Effectiveness of Using Cisco Packet Tracer as a Learning Tool: A Case Study of Routing Protocol

Noor Maizura Mohamad Noor, Nadiah Yayao, and Sumazly Sulaiman

***Abstract*—Computer network experts are in high demand nowadays. The purpose of this research is to study the effectiveness of using Cisco Packet Tracer as a learning tool. This scenario is considered important to Higher Learning Institutions in order to ensure all students graduated with sufficient network skills. Therefore, computer network requires understanding of both theory and practical, hence network simulation software should be recommended to overcome this problem. Respondents of the study were the 132 second year students from the Bachelor of Computer Science (Software Engineering) and Bachelor of Computer Science (Informatics Maritime) who took the Data Communication and Network course in Universiti Malaysia Terengganu. The questionnaire and simulation of routing protocol performance case study were used as the research instruments in this study.**

***Index Terms*—Computer network, cisco packet tracer, routing protocol, simulation software.**

I. Introduction

Computer network is a crucial subject in multiple degree programs, such as Electrical Engineering, Computer Engineering, Computer Science, Information Engineering, Software Engineering, and other programs [1]. Computer network area requires professionals with solid networking theory and practical hands-on experience. Together with the fast technological advancement in the field of computer networks and Information Technology industry, the need for a large number of skilled network experts also increased [2]. Table I shows some technical occupations and predictions for networking students in the U.S for the years 2008-2018. [1]

Hence, simulation software is recommended to help a learner of networking subject to have an active learning experience and students can bring the real networking environment into the classroom to make more interactive and effective. While simulation software cannot provide students with important practical skills such as cabling and physical connectivity, the software is very useful and cost-effective [3]. There are few networking simulation tools had been created by different companies such as Cisco Packet Tracer, Boson NetSim and GNS3 [4]. Cisco Packet Tracer is developed by Cisco Systems and currently widely used in academies around the world.

There are issues arose in finding the best method to learn this critical subject especially in understanding technical concepts and routing protocol concepts [5], [6]. Therefore, a study on the effectiveness of using Cisco Packet Tracer as a learning tool needs to be investigated.

TABLE I: Employment by Occupation, 2008 and Projected 2018 (Numbers in Thousands)

2008 National Employment Matrix	Employment Number	
	2008	2018
Computer programmers	426.7	414.4
Computer software engineers and applications	514.8	689.9
Computer software engineers, systems software	394.8	515.0
Computer systems analysis	532.2	640.3
Database administrators	120.4	144.7
Network and computer systems administrators	339.5	418.4
Network systems and data communications	**292.0**	**447.8**
All other computer specialists	209.3	236.8
Computer hardware engineers	74.7	77.5
Electronics engineers, except computer	143.7	144.1

II. Literature Review

A. Problems in Computer Network Course

Computer network course faced various issues, especially related to large class sizes, plagiarism, module franchising, and requirement of practical works [5]. In addition, lecturers or instructors of computer network found teaching this subject is challenging because of the abstract network concepts [7]. Shanmugam *et al*. (2011) claims it is harder for the students to reflect the networking principles, algorithms, protocols used between hardware devices, PC's, Servers, switches, hubs, routers and firewalls. Networking students have to learn the numerous types of protocols and their roles in data communication in details, students will be harder to visualize their functions in the lectures [8]. According to Anuar Hassan and Ahmad Zamzuri (2010), 66.7% is reported routing protocol topic is the hardest topic to be taught by lecturers [6]. In conclusions, there are two main problems to be solved, which are problems in understanding technical concepts in computer network course and problems in understanding routing protocol concepts. Exposito *et al*. (2010) agree routing protocol using complex algorithm and not easy to understand at the first glance [9].

B. Previous Studies

Javid (2014) has investigated the roles of Packet Tracer based on teacher and students' experiences. The findings of this study concluded there are lot of benefits and advantages

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of using a Packet Tracer in learning basic and important concepts of computer networks which can be challenging to understand theoretically [10].

Mohd Syahrizad & Ahmad Zamzuri (2012) interviewed lecturers in Malaysian Polytechnics to determine the major issues arose in teaching networking students using Cisco Packet Tracer. The researchers concluded students faced problems to apply the theory learned using simulation with the real situations. The syllabus using Cisco Packet Tracer should be re-evaluated to ensure the method is effective for students [6].

Tu, (2012) analyzed the comparison between Cisco Packet Tracer as a virtual experiment technology and the real experiment using physical equipment. He concluded Cisco Packet Tracer has many benefits such as economy, convenience, flexibility, safety and easy to expand. In teaching computer network course, the process of real network equipment practice should be added into after the completion of virtual experiment teaching to enhance students' skills [11].

Shanmugam *et al*. (2011) developed methods on how to simulate the gap between theoretical lectures and laboratory experience and improvement in student's learning outcome. The findings of the study concluded skills in designing network topology and solving problems has greatly improved when students using the Cisco Packet Tracer [8]. Based on the related previous works, the effectiveness of using Cisco Packet Tracer as a learning tool in computer network course need to be investigated and routing protocol is chosen as a case study. As a learning tool, the aspect of related learning theories is emphasized and discussed in next section.

C. Learning Theories

The study of computer network course is challenging because students have to learn technical jargon and master concepts covered in the lectures. Based on this scenario, cognitive load is used as the primary theoretical framework. According to Sweller (1988), cognitive load is based on cognitive psychology and states that humans have limited capacities to process information [12]. Mayer (2005) holds the view that overloading student's cognitive resource will decrease learning process [12]. In accordance with the viewpoint, cognitive theorists suggested instructions should be designed with multimedia to enhance learning process [13].

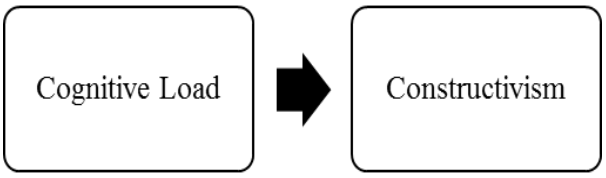

Fig. 1. Learning theories of using simulation software.

Constructivism approach is proposed in this study which students construct new ideas based upon their current or past knowledge through their own experiences [14]. Constructivism is a major educational theory today that has been broadly tested in the science and mathematics fields. This approach will allow students develop their own knowledge in dynamic and flexible environment.

Fig. 1 depicts the overview of learning theories related in this research. According to Brookfield (1990), simulations assist constructivist learning through engaging participants' psychomotor, affective and cognitive learning domains. These learning domains will affect students' experience deeper and memorable [15]. Sims (2002) also agree the learning process can leave a memorable impression to constructivists [16]. This research focus on simulation software named Cisco Packet Tracer that provides students to have an active learning experience and bring the real networking environment into the classroom.

D. Cisco Packet Tracer

Cisco Packet Tracer is effective education simulation software that supports computer networking students to experiment and practice network task. Cisco Networking Academy Program (CNAP) introduced Packet Tracer as a tool for teaching and learning of computer network course by providing "simulation, visualization, authoring, collaboration capabilities and assessment" [17].

By using Cisco Packet Tracer, students able to learn and built their network topologies in a visual way by dragging, placing, connecting, and clustering virtual network devices such as hubs, switches, routers, workstations and servers [9]. Packet Tracer is chosen among worldwide academies because it is absolutely for CNAP, easy installation (Windows and Linux) and an initial platform for students that are just starting out in the ICT networking [17].

Packet Tracer allow users experience using various networking devices such as routers, switches, wireless access points, computers, links and applications in a user friendly simulation environment [18]. This software supports many networking protocols, multiple platform support, logical and physical workspaces; real time and simulation mode and (CLI) [18]. Hence, students can easily understand the functionality and the process of routing protocols. The topic is actually the most challenging topic in computer network course [6].

E. Routing Protocols

Syahrizad *et al*. (2012) claims routing protocol is the most challenging and the hardest topic in computer network course [6]. Routing protocol is compulsory to learn and play role to determine the route to be preferred from source to destination in the network. In this era Internet of Things (IoT), routing protocols are essential due to rapid communication networks. They take part in the network and forward the packets to correct path and also observe the data so that it remains in a control manner. Initially, the concept of routing protocols was studied, starting with an overview of the Interior Gateway Protocols (IGP). Fig. 2 summarizes the hierarchical view of dynamic routing protocol classification. Interior Gateway Protocol (IGP) should be used for the routers in same domain network such as Routing Information Protocol (RIP), Enhanced Interior Gateway Routing Protocol (EIGRP), Open Shortest Path First (OSPF) and IS- IS (Intermediate System – Intermediate System). In contrast, Exterior Gateway Protocol is used in different domain network. Border Gateway Protocol (BGP) is the only routing protocol classified as EGP [19].

Later we focus on Distance Vector Routing Protocols especially Enhanced Interior Gateway Routing Protocol (EIGRP) and Routing Information Protocol (RIP). Our work emphasized on the comparison between both routing protocols as both of them are considered as pre-eminent routing protocols for the real time applications [20]. In addition, both EIGRP and RIPv2 have same features, which are classless routing protocol and supports VLSM [21]. The comparison of both routing protocols is based on performance metrics which use specific formulas.

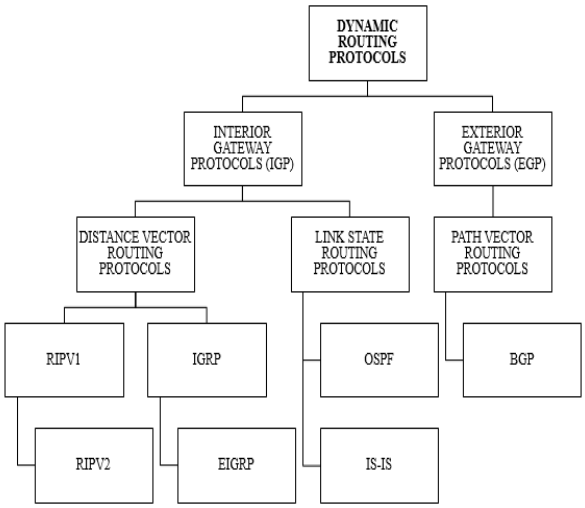

Fig. 2. Routing Protocol classifications.

III. Methodology

A. Research Questions

As the purpose of the study is to measure the effectiveness of using Cisco Packet Tracer as a learning tool, three research questions has been developed as shown in Fig. 3.

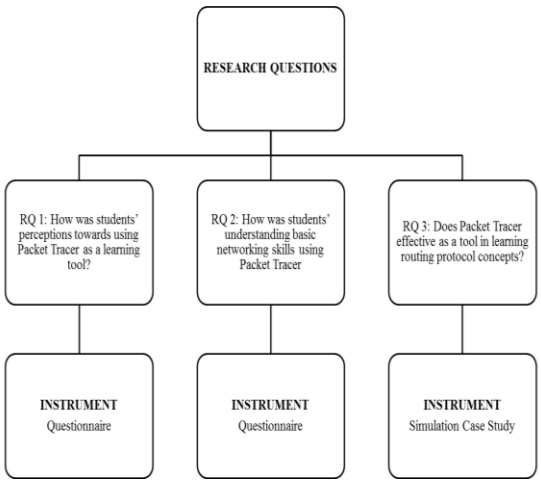

Fig. 3. Research questions.

Research 1 and research question 2 use the four-point Likert scale questionnaire as instruments. Before students participated in this questionnaire, they have been taught a Cisco Packet Tracer module and a series of exercises to ensure students comfortable with the software. This questionnaire is divided into 3 parts namely Part A (Self Information), Part B (Students' Perception on using Packet Tracer) and Part C (Students' Understanding Basic Network Configuration Skills). Research Question 3 is measured by using simulation experiment of routing protocol performance as an instrument.

B. Research Design and Procedure

Respondents of the study were the 132 second year students from the Bachelor of Computer Science (Software Engineering) and Bachelor of Computer Science (Informatics Maritime) who took the Data Communication and Network course in Universiti Malaysia Terengganu.

In the first week of practical session, students are exposed on how to use Packet Tracer to create a simple network topology by referring the module created by the researcher. Then they implemented a series of exercises comprises of Tutorial 1, Tutorial 2 and Tutorial 3 before participating in this questionnaire. Fig. 4 and Fig. 5 show part of activities involved during the completion of exercises. In the end, all students supposedly able to:

- Cable devices and establish connections using Cisco Packet Tracer
- Erase and reload the routers
- Perform basic router configuration
- Verify and test configurations using show commands

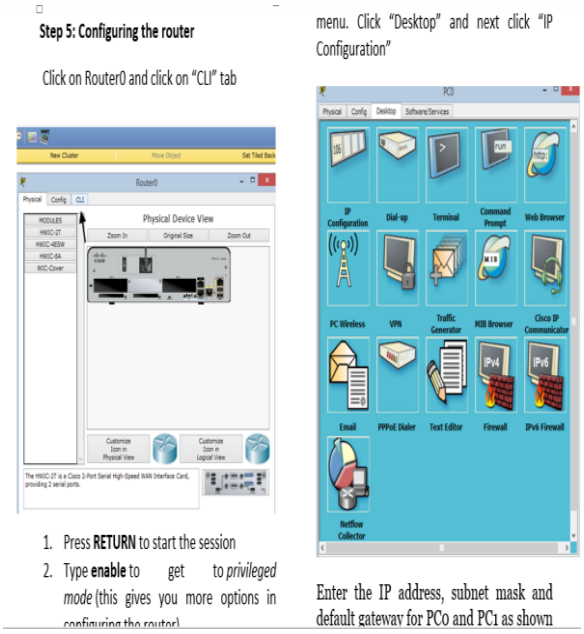

Fig. 4. Screenshot of cisco packet tracer module.

The data collected for research question 1 and research question 2 will be analyzed using software program The Statistical Package for the Social Sciences (SPSS) Version 20. Cronbach's α (alpha) was conducted to determine the coefficient of reliability for the questionnaire.

As the purpose of research question 3 is to compare the performance of routing protocol, four performance metrics are chosen and to be measured in this research study. The metrics are round trip time, throughput, packet loss and packet delivery ratio as depicted in Fig. 6. All metrics are calulated and analyzed using specific formulas. Two network topologies are created using Cisco Packet Tracer. Both topologies consist of 7 routers, 2 switches, 1 personal computer and 1 server. The procedure begins with one topology configured using EIGRP and another topology is

configured with RIPv2 as shown in Figure 7. All metrics are implemented and 10 measurement test has been recorded to ensure the validity of result.

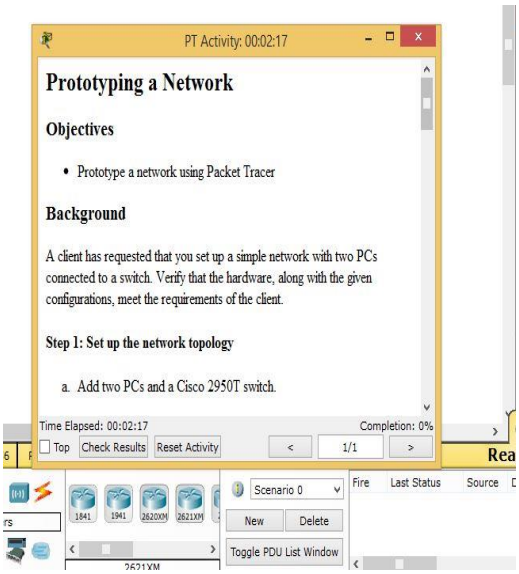

Fig. 5. Screenshot of tutorial 2

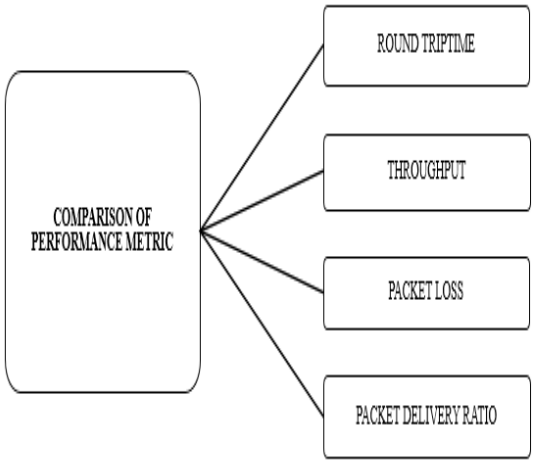

Fig. 6. Performance metrics of routing protocols.

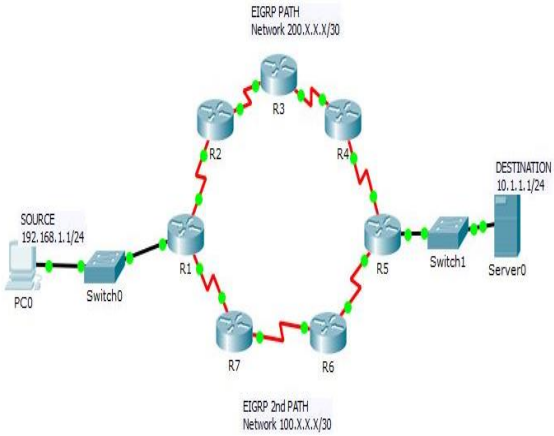

Fig. 7. Simulation experiment topology.

IV. Results and Discussions

According to Cohen *et al*. (2000), reliability is a test of accuracy and consistency. To measure the reliability of data, Cronbach's α (alpha) was conducted. The results are presented in Table II. The items on the questionnaire consistently measured the constructs with an overall reliability score of 0.921. This score is acceptable as values in the magnitude of 0.7 to 0.8 are generally considered reliable [22].

TABLE II: Cronbach's Alpha Value

Cronbach's Alpha	N of Items
.921	32

Students' perceptions on using Cisco Packet Tracer obtained a composite mean of 3.1705, which is verbally interpreted as "Agree". This agreement includes Packet Tracer increases practical knowledge (x=3.58) got the highest rank; followed by Packet Tracer enhanced students' understanding of network technical concepts (x= 3.55) and Packet Tracer be able to enhance skills among students (x=3.52). Cisco Packet Tracer is acknowledged to enhance and improve the practical knowledge of computer networking principles among students. Table III summarized the weighted mean of students' perceptions towards Cisco Packet Tracer.

TABLE III: Students' Perceptions on Using Packet Tracer

	Students' perceptions on using Cisco Packet Tracer	Weighted Mean	Verbal Interpretation
1	Enhance and improve the practical knowledge of computer networking principles	3.58	Agree
2	Facilitate learning network technical concepts	3.55	Agree
3	Enhance my skills in computer network course	3.52	Agree

Based on Questionnaire, Packet Tracer is chosen as preferred method of learning computer network instead of traditional lecture. The use of Packet Tracer in computer network will solve the problems arose among students such as lack of skills and hardly understand the subject. This result is similar with Shanmugan *et al*. (2011) whom claimed skills in problem solving, designing and troubleshooting has greatly improved when students using software.

TABLE IV: Students' Understanding Basic Network Configuration Skills

	Students' Understanding Basic Network Configuration Skills	Weighted Mean	Verbal Interpretation
1	Know how to draw topology	3.37	Agree
2	Understand Ping Command	3.35	Agree
3	Understand purpose of lab activities	3.30	Agree

Students' understanding of basic network configuration skills obtained a composite mean of 3.2014 which is verbally interpreted as "Agree". This agreement includes draw topology skills (*x*=3.37) got the highest rank; followed by understand ping command (*x*=3.35) and understand the purpose of lab activity (*x*=3.30). Table IV summarized the weighted mean of students' understanding basic network configuration skills. Based on this result, student able to

perform basic network configuration skills after completed all series of exercises.

Based on simulation case study, the performance of EIGRP is obviously better than RIPv2. Round Trip Time (RTT) is the length of time taken for a signal to be sent from Source router to Destination router plus length of time which an acknowledgement is received [23]. In terms of RTT, EIGRP took less time to transfer data from source to destination compared to RIPv2. The next section of comparing the performance metric is calculate the throughput. Throughput is the amount of data packets per unit time is delivered from one node to another node in the network through a communication link. The result shows that EIGRP got highest throughput which is 4.78ms compared to RIPv2 which is 2.54ms. In terms of the percentage of packet loss, the result shows EIGRP has less value than RIPv2. Another metric is Packet Delivery Ratio which is the ratio of the number of delivered data packet to the destination. Simulation result shows that EIGRP has greater packet delivery ratio compared to RIPv2. Result of comparing the performance of routing protocol is shown in Fig. 8 and Fig. 9.

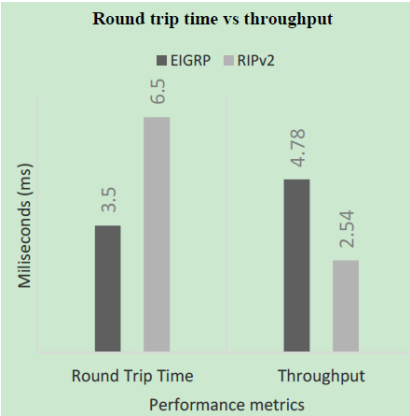

Fig. 8. Round trip time and throughput.

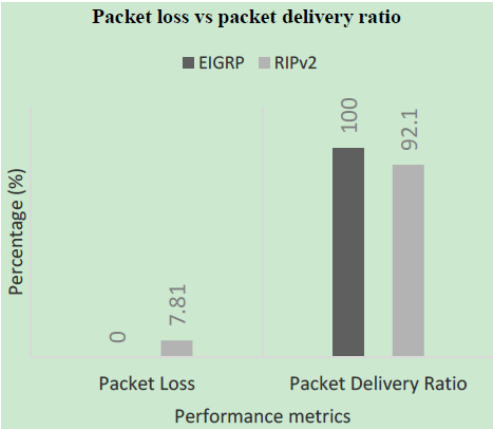

Fig. 9. Packet loss and packet delivery ratio.

V. Conclusion

Simulation software such as Cisco Packet Tracer is necessary to use as a learning tool in computer network course. Cisco Packet Tracer is comprehensive education software with innovative features that assist students and lecturers learning computer network become enjoyable and interesting.

Based on this study, students mostly agree this simulation software approach is able to assist them to enhance their practical knowledge of computer networking principles; facilitate learning network technical concepts; and enhance their networking skills. The ability of Packet Tracer in comparing the routing protocols shows that Packet Tracer is effective as a tool in learning routing protocol concepts which is considered as the toughest and essential topic in this course.

In conclusion, Cisco Packet Tracer is an effective learning tool for computer network course especially in understanding technical and routing protocol concepts. For future work, we plan to study and measure the effectiveness of using Packet Tracer based on students' examination result.

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