Cisco Packet Tracer Simulation as Effective Pedagogy in Computer Networking Course

Nazre bin Abdul Rashid [(⊠)], Md. Zaharbin Othman, Rasyidibin Johan,
Salman Firdaus bin Hj. Sidek
Universiti Pendidikan Sultan Idris, Perak, Malaysia
nazre03bin@gmail.com

Abstract—The Computer Networking course commonly taught in mixed mode involving lecture and practical session whereas beside face-to-face theory session, students need to experience hands-on activities in order to appreciate the technology and contents. Nevertheless, the abstraction in Computer Networking course such as the complexity in TCP/IP network layering, the connection and configuration of client and server's framework, differences in static and dynamic IP address configuration had imposed a great challenge for students to understand and grab the main concept of computer networking technology. As such, an approach of using computer network simulation and visualization tool in teaching and learning Computer Networking course is seen beneficial for educators and students. In this research, computer network simulation software of CISCO Packet Tracer was utilized in Computer Networking (MTN3023) course. Students (N=55) were exposed to CISCO Packet Tracer on which they developed Wide Area Network (WAN) that consists of configuration activities of Personal Computer (PC), Servers and Switches according to CISCO standard. Subsequently, student's feedback and their insight on the effectiveness of CISCO packet Tracer in learning computer networking were probed using questionnaire. All the feedbacks were investigating statistically using SPSS 16.0. From the analysis, the descriptive results shown that all students were agreed (N=32 : Strongly Agree; N=23 : Agree) that CISCO Packet Tracer had successfully help them to understand several key concepts of computer networking and at the same quash some abstractions they faced in the course. In a nutshell, CISCO Packet Tracer as a simulation and visualization tool had been proven to be an effective software in supporting the teaching and learning of computer networking course.

Keywords—Computer networking, Cisco Packet Tracer, simulation

1 Introduction

On the basis of the 11th Malaysia Plan (2016 - 2020), the Malaysian Public Sectors ICT Strategic Planning had drawn Infinite Computer Network connections as vital infrastructure and framework to help drive the nation economies in achieving its sustainability (MAMPU, 2016). On top of that, the significant and relevancy of Computer Networking based subject in Malaysia Higher Education setting is ever-essential as it

had been included as Body of Knowledge in all Computer Science, Software Engineering, Information Technology and Information System domains (Malaysian Qualifications Agency (MQA), 2015). Thus, the quality of teaching and learning of Computer Network subject in higher education is prominent as to nurture graduates who are subject-matter competent and qualified especially when corresponded to the industrial standard.

The Computer Networking subject commonly taught in mixed mode involving lecture and practical session whereas beside face-to-face theory session, students need to experience hands-on activities in order to appreciate the technology and contents (The Joint Task Force on Computing Curricula, (ACM), & Society, 2013).

In Universiti Pendidikan Sultan Idris the Computer Networking subject for undergraduates (MTN3023) is taught by using Internet as an example. As a result the TCP/IP network protocols and services are forming the core content of the subject. At the same time the subject is being taught using the top-down approach which covered on the top layer of application layer first, then to the second transport layer, network layer and down to last layer of the data-link layer (Kurose & Ross, 2017).

As such, in a TCP/IP network the abstraction of interconnecting layers are eminent especially on the protocols, services and activities among the layers. Students are also facing challenges to grab the concept of the inter-connected layers as far as the actual network configuration is concerned either in the Local Area Network (LAN) or Wide Area Network (WAN) setting (Chang, C., Chang, & C., 2004). As a result, in this research, the network simulator is used to assist students in learning computer networking and by that enabling them to comprehend the subject easier.

2 Challenges in Teaching Computer Networking

From the lecturer' perspective, it additionally turns out to be progressively hard to educate the computer networking subject successfully, halfway on the grounds that the Internet's influenced has invited in students with different foundations. Consequently, it is difficult to give one teaching approach to all. Indeed, even among students with comparative instructive backgrounds, for example Computer Engineering students, some of them may have taken proficient examinations, for example, Cisco's CCNA, before going to a first course on Computer Networking, while others are not by any means ready to grab the term TCP/IP.

Yet, the standards basic terms in Computer Networking are naturally extremely intricate. The layered model comprehends and deal with the intricacy. However, most students would discover this layering approach has its own deficiency. For instance, the layers are not autonomous of each other, and a system layer has overlapping function between them. Accordingly, getting the entire picture correctly is as of now a real challenge to numerous students. Computer Networking ideas and conventions are additionally extremely conceptual to numerous students. For instance, discussing a LAN switch or router without seeing one is as of now a hindrance for some students. Also, examining the application layer DNS database without an earlier comprehension of how the server function will not help either.

On the other hand, compared to Computer Programming and Computer Architecture courses, devices and infrastructure arrangement for hands-on laboratory in Computer Networking is always being set in advance. As a result students are likewise being hindered the opportunity to configure their own network vis-à-vis a Local Area Network (LAN). Subsequently they students would overlook some basic configuration such as setting a static or dynamic IP for computers in LAN environment.

All the arguments above lead to the necessity of using simulations in the Computer Networking teaching and learning as to facilitate the problems. Moreover the Cisco hardware such as routers and switches are costly and need for some level of expertise to handle. By using the simulations, lecturer and students could experience the Cisco hardware without the burden of buying.

Research Objectives

The main objectives that need to be fulfilled throughout the research is divided into three which are delineated below:

- To examine the impact of Cisco Packet Tracer as simulation in practical session of the Computer Networking subject.
- To analyse students understanding of TCP/IP network based on network that develop and configured using Cisco Packet Tracer.
- To investigate students' acceptance and the effectiveness of CISCO Packet Tracer in teaching and learning of Computer Networking subject.

3 Research Importance and Limitation

The research given a good direction in accessing the effectiveness of Cisco Packet Tracer utilization in Computer Networking subject. The Cisco Packet Tracer allows students to build self-contained computer networks as well as implement all necessary configurations such as placing physical wire connections, setting IP addresses and simulating data transmission simulations. Generally, Cisco is a renowned company which giving training, teaching and learning and certification of Computer Networks commercially. Using the Packet Tracer, the students will gain the experience of using the software and hardware base from Cisco without the need for registration and attendance to training which is apparently costly for them.

The research is conducted in UPSI and focusing to the undergraduates registered for subject Computer Networking (MTN3023) in semester 2 session 2016/2017 (A162) as the participants. At the meantime, the Cisco Packet Tracer is the only network simulation being used throughout the research.

4 Overview of Computer Networking Simulation

Network simulator provides network visualization to students. As such, it can be used to enhance and improve the practical knowledge of computer networking principles among students (Anisetti et al., 2007). Moreover, students can design mini projects with solutions with more innovation and creativity. As with other tools, students are

able to understand the use of different networking protocols but they are not able to understand the application of these protocols in the real networks, thus packet tracer can be used to design and configure a network, and understand the application of various protocols (Nawaz, 2013).

As students hardly access some different real networking devices, because of a cost and technical issues, movement of packets from source to destination cannot be seen in a real time, thus by using network simulator, students can access the virtual network devices any time and no damage can be caused to devices, moreover the movement of packets can be shown by simulations (Sarkar, 2005).

Network simulators can further be used, to understand the difference between different networking devices like hubs, switches, routers etc. and their appropriate use while connecting various Computers to design a network. How to assign logical address to various networking devices like computers, routers, switches appropriately. While moving from source to destination, which route is selected by a packet depending on various routing protocols? Type of cable to be used while connecting different networking devices (Kainz, Cymbalak, Lamer, Michalko, & Jakab, 2016). Checking connectivity between different networking devices by running various networking tests. Basic networking concepts like DNS, DHCP, SMTP, routing etc. can be easily explained by using packet tracer and students can build, configure and troubleshoot networks using packet tracer. It also makes teaching easier; students can create their own scenario based labs and provides real simulated and visualization environment (Chang et al., 2004).

4.1 Cisco packet tracer

Cisco Packet Tracer, a visualization and simulation software tool could be accessed for free by Cisco to students registered in a network academy program but could still be used by those outside the academy for educational purposes (Liangxu Sun, Jiansheng Wu, Yujun Zhang, & Hang Yin, 2013). Packet Tracer is at times utilized as a part of substitute for utilizing genuine equipment (Holvikivi, 2012). This because it utilizes insignificant equipment assets, keeps running on an assortment of stages and is extremely savvy (Frezzo, Behrens, & Mislevy, 2010).

Cisco Packet Tracer has a variety of preferences over the utilization of physical gear. It is simpler to introduce and utilization of it which basically costs nothing rather than physical gear that costs thousands (Makasiranondh, Maj, & Veal, 2010). Also, dissimilar to customary network test systems, Packet Tracer's representation highlights and recreation mode extraordinarily helps students outwardly observe the packet development through the network and this seemingly prompts enhanced learning (Herbert & Wigley, 2015). Thirdly, not at all like physical gear, Packet Tracer requires minimum measures of disk space and Random Access Memory (RAM) since it is just emulating the real environment where no real packet transmission is happening (Gil et al., 2015). Fourthly, on the grounds that Packet Tracer does not really utilize any physical network gadgets, there is no danger of harm or interruption striking the network (Frezzo et al., 2010). Fifthly, Packet Tracer additionally gives the tools to enable teachers to set appraisals, assignments, tests and exercises. Likewise, it is conceivable to utilize Packet Tracer for group tasks (Javid, 2014).

Packet Tracer is virtually free in comparison to local or remote practical labs that potentially costs thousands of dollars to build and maintain. Furthermore, Packet Tracer is portable3 and can be deployed at home for additional practice. Packet Tracer is not only a networking simulator. It combines an array of features such as a command line interface, visual learning systems and an easy to use graphical user interface. Despite this, the Cisco Packet Tracer Data Sheet does provide some perceived benefits of using Packet Tracer, for instance, its ability to use an (almost) unlimited number of devices for troubleshooting, practice and discovery (Packet Tracer 5.0 Data Sheet, 2008).

According to a survey undertaken by Mohd Syahrizad Elias and Ahmad Zamzuri Mohamad Ali, an interviewed senior lecturer who teaches networking at the Malaysian Polytechnic Institutions was quoted as saying 'Using a network simulation tool to engage students in active learning enhances their understanding of complex data communications concepts' (Mohd Syahrizad & Ahmad Zamzuri, 2014).In addition, Packet Tracer is also be used to encourage deep thinking and learning, then the tool is effective and useful (Coffman, 2006).

Assistant Professor at R.K University, India, Sheikh Raashid Javid arguing in his paper, 'The Role of Packet Tracer in learning computer networks' that Packet Tracer is necessary for learning computer networks because it provides; assessment of student activities, visualisation features designed to improve the learning of students and a cost-effective supplement to physical equipment (Javid, 2014).

Similarly, the paper, 'Visual Learning Tools for Teaching/Learning Computer Networks: Cisco Networking Academy and Packet Tracer', also supports the premise that Packet Tracer provides necessary visualisation tools that are required to understand the complex networking concepts that are not visible on a physical network (Janitor, Jakab, & Kniewald, 2010). Both these papers recommend the use of Packet Tracer as a supplement to physical equipment and not as a replacement.

5 Utilization of Cisco Packet Tracer in UPSI

The computer network simulated was consist of the DHCP, DNS and HTTP servers along with switches and Personal Computer or Laptops. Students will learn this configuration by a lab in Cisco packet tracer and try to understand the working of servers, but before stating this lab students also learn basics of servers and switches like why servers being used and why servers needed in our daily life. Below are some of the definition of several key hardware used in the simulation:

Switch: A network switch is a computer networking device that connects devices together on the same network. In other words, we also say that the switch is a networking device which connect a large number of systems on the same network. A switch is a medium through we send and receive data packet from one system to another in a same network. If you want to connect systems from the different networks in that case switch is useless in that situation, we use a router to connect systems from different networks.

DHCP server: The DHCP (dynamic host configuration protocol) is a standardized network protocol which is used on internet protocol (IP) networks. DHCP is used to

assign IP automatically to the system with the help of a machine called DHCP server. A DHCP server enables computers to request IP addresses and networking parameters automatically. In the absence of a DHCP server, each computer on the network needs to statically (manually) assigned to an IP address.

DNS server: DNS (domain name server) is a server which is used to assign names to an IP address. It allows you to connect to any website or network by simple names instead of their IP address. It is really very hard to memorization of IP addresses of any website and network so here DNS help us by convert the number into a name. Now we just type only name instead of IP of any website and network to search it on the internet.

HTTP server: HTTP (hypertext Transfer Protocol) is a medium which is used to make communication in between client and server. The primary function of a HTTP server is to store, process and deliver web pages to clients. Pages delivered are most frequently HTML documents, which may include images, style sheet and scripts in addition to text content.

Personal computer/laptop: The personal computer or laptop were utilized as basic nodes in the network. These devices are important as students would learn how configure IP address statically or dynamically. They would also be used for connection testing such as using PING command for pc-to-pc or pc-to-server communication.

The big picture simulation consisting all the devices that mentioned above is depicted by Figure 1 below:
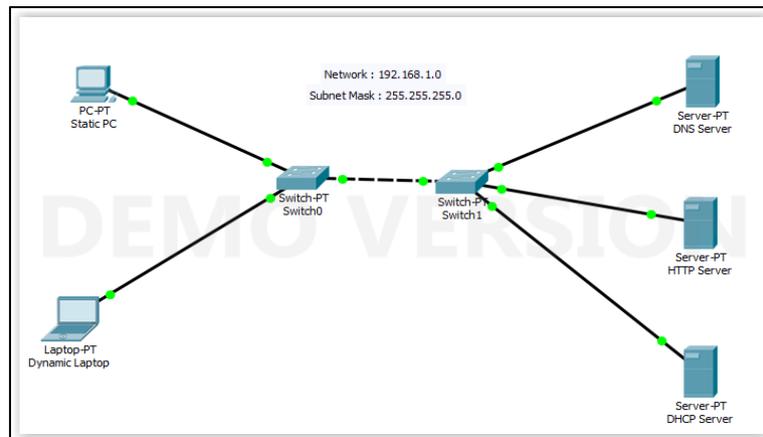

Fig. 1. Computer network simulation using Cisco Packet Tracer

6 Results and Discussion

In this section the students' perception and feedback on TCP/IP Network particularly on the layering concept is shown. Figure 2 shows that majority of the students (N=44, 80%) accepted the facts the layering concept is hard to conceptualize and imagined. This is concurred to some of the previous research findings for instance by Huang.

Nevertheless, after being exposed to Cisco packet Tracer, students gained valuable insight and feel more comfortable in designing and configuring their own Local Area Network (LAN) without worries on the layering abstraction. This situation had been shown in Figure 3 where all students are confidence in creating LAN to the extent that 19 are very confident in their response.
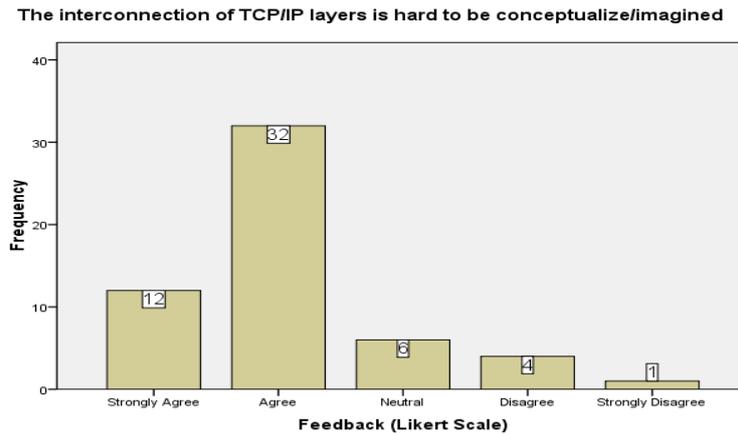
The interconnection of TCP/IP layers is hard to be conceptualize/imagined

Fig. 2. Students' perception on Computer Network TCP/IP layering abstraction

Student is confident to configure a real Local Area Network after using CISCO Packet Tracer
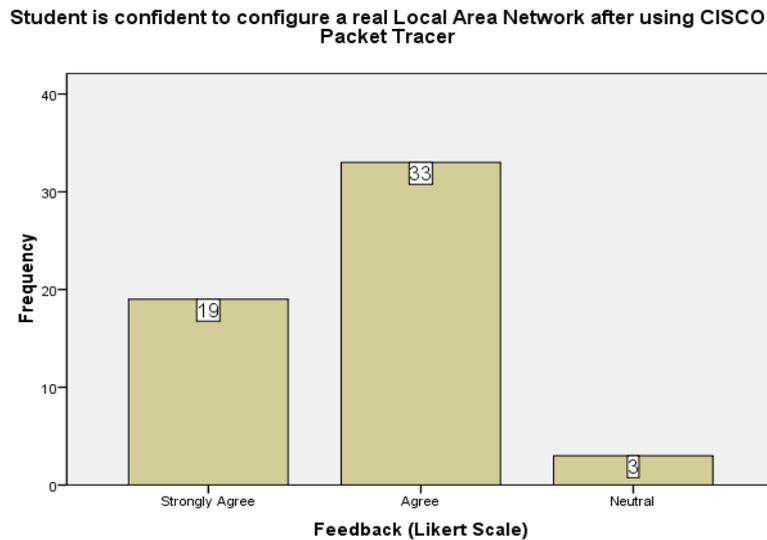
Fig. 3. Students' confident in configuring LAN after exposed to Cisco Packet Tracer

Students' critical assessment on Cisco packet Tracer is shown in this section. Figure 4 shows that all students are able to simulate the LAN environment which compromising several key hardware such PC, Notebook, Servers and Switches as being outlined

in the previous chapter. They also manage to specify the best and correct connectors (wires) to connect every devices in the LAN. In the survey 35 subject given the response of "Strongly Agree" to the questions which indicated their appreciations on the utilization of Cisco Packet Tracer in the MTN3023 course.
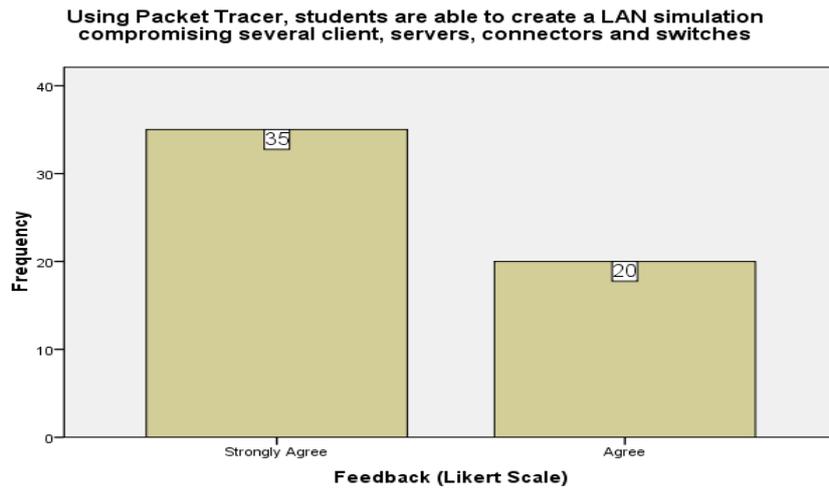

Fig. 4. Students' ability to create LAN using Cisco packet Tracer

In LAN configuration and development, students are required to plan the network and one of the important part is to manage the network IP class. Using Cisco Packet Tracer, students were exposed with the configuration of IP address for each node. By that they are bound to know the class of IP and its corresponding network address, subnet mask address and broadcast address.

Figure 5 shows that 28 subject are "Strongly Agree" and 24 subjects are "Agree" to the fact that those information are easily specified and understood by Using Cisco packet Tracer. Students also got experience in configuring each nodes IP address using the simulation either by static or dynamic configuration.

Figure 6 shows 54 subject are in the group of "Strongly Agree" and "Agree" combined in term of their ability to correctly configured IP address for each node in the simulation. Meanwhile Figure 7 shows all students are in agreement that Cisco Packet Tracer gave them chances to configure IP address in both static and dynamic conditions.
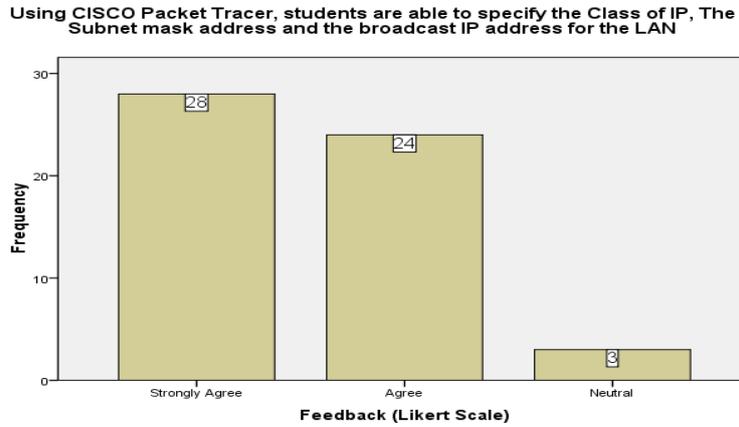
Using CISCO Packet Tracer, students are able to specify the Class of IP, The Subnet mask address and the broadcast IP address for the LAN

Fig. 5. Students' ability to specify IP address information using Cisco packet

Using CISCO Packet Tracer, students are able to configure the IP address for each nodes in the LAN
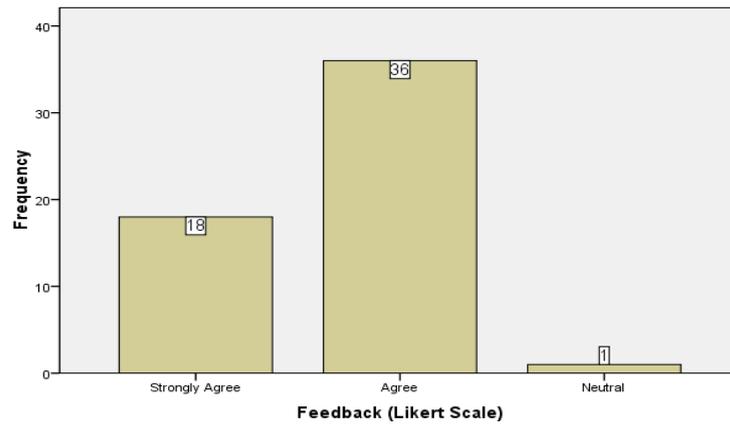

Fig. 6. Students' ability to configure IP Address for each node in Cisco Packet Tracer
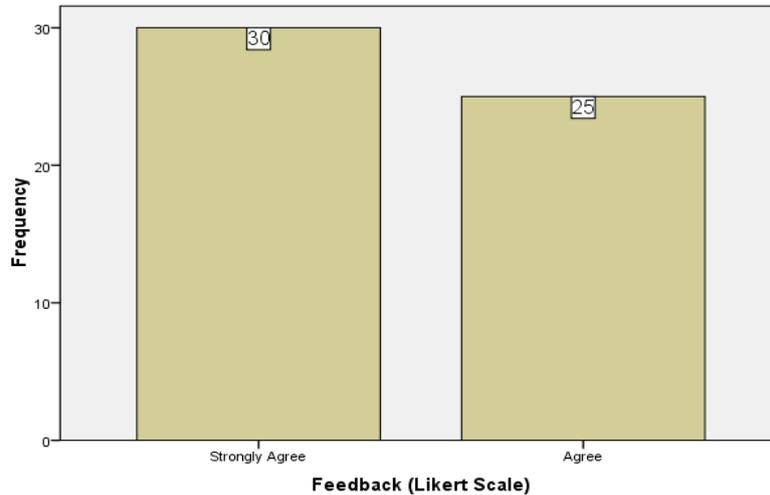
Fig. 7. Students' ability to configure Static and Dynamic IP address in Cisco Packet Tracer

One of the main architecture in Computer Networking is client and server environment. By that, it is vital for student to grab the concept on this architecture. Figure 8 gave a strong indication on the effectiveness of Cisco Packet Tracer in simulating the architecture and exhibiting the environment to students. Here, students' overview on the functionality of servers are shown which depicted all students to concord (27 Strongly Agree and 26 Agree) on Cisco Packet Tracer capability to simulate the server connection and communication to clients.
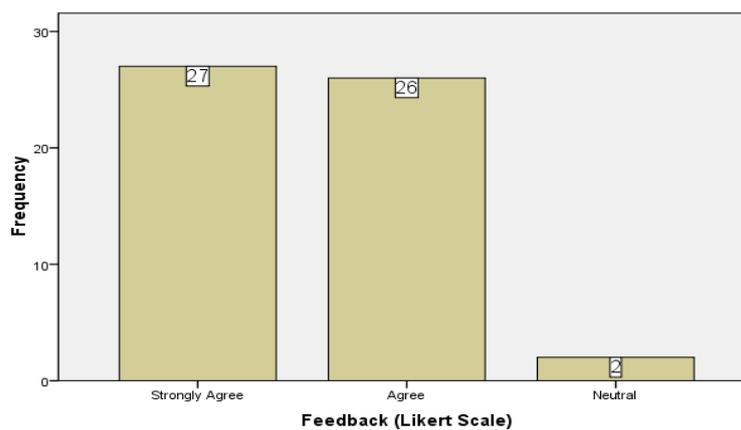

Fig. 8. Students' overview on servers' functionality using Cisco Packet Tracer

Finally, students' overall feedback on the utilization of CISCO packet Tracer as simulating tool in teaching and learning of MTN3023 (Computer Networking) course is depicted by Figure 9. It is clearly shown that all students (34 Strongly Agree and 21 Agree) that CISCO Packet Tracer had help them in their understandings on how computer networks work. Their feedback is truly based on the potentiality of CISCO Packet Tracer in simulating key computer network concept as being explained and shown in the above paragraphs and figures.
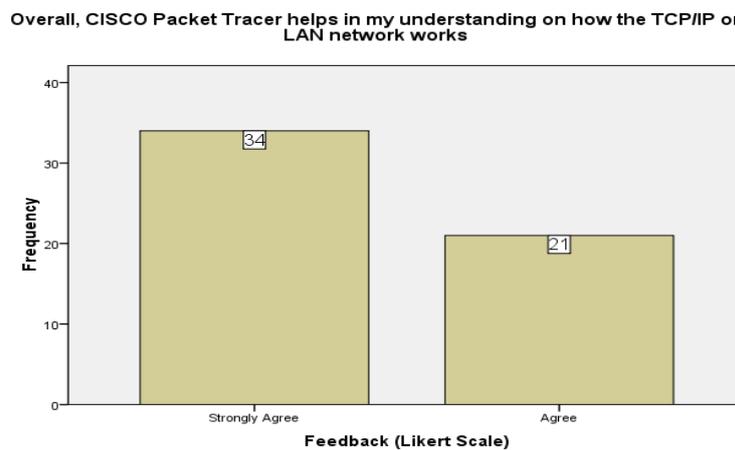

Fig. 9. Students' overall feedback on CISCO Packet Tracer

7   Conclusion

The CISCO Packet Tracer deployment in the course and students' feedback on its utilization is based on the objectives which had been outlined in the related section. Each objective and the explanation on its fulfilment are reported as the following:

Objective 1: To examine the impact of Cisco Packet Tracer as simulation in practical session of the Computer Networking subject

The CISCO Packet Tracer had been deployed and utilize in the MTN3023 Computer Networking subject as a simulation tool. Based on the subjects' feedback which exhibited in Chapter 4 they had gained experience and confidence to configure Local Area Network (LAN) after being exposed to CISCO Packet Tracer. As such, the CISCO Packet Tracer had been discovered of putting a positive impact on students' understanding and tendency towards the course.

Objective 2*:* To analyse students understanding of TCP/IP network based on network that develop and configured using Cisco Packet Tracer

Students had given a very positive and good feedback on how CISCO Packet Tracer enhanced their understanding of TCP/IP network. The simulation helps to ease the abstraction of TCP/IP layering framework which always be an obstacles in TCP/IP understanding among students. Moreover using CSICO Packet Tracer students were able to configured basic TCP/IP settings such as IP address configuration, connections and

server configuration. On top of that, students also exposed to client –server environment which could be easily simulated using CISCO Packet Tracer. By understanding the client-server environment alone had benefitted students in a very large view as the framework is forming a vast aspect of TCP/IP network.

Objective 3*:* To investigate the effectiveness of CISCO Packet Tracer in teaching and learning of Computer Networking subject

One of the hardest things in Computer Networking teaching and learning is to simulate the real world network without an appropriate hardware (which is costly to buy). By using CISCO packet Tracer simulation tool the challenge had been smoothen and students had a big opportunity to simulate real world network easily and effectively. This had been proven by a feedback by students who sense that they are more confident configuring LAN after using the simulation. They also feel that their understanding on the TCP/IP network had been better than before. Moreover, the CISCO Packet Tracer allows them to configure each nodes (PC, Servers etc.) which give them opportunity to explore and dictate the network development with their own wisdom. Finally, based on students' overall feedback the effectiveness of CISCO Packet Tracer is ever-essential in assisting them to master the computer network course.

Overall, the CISCO Packet Tracer had been successfully deployed as a simulation tool in Computer Networking course and the students' feedback is enormous. Its help to support the practical part of the course with a minimal cost. On top of that, the simulation also seen as stepping stone for the students to go for professional CISCO certification as by using CISCO Packet Tracer they were actually working with real CISCO hardware.

Moving forward the CISCO Packet Tracer should be used to support the lecture materials on which the top-down approach in Computer Networks teaching and learning had been employed in Universiti Pendidikan Sultan Idris. The network layer abstraction must be look into and investigated in deeper manner. Then, The CISCIO Packet Tracer could be used to simulate the main layer abstraction by which students' understanding on the abstraction is answered.

8   Acknowledgement

9   References

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10 Authors

Mr. Nazre bin Abdul Rashid holds a PhD in Electrical Engineering by the UniversitiTeknologi Mara (UiTM), Malaysia and he is currently a Senior Lecturer at the Department of Computing, Faculty of Arts, Computing and Creative Industry, Sultan Idris Education University (UPSI), Malaysia. His main area of interest is the study on human potentials focusing on the brain signals (EEG) and on ICT adoption towards teaching and learning in the higher institution domain. He is an active member of IEEE and Malaysia Board of Technologist (MBOT). nazre03bin@gmail.com

Tn. Hj Md Zahar bin Othman is a Senior Lecturer at the Department of Computing, Faculty of Arts, Computing and Creative Industry, Sultan Idris Education University, Malaysia. He had with him 30 years' experience in teaching Computer Science courses such as Computer Networking, Computer Security, System Administration and Object-oriented programming. Devoted towards an Open-Source systems, Mr. Md Zahar had a very keen interest in Python programming and had been actively involved in promoting the language to Malaysia higher institutions and schools. zahar@fskik.upsi.edu.my

Mr. Rasyidi bin Johan holds a Master's Degree in Information Technology by the Universiti Teknologi Mara (UiTM), Malaysia. He is currently a Lecturer a at the Department of Computing, Faculty of Arts, Computing and Creative Industry, Sultan Idris Education University, Malaysia. His research interest is mainly on on-line system development, intelligence system and multimedia digital application. Mr. Rasyidi has a great interest in Windows-based programming and had won several awards on his Automation Format Thesis (AF-Thesis) application system. rasyidi@fskik.upsi.edu.my

Mr. Salman Firdaus bin Hj. Sidek received his Master's degree in Computer Science from UniversitiTeknologi Malaysia (UTM). He is a Lecturer a at the Department of Computing, Faculty of Arts, Computing and Creative Industry, Sultan Idris Education University, Malaysia where he thought several courses encompassing Computer Architecture and Organization, Operating System and Computer Networking. Mr. Salman is actively involved in MOOC initiative in UPSI and his MOOC system had won several awards at national level. Mr. Salman is currently pursuing his doctoral degree in Gamification. salmanfirdaus@fskik.upsi.edu.my