Evaluation of Well-known Network Simulators in Network Modelling for Resource Limited Environment

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Abstract

It is convinced that practical hands-on skills are of paramount importance to network technology students. But limitation in using expensive real network devices in hands-on lab becomes a huge barrier for interactive and effective learning. Here comes the role of network simulators as they offer functionality that closely mimics a real network with significantly low cost. For our students in Universities of Computer Studies, Packet Tracer (PT) has been integrated as a learning aid in computer networking field for several years. As there are many learners who want to use an alternative one like Graphical Network Simulator (GNS)3 other than PT, they try to compare and choose between the two simulators. Already set ***qualitative*** *criteria which have been used in GNS3 and PT evaluation is presented to be helpful in the work of choosing a suitable network simulator. In this paper, we reveal some* ***measurable criteria like CPU and memory utilization*** *by applying different routing protocols to simulation environments implemented on PT and GNS3 to be more apparent in the performance evaluation of these two simulators. It is also intended to examine how the complex network topology affects the CPU and memory utilization of the two simulators.*

Key words: Packet Tracer (PT), Graphical Network Simulator (GNS)3, CPU and memory utilization

1. Introduction

For undergraduate students in Universities of Computer Studies, there are at least three courses related to computer networking field which require extensive hands-on practices from which they can obtain more knowledge and skills. But it is a rare chance for students to practice individually with actual network devices such as routers, switches, and so on, in their labs. This degrades students' understanding of networking technology concept and effectiveness. A possible way to reduce this degradation is using simulators to help students getting more effective learning in networking technology. More important thing for applying network simulators is that it can reduce using costly real network devices in hands-on labs.

For our students in Universities of Computer Studies, a tool named Packet Tracer (PT) has been integrated as a learning aid in computer networking field for several years. This tool provides network simulation, visualization and collaboration capabilities. There have been good feedbacks from students as well as the lecturers showing that using Packet Tracer as a pedagogical tool in computer networking motivate the interest of the students. As a consequence, they become more innovative and creative in their studies.

There are many developed network simulators which are used in networking courses: Packet Tracer (PT), Graphical Network Simulator (GNS) 3, OMNet++, OPNet, NS-3, etc. [1]. Among alternative ones, (GNS3) became popular these days as an emulator software which allows running actual networking software images on a computer.

As there are many learners who want to use an alternative one like GNS3 other than PT, they try to compare and choose between the two simulators. Some criteria have already been used in network simulators evaluation which will be helpful for those learners who want to choose an appropriate one to apply to his network.

In Section 2, some works on application and evaluation of network simulators are reviewed. In Section 3, qualitative criteria of PT and GNS3 which have been set to evaluate them are reviewed. Moreover, routing protocols used in our simulated networks are briefly explained in this section. In Section 4, we implement two simulation network topologies on PT and GNS3, each having 4-router and 8-router, to which static and dynamic routing protocols are applied. CPU and memory utilization obtained from these simulations are recorded to be used in evaluation processes. Discussion on how simulated network topology complexity affect the CPU and memory utilizations of the two simulators is made in Section 5. To be helpful in choosing a suitable network simulator for the resource limited learning environment, some recommendations are also provided in Section 6.

2.Related works

It has been studied that network simulators can help students to examine network behavior and compare performance in various scenarios without requiring dedicated hardware. There exists a wide range of simulators that offer different degrees of functionality and flexibility. The following works not only provide effectiveness of simulators application but also suggest some criteria for students and lecturers in choosing appropriate simulator that meets their needs for a given network domain.

Authors in [1] surveyed most common network simulators and analyzed their pros and cons to encourage personalized learning using those simulators so that learners can learn at their own pace and explore networking topics that reflect their learning needs. They proved that, by using these simulation tools, students got more opportunities in learning networking protocols details, achieved a deeper understanding of network internals, and gained practical networking skills.

Authors in [2] proposed an approach based on a set of criteria to evaluate network simulators in order for the researchers in network domain to select the most appropriate one for a given scenario. Their criteria include ten items that can be applied to different network simulators in order to obtain a measurable and comparable assessment. To illustrate the applicability of their proposed approach, they evaluate Packet Tracer. Their results not only highlight general aspects of Packet Tracer's behavior but also show its inefficiencies as well.

Authors in [3] address that both Packet Tracer and GNS3 provide extensive functionality and hence are valuable, cost-effective teaching tools. Each tool has advantages and disadvantages. The authors also recommend use of simulator which is beneficial to student learning.

The authors in [4] used GNS3 and PT to compare their effectiveness in assisting the students to learn networking technology. They studied the different effect of the two simulators upon the learning performance and learning achievement of the students.

Students satisfaction associated with using simulation tools in computer network courses was assessed in [5]. It was found that most of the students desired of using the real physical equipment. But in the case of budget and resource
constraints, using simulators as a supplementary tool to meet the learning outcomes was recommended as the best solution.

In [1],[2], and [6], authors proposed a set of qualitative criteria and evaluated some commonly used network simulators including GNS3 and PT. But it is convinced that measurable criteria can provide more apparent evaluation of the simulators. So, in our work, CPU and memory utilizations of PT and GNS3 obtained from their simulation scenarios with different routing protocols configurations are set as measurable criteria.

3. Literature Review

3.1. Review on Evaluation of GNS3 and PT

In this paper, as we emphasized only on GNS3 and PT, we summarized the evaluation of these two simulators according to their qualitative criteria in Table 1.

Table 1. Evaluation of GNS3 and PT

Criteria	GNS3	PT
(i) Interactive GUI design	Only one work space	Two work space: logical and physical; Two operation modes: real-time and simulation
(ii) Memory requirement	RAM 2G minimum	RAM 2G minimum [7]
(iii) Cisco technology integration	Does not fully integrate with all Cisco's technology	Incorporate with much Cisco's technology
(iv) Supported protocols	Most protocols in different network layers	A subset of protocols
(v) Supported commands	All commands available to the installed IOS	does not support all Cisco IOS commands
(vi) Supported network component functions	Can test actual services and applications	Just simulation, Virtual machines cannot be integrated.
(vii) Traffic analysis	analyze data traffic (Real-Time NetFlow Analyzer) [8]	It is possible in real time
(viii) Cable connection	Not obvious.	More realistic.
(ix) Operating system support	Windows/Linux	Windows/Linux

From the above table, it can be said that the two simulators have some similarities and differences. So, it is not so apparent to say which one is better. Practically, it would be more reasonable of choosing a suitable one than a better one. In general, it is possible to use a new one just by installing on our desktop or laptop. But in real, there are some facts to be taken into account: is this

new tool more interactive, efficient, and effective like/than the one we used before? If it is, we will use it. Or, we will continue to use the current one because we are familiar with using it. So, it would be better to examine some common functionalities and capabilities of PT and GNS3 which are evaluated in Table 1.

In our work, we are going to reveal some measurable criteria like CPU and memory utilization of PT and GNS3 and incorporate it to the afore mentioned qualitative criteria set, which would provide more apparent evaluation in choosing an appropriate network simulator.

3.2. Routing protocols

Routing could be done statically or dynamically. Static routing involves the developing, maintaining and updating
routing table manually such that a change in network topology affects its routing information. On the other hand, dynamic routing uses routing protocols such that routing information is not highly dependent on the network topology being static. Dynamic routing protocols allow routers to dynamically learn information about remote networks and automatically add this information
to their own routing tables. Compared to static routing, dynamic routing protocols require less administrative overhead. However, the expense of using dynamic routing protocols is dedicating part of a router's resources for protocol operation, including CPU time and network link bandwidth [9].

In this work, we used a static routing and three dynamic routing protocols named OSPF, EIGRP, and RIP; some typical characteristics of them are summarized in Table 2.

Table 2. Typical characteristics of some dynamic routing protocols

Characteristics	RIP	OSPF	EIGRP
Long form	Routing Information Protocol.	Open Shortest Path First.	Enhanced Interior Gateway Routing Protocol.
Distance vector (or) link state protocol	distance vector	link state	Hybrid
Metrics used	hop	bandwidth and delay	bandwidth, delay, load and reliability
Algorithm used to calculate the best path	Distance vector	SPF algorithm	Diffusing update algorithm
Usage of Areas / Tables	Networks are not divided into areas or tables.	Autonomous System, Areas, Stub Areas and Backbone areas	Neighbour Tables, Topology tables, and Routing tables.
Maximum hop count	15	Unlimited.	255
Convergency	slow	fast	very fast
VLSM support	Yes	Yes	Yes
Administrative Distance (AD) value	120	110	90

4. Implementation of Simulation Environment

Both simulators were installed on the same computer with the following specifications: Intel Core i7@ 3.6 GHz CPU and 4G memory on which Windows 10 (64-bit) is running. Here, GNS3 2.2.7 and Packet Tracer 7.2 were used as network simulators. We installed GNS3 all-in-one locally and used same IOS image for all simulated routers.

We implemented same simulated network topology for GNS3 and PT: a four-router and an eight-router designs. The parameters for CPU and memory utilizations were collected from the "Performance" tab which is situated under the "Windows Task Manager".

Step by step configuration of each routing protocol on each network topology is done, and the CPU and memory utilization for each routing protocol are recorded.

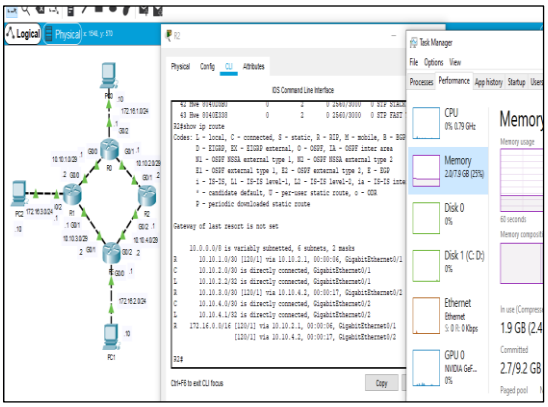

Figure 1. CPU and memory utilization of RIP configured 4-router network on PT

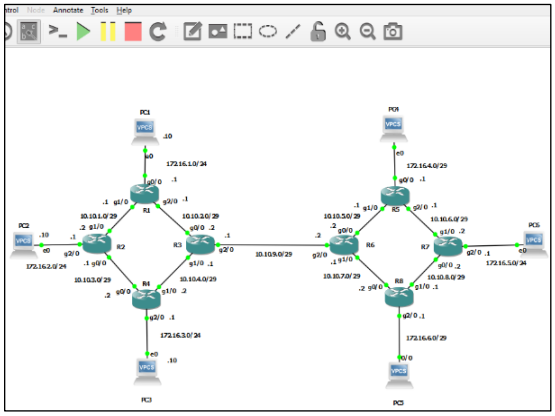

Figure 2. Eight-router topology on GNS3

5. Results and Discussion

All the required information collected from the simulations are visualized in Figure 3 through 6 in which CPU and memory utilizations of PT and GNS3 while running 4-router and 8-router topology; each is configured with of one of the four routing protocols at a time are compared.

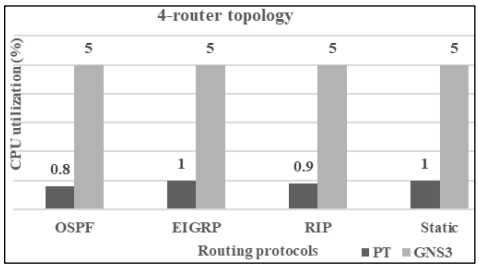

Figure 3. Comparing CPU utilization on 4-router topology

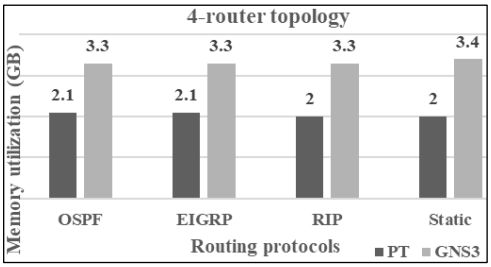

Figure 4. Comparing memory utilization on 4-router topology

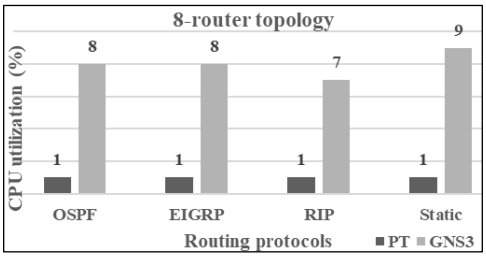

Figure 5. Comparing CPU utilization on 8-router topology

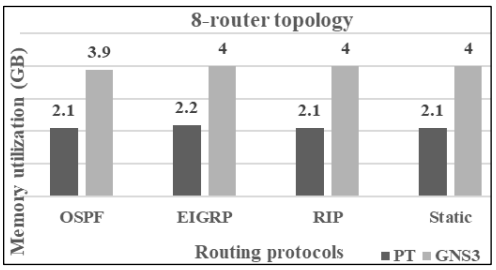

Figure 6. Comparing memory utilization on 8-router topology

From the above results, it can be said that using different routing does not affect much on CPU and memory usage of either simulators. Regarding GNS3, CPU and memory usage is always greater than that of PT even if the same topology is used.

Some comparisons were made in Figure 7 through 10 to see the effect of topology complexity on CPU and memory usage of the two simulators.

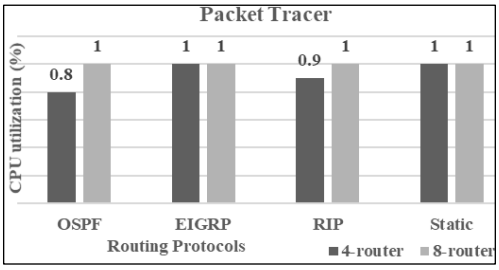

Figure 7. Comparing CPU utilization of PT on both topology

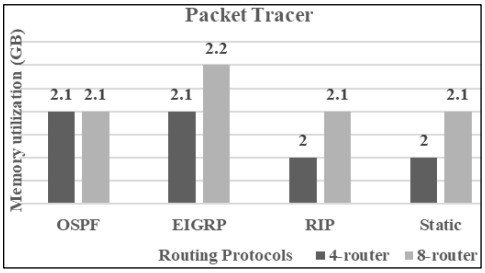

Figure 8. Comparing memory utilization of PT on both topology

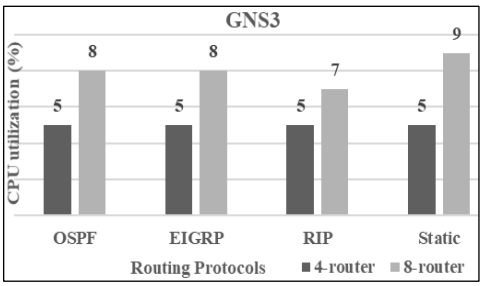

Figure 9. Comparing CPU utilization of GNS3 on both topology

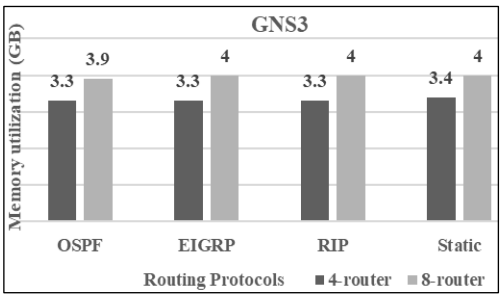

Figure 10. Comparing memory utilization of GNS3 on both topology

No significant difference on both CPU and memory utilization of PT is noticed upon the topology change. On the other hand, with more complex eight-router topology, GNS3 used the CPU more than 1.5 times and the memory, nearly 700 MB (0.7 GB) more of that used in less complex four-router topology.

To sum up, it can be said that complex topology design affects the CPU and memory utilization in GNS3 to some extent. Based on our work, it can be said that the more complex the topologies become, the higher the utilization of the CPU and memory will be with GNS3 which might be some issues for the resource limited learning environment.

6. Conclusion

We have evaluated PT and GNS3 based on their CPU and memory utilization in running the same and different topology and routing protocols. According to our experiences and our work here, PT seems more familiar for the learners, even if the user is a novice, to model and visualize the behavior of a network through the simulation mode from which user can understand the fundamental concepts of networking technologies. As GNS3 needs more resources and more professional skills to implement than PT does, but has capability to validate, test and verify new networking protocols and algorithms in a cost-effective manner, it would be better to reserve it for the learners to their advanced studies in computer networking field.

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