Conclusion

In this article, we evaluate the performance of four network simulators with respect to different parameters. Packet Tracer is a network simulator and embeds only limited real equipment features, GNS3 is a network emulator based on Dynamips and QSEMU running real IOS images, virtual machines, the main limitation of GNS3 is the amount of resources (CPU / memory) available on the PC for running the lab's emulated IOS images and virtual machines for clients & servers simulation. Mininet is a unique open-source network simulator that is developed to support research and education in Software Defined Networking, I found the Mininet command-line interface to be very easy to use, because Mininet uses network namespaces as its virtualization technology, it can support a large number of virtual nodes without slowing down the simulation, and NetSim simulate a variety Cisco routers but not all, also don't have a fully functional IOS.

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