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Multi-Phase Methodology for Proposing a High Performance Switched Campus Network: University of Kufa Case Study

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Abstract: In this study, current network architecture and characteristics of the campus network at the University of Kufa (UoK) is presented and survey. The research methodology includes preliminary study, data collection and analysis, modeling, proposing and evaluation phase. A survey questionnaire is conducted to evaluate the current network performance from the user's perspective and administrators for different colleges. Data are collected from 186 respondents that included 178 employees and 8 admins through online and paper surveys. Survey results have shown that most users are not satisfied with the existing network performance regarding several network services such as availability, Quality of Service (QoS). Additionally, the survey is validated by three experts through a structured interview. Most of the feedback from the experts match the results of the questionnaire. Thus, after identified several factors that could be influenced, we proposed a number of criteria to enhance the performance of the current network such as fault-tolerance, scalability, Quality of Service (QoS) and security. To achieve the proposed criteria, packet tracer software is used to design and simulate the new network architecture. The proposed campus network design is capable of delivering a service with 24/7 availability, ability to accommodate the increased number of users in future, the ability of packet prioritizing and improved security. Finally, a structured interview is conducted to validate the proposed design by five experts. Most of the feedback of the experts' match the results of the research that led the proposed switched campus network is acceptance.

Key words: High performance network, switched network, network scalability, network usability, network security, QoS

INTRODUCTION

Divers of engineering and architectural aspects should be leveraged in modern converged campus networks from the design standpoint. These principles encompass resiliency, modularity and hierarchy in campus networks. Performance of a network is influenced by the user satisfaction which is related to network services provided. Fault tolerance, scalability, Quality of Service (QoS) and security are four basic advantages that need to address in terms of network architectures to meet user satisfaction (Oppenheimer, 2004). Availability means the amount of time that a network is available to users without interruptions and it achievable by accomplishing three criteria such as reliability, redundancy and resiliency. Scalability refers to how much growth a network design can support in future as the network users increase. Whilst, QoS can be defined as the priority of data transfer within the network, data include: voice, video or data application and the security define protect the network from attack or theft and it two types: software and hardware. Recently with the rapid development of network technology, the increasing complexity of network architectures and the increasing diversity of network services have resulted in a high demand for network capacity and network performance (Liu *et al*., 2012). As well, managing a network includes making changes as the network grows to carry more traffic or reach more users and troubleshooting the network when things go wrong or performance isn't as desired (Abdulkareem *et al*., 2016).

Several studies have critically analyzed network performance based on factors like data loss, jitter and ping. However, network outage was not considered adequately mainly because of the challenges to find a way to precisely measure network failure (Choi *et al*., 2007). In

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1996, Beeharry and Schneider have examined University of Mauritius network development, changing nature of the computer science, proposed recommendations (Beeharry and Schneider, 1996). As well, Baek *et al.* in 2007, attempted to present a campus network study that provided insights into behaviors and conditions of access network availability, the analysis that provided in both link failure and outage. The proposed network was required modeling the characteristics of the access network and developing a tool to find error-prone links, nodes and parts of the network in a more scalable and effective manner (Choi *et al*., 2007). Likewise, Mukarram *et al.* in 2009 proposed a design and implementation for Ether-Trace, passive layer-2 topology discovery tool that operated in Virtual Local Area Network (VLAN) environment, exam in sharing affects the accuracy and specificity of fault diagnosis. The limitations of the proposed design required more topology examines the relationship between VLANs and Internet Protocol (IP) topologies in campus and enterprise network, also required designing tools could improve network planning and operations (Tariq *et al*., 2009). On the other hand, in 2011, Adam and Elizabeth have analyzed the issues and challenges that are involved in moving very large files over a campus network that shared by thousands of concurrent users running a variety of applications. Campus networks can be handled large file transmissions if the control is placed in the purview of a system agent such as the border controller (Villa and Varki, 2011). Also Zubair *et al.* in 2012, integrated security with QoS and the limitation is the proposed approach provided payoffs to the users participating in the game, also it revealed complex and contrasting demands for different quality of service and security (Fadlullah *et al*., 2012). Finally, Karl and Mike, 2015 described a successful approach to designing and implementing a High-Performance Computing (HPC) class focused on creating competency in building, configuring, programming, troubleshooting and benchmarking HPC clusters, the limitation is required these clusters extremely large to powerful and also requiring use these clusters to debug parallel programs (Frinkle and Morris, 2015).

In this study, four main objectives were taken into consideration to design a high-performance switched campus network: UoK case study. We present a study that evaluates the current performance metrics for the University of Kufa network by making a questionnaire to employees and administrators that contain structured questions with relation to availability, scalability and QoS. The objectives of this study are: to investigate the current network characteristics by showing the direct correlation between network design and the University's demand, to identify the various obstacles and factors that would be encountered in order to build an appropriate and reliable high-performance switched campus network, to design a high-performance switched campus network: University of Kufa (UoK) case study, to evaluate and analyze the proposed design based on fault-tolerance, scalability, quality of service (QoS) and security metrics by using packet tracer software.

MATERIALS AND METHODS

When an issue or problem occurs, a systematic approach to solve this problem must be applied. Therefore, the methodology scope is wider than the methods in research (Kothari, 2010; Ali, 2016). This study introduces the methodology employed in this study to propose a high performance switched campus network among the University of Kufa as a case study. Also, highlights all the metrics used in the network campus design. The research methodology aims to provide a deep understanding of the study field. Figure 1 shows the five phases that explain the research methodology, achieving the research objectives presented in study. The preliminary phase or phase one, investigate network characteristics by present the direct correlation between network design and university demands and highlights network characteristics and criteria. Phase two or data collection and analysis phase describes the research instruments which is questionnaire and experts interview to validate the questionnaire as well as present methods for data collection and analysis. Modelling phase or phase three identify and evaluate the performance of the existing UoK campus network. Define the various obstacles and factors based on previous phases which lead to propose a campus design with a high-performance network. Proposing phase or phase four which proposing a high-performance switched campus network depend on phase three results. Finally, the evaluation and conclusions phase or phase five which evaluates and analyzes the proposed switched campus network design according to fault-tolerance, scalability, Quality of Service (QoS) and security metrics as well based on prototype simulation which is packet-tracer and experts interview. Each phase involves separate processes but each phase is based on the outcomes of the preceding phase. Figure 1 illustrates this study's methodology with five phases through a flowchart.

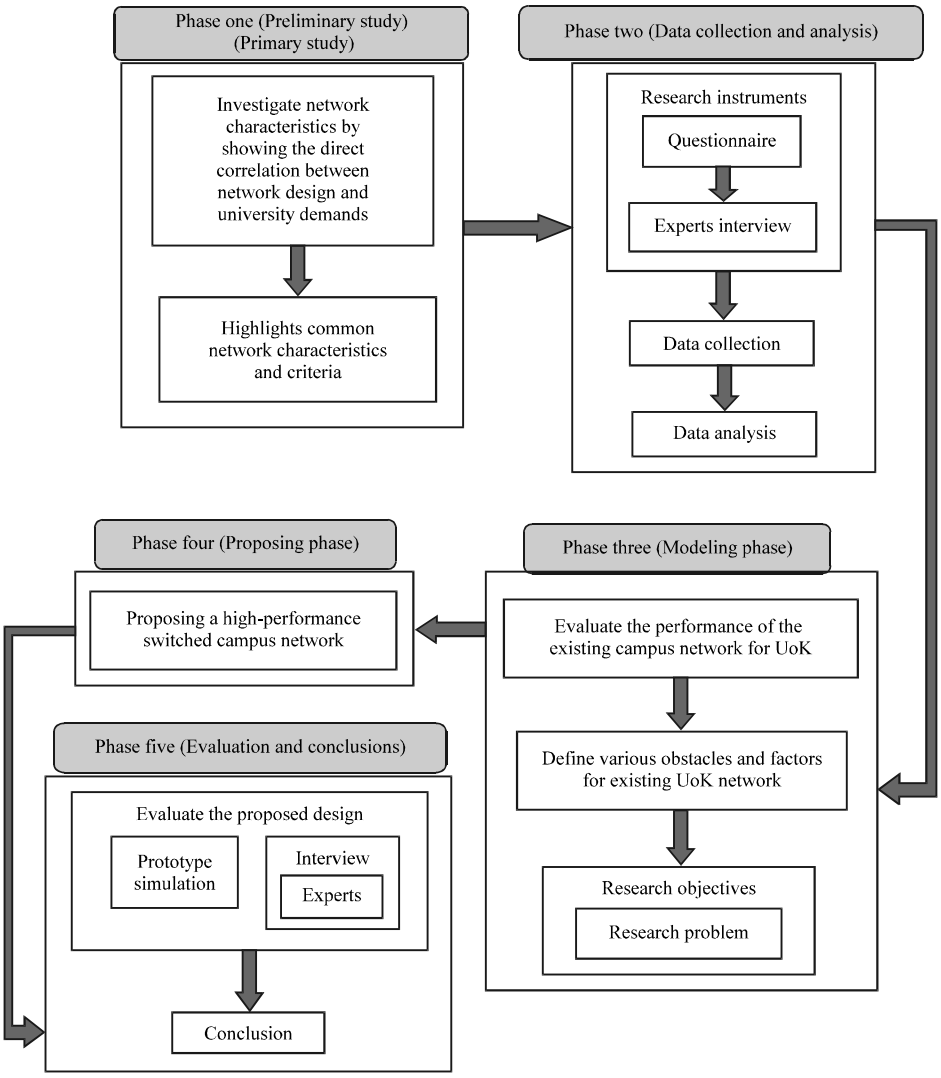

Fig. 1: Five phases of the research methodology

RESULTS AND DISCUSSION

Preliminary study (phase one): Preliminary study or phase one achieves the first objective which is to investigate network characteristics by present the direct correlation between the existing network performance and university demands. This phase investigates common network advantages and characteristics considered by public sectors in designing a campus network. The literature review helped in identifying the problem statement sub-phase. Conceptually, this review provides insights into previous and existing work conducted in the same area according to the main components (keywords) in the title of the research. This review also defines the direct correlation between network design and university demands. Factors that affect network campus design among an academic sector are highlights and discuss in the next phase.

University of Kufa (UoK) is located in southwestern Iraq. Campus network comprises multi-buildings in a particular network, it usually is LAN network. The UoK campus network comprises of 21 LANs. These LANs are distributed among UoK faculties. Collectively, UoK campus network follows hierarchical network design (Fig. 2). The hierarchical network design will not only provide an expanding the network in the future but also makes it easy to troubleshoot any issue that may occur on any node or part of the network. However, due to lack of documentation, the hierarchical network design was put into a good use. It is not clear how many devices and

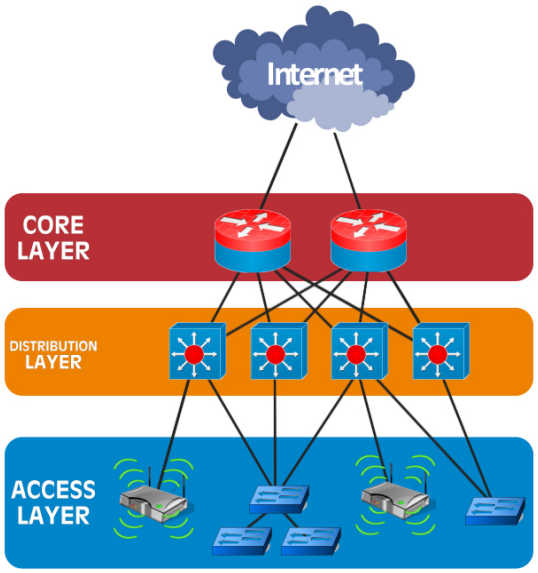

Fig. 2: Hierarchical design of the UoK campus network

what are functionalities of each device used in each block of the hierarchical design. Which led to difficulty in maintaining and expanding the network. Moreover, it was a big challenge to collect detailed data about the current network characteristics.

Data collection and analysis (Phase two)

Research instruments: A questionnaire is used to collect original data to describe a population to be observed directly (Mouton, 1996). This design was selected to meet the objectives of the study, namely, to investigate the current network characteristics by showing the direct correlation between network design and the University's demand. As well as, to identify the various obstacles and factors that would be encountered in order to build an appropriate and reliable high-performance switched campus network (Fig. 3).

First, the questionnaire was designed using the Google form tool for online survey. In addition, the questionnaire was designed in two languages, namely, English and Arabic, to ensure the simplicity of the survey. These methods help respondents understand the questionnaire and provide adequate answers. Furthermore, we considered respondents from two independent groups; namely admins and employees. These groups are working in the networking campus among 11 faculties and two centers. Second, the questions of the structured questionnaire were related to the influence factors of this study such as availability, scalability, QoS, security and documentation. The questionnaire was divided into five sections with 25

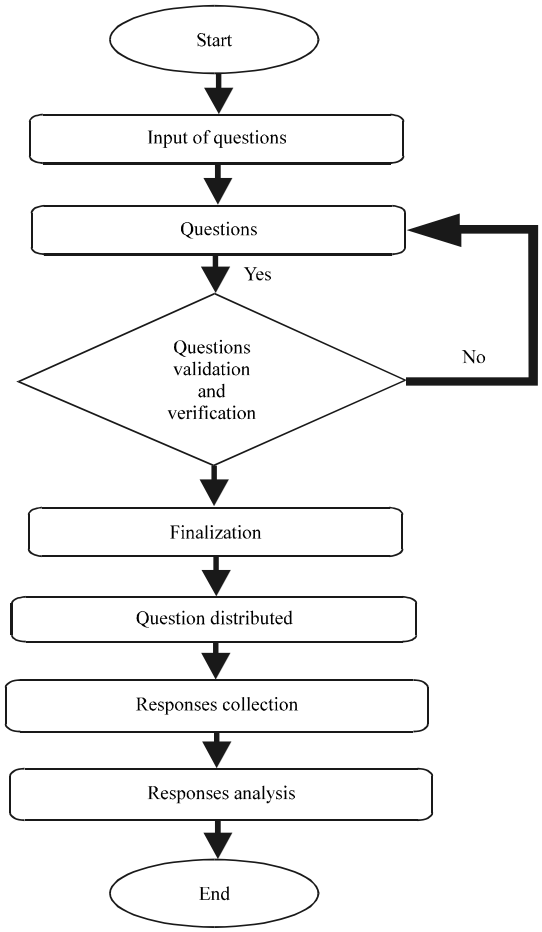

Fig. 3: Research instruments

questions in total. Third, validation and verification were performed by interviewing and consulting three experts. In this stage, the questions were revised and polished many times to make the questionnaire clear for the respondents. A final form of the questionnaire was created and readily distributed among the respondents. Fourth, distribution was conducted in two ways namely, online and hard copy. The advantage of the online survey is that the online form can be simply accessed via. a link shared through the email, social networks, etc. For the hard copy form, the process of distribution was completed by distributing the form among employees and network admins in 11 faculties at the University of Kufa. Fifth, all responses collected from the particular respondents were collated (see next sub-phase). Finally, an analysis was conducted after data collection.

Data collection and analysis: The questionnaire was delivered manually by hand to the target respondents. However, other responses were obtained through the

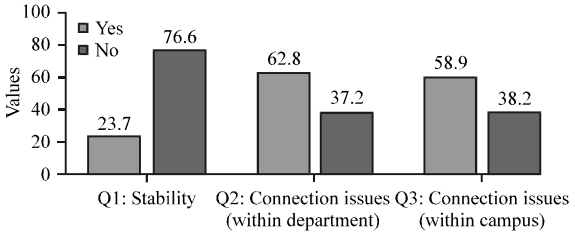

Fig. 4: Respondents answers to three questions of the survey

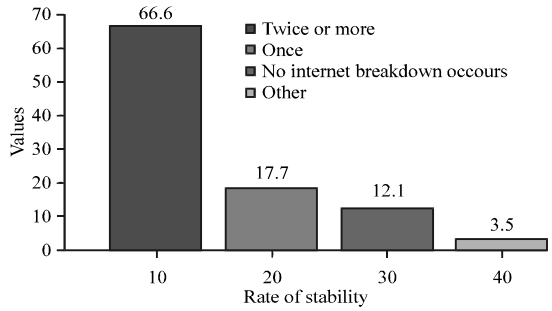

Fig. 5: Bar chart shows percentage of respondent's answers regarding to the internet stability connection

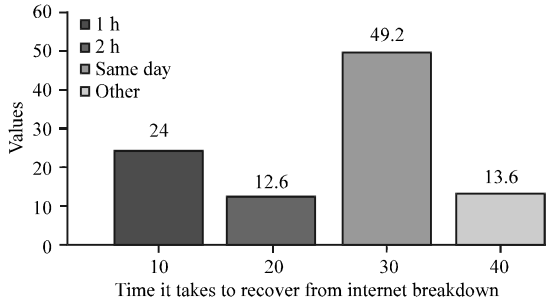

Fig. 6: Percentage of respondent's answers among the rating of the internet breakdown recovery

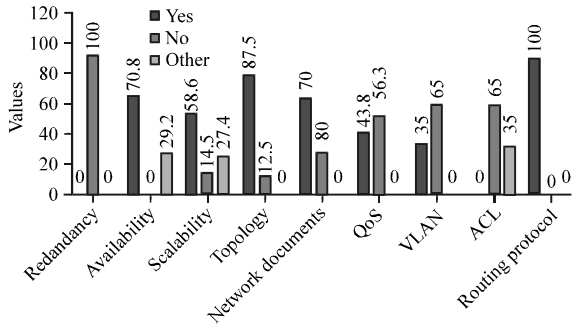

Fig. 7: Percentage of respondent's answers respect to the response time (in milliseconds) via. pinging two devices inside campus network

electronic form. The Google drive tool provided the section concerning the collection of responses. These responses were stored in an Excel sheet containing all submitted forms. For the hard copy forms, the data was entered manually into excel sheet (or Table). The number of responses included 178 employees and 8 admins among 11 faculties and 2 centers. Data were analyzed with the statistical package for the Microsoft Excel. Data analysis was established to identify which network metrics or factors are influenced such as availability, scalability, QoS, security, documentation, redundancy, VLAN, ACL and fault tolerance. A total of 186 respondents participated in this study. Internet stability and network issues when getting the service are described based on the results of Fig. 4 and 5, respectively.

Figure 4 illustrated respondent's answers to three questions of the survey. It can be seen from the first bar chart which represents the first question of the survey, that 76.6% of the respondent's statement that the network connection is not stable. The second bar chart shows that 62.8% said "Yes" when asked whether they have issues connecting to the network inside their faculties. The last chart shows that 58.9% of the respondents have issues connecting to network when visiting other faculties.

One way to determine the reliability of the network is by calculating how many times the network signal drops per unit of time. The bar chart in Fig. 5 is shown how often the employees of the University of Kufa loses network availability per day.

As well as, the results of the internet breakdown recovery. Based on the Fig. 6 results, noted that the highest percentage of the recovery from breakdown was the same day. As a long time, Fig. 7 presents the percentage of respondent's answers when asked about the response time (in milliseconds) when pinging two devices inside campus network (Fig. 7). Based on the previous results from Fig. 5 and 6 that concluded the Availability criterion was unverified. On the other hand, QoS, VLAN, Redundancy Metrics for the UoK Network were questions distributed and analysis as we see in Fig. 8.

Figure 8 summarized responses from admins when given a series of questions associated with network redundancy, QoS, VLANs and other criteria that can directly impact network performance. According to Fig. 8, all the admins who participated in this study have admitted that the network does not offer any level of redundancy. However, more than half claim that the network offers a good level of availability. When asked about the availability of network documentation, 70%

Table 1: Performance of the existing network design

	Common network campus performance metrics					
Network campus design	Availability	Scalability	QoS	Security	Documentation	Redundancy
UoK existing design	•	Limited	•	•	•	•
Propose design	•	•	•	•	•	•

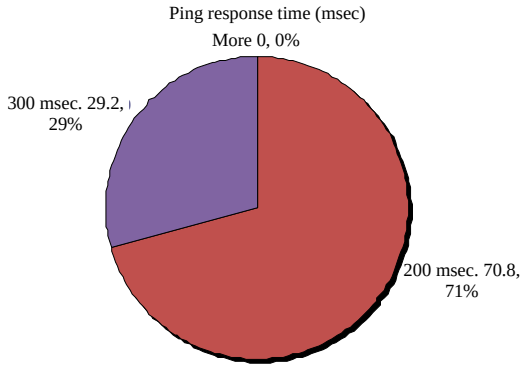

Fig. 8: Questions to the network admins regarding to QoS, VLAN, redundancy metrics for the UoK network

assured that information regarding hardware and software used in the network is well maintained and documented to be used when needed. Despite that the majority state that the UoK network is scalable to a certain level, 14.9% said that the network is not scalable and might not handle the increased number of users in future.

Modelling phase Three: The results of the analysis performed on the collected data were used to determine the key factors to be regarded as an input in this phase. The purpose is to identify influence factors and propose an appropriate design for UoK network campus. Based on the previous results in data analysis section. There are many reasons for low network usages, from Fig. 4, noted that the uncertainty percentage of scalability criterion was 76.6 and config IP was 62.8 (connection within faculty) and config IP was 58.9 (connection within campus), then scalability criterion unverified in the campus network. And from Fig. 5, the highest percentage was (2 or more) mean the signal is interrupted twice or more per day and based on the Fig. 6 results, noted that the highest percentage of recovery from breakdown was same day, then regarding to the results of the Fig. 5 and 6 that concluded the availability criterion was unverified. From the results of Fig. 8, the Redundancy, QoS and VLAN unverified also. Identifying the various obstacles and factors in the existing UoK network services would lead to building a more successful design that addresses all obstacles and factors. The limitations of the previous network characteristics are shown in Table 1.

As can be seen from Table 1, no redundancy measures available in the current campus network design. Which is why many employees, according to the survey data, have reported issues with the network stability. UoK network admins admit that there is a single link that connects the UoK network to the ISP. This means when the link between ITRDC and ISP fails, the entire campus network including faculties and centers will lose connection to the Internet. To avoid this problem, two links are established to ISP. Where one link acting as the primary and the other one as the backup link. The backup link will be used only when the primary link fails. Switching between links is done automatically by setting floating routing configuration on ITRDC router, so that, no manual adjustment is needed if the primary link is failed. Another issue can be concluded from the above table is the lack of any documentation regarding the network. The logical and physical topology of the current network is not clear nor documented adequately. That means troubleshooting can be extremely difficult especially if the network admin has no background information regarding the current network infrastructure. Designing the entire campus network using a network simulation software like packet tracer can mitigate this problem. In our proposed network design we used packet tracer to provide an easy and comprehensive presentation of the campus network. A table with IPv4 addresses is also documented and provided. The IPv4 addresses table include network subnets which are calculated according to campus network requirements. The table also shows all networking device's names and interface addresses which act as a reference that the network admin can refer to whenever troubleshooting is needed.

Proposing design (HPSCN) phase Four : In this phase, two related sub-phases that pertain to the problem statement are highlighted to address the main objectives of this study. In addition, this phase introduced the proposing network design campus for UoK to provide common network characteristics that identify the research questions that must be answered according to the objectives and problem statement. Based on results from the previous analysis, the basic criteria of the campus network are not achieved by the current UoK network. So, we propose a new design for the network using packet tracer as a software used to simulate the proposed design network (Fig. 9).

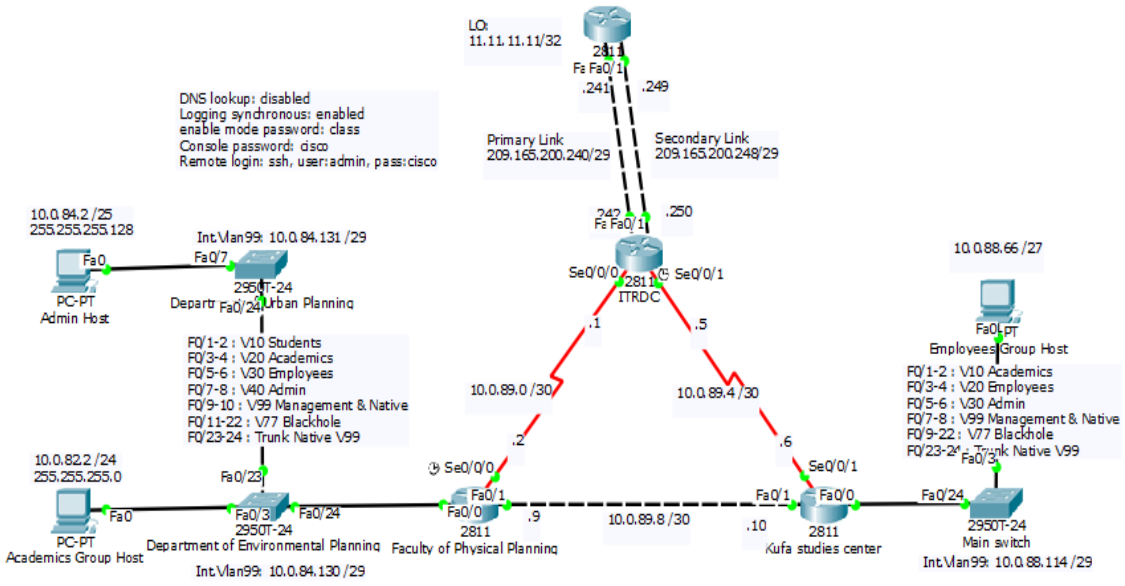

Fig. 9: Prototype simulation of the proposed UoK network campus design

The proposed network design is simulated using Cisco packet tracer software. The network design simulates campus network that includes three major areas these are: Faculty of Physical Planning, Kufa Studies Center and ITRDC. In terms of technical details of the network; routing, switching, IP addressing and subnetting were all taken into account during designing phase. To meet routing requirements, the network utilizes OSPF routing protocol for maximum compatibility among the network departments. Regarding the connectivity with ISP, two connections were utilized. With one connection act as a backup connection in case the primary connection is failed, this has increased the reliability of connection to the internet. The LANs used in the network are not only complex but quite large in size too. Thus VLAN technology was used to control broadcast through the network for the purpose of improving the security and organize user groups using 802.1 trunk routing for IPv4. Port-Security will be enabled across switch ports that are operating in access mode. IP address subnetting process was implemented while taking into account the potential growth in future. As a result, the network is designed to accommodate doubled the number of users. This is important to ensure scalability as more departments and courses are added almost every year to the university.

Survey results have shown that most users are not satisfied with the existing network performance regarding several network services such as availability, Quality of Service (QoS). Additionally, survey results are validated by three experts through a structured interview. Most of the feedback of the experts match the results of the questionnaire. Thus, we proposed a number of criteria to enhance the performance of the current network such as fault-tolerance, scalability, Quality of Service (QoS) and security. To achieve the proposed criteria, packet tracer software is used to design and test the new network architecture.

Evaluation and conclusions phase Five: A set of common factors and relationships was proposed based on literature. A survey was conducted to test these relationships. The findings of the survey were evaluated and validated by three experts. The feedback and comments of the experts were used to finalize the proposed UoK design network. Different methods were used to evaluate the performance of the proposed UoK switched campus network. Firstly, packet tracer simulation tool was used to test and evaluate several criteria of the proposed campus design. These metrics are availability, scalability and QoS as we preset in this section. Secondly, a structured interview is conducted to validate the proposed design by five experts.

By using packet tracer simulation tool, the proposed design meet and achieve the following characteristics: Availability criterion was validated by the alternative path as shown in Fig. 9 (packet tracer). From scalability end, the range of IPs for physical planning faculty was

10.0.80.0/21 because the number of users increases continuously then calculate at least 100% growth over 5 next year, this calculation include students, academics, employees and admin groups. Ranges of IPs for Kufa studies center was 10.0.88.0/24 without calculating growth because of the number of users approximately constant. Then this criterion verified by calculating an increase in the number of users within the next 5 years. Moreover, five experts that conducted interviews in the area of networking were asked to validate the outcomes of the proposed campus design. The choice of the experts was based on their expertise in this area. However, their number was based on their willingness to participate in this study. The majority of the results provided by the experts matched the outcome of the analysis. The experts indicated that the causal relationships are significant. Thus, we conclude that the network design is acceptable.

CONCLUSION

In this article, we briefly examine the network architecture and characteristics for the University of Kufa. Survey questionnaire is conducted to discuss the issues and constraints of the current network utilization in the expanding university. A number of objectives are proposed to design a High Performance Switched Campus Network (HPSCN): the University of Kufa as a case study. These objectives are achieved by investigating the characteristics of the current network by showing the direct relationship between network design and university networking demands. The survey data helped to design a high-performance switched campus network. The proposed network design is evaluated and analyzed the proposed design based on several metrics such as fault-tolerance, scalability, Quality of Service (QoS) and security by using packet tracer software simulation program as well based on five expert's assessment. Finally, proposed recommendations to develop a high-performance network on campus that is fully scalable, more secure and effectively used. In addition, the proposed campus network design is capable of delivering a service with 24/7 availability, ability to accommodate the increased number of users in future, the ability of packet prioritizing and improved security. As part of the future directions, we are planning to extend the proposed network design to involve more colleges. And also include IPv6, manageability and adaptability metrics for the future network design.

REFERENCES

Abdulkareem, K.H., M.S. Azmi, N.S. Ali and M. Nasser, 2016. Factors Affecting Qualifications Gap For Network Technicians: Baghdad Universities Case Study. Int. J. Recent Trends Eng. Res., 2: 5-11.

Ali, N.S., 2016. A four-phase methodology for protecting web applications using an effective real-time technique. Int. J. Internet Technol. Secured Trans., 6: 303-323.

Beeharry, A. and G.M. Schneider, 1996. Creating a campus network culture in a newly developing economy. Inf. Technol. Dev., 7: 3-16.

Choi, B.Y., S. Song, G. Koffler and D. Medhi, 2007. Outage analysis of a university campus network. Proceedings of the 16th International Conference on Computer Communications and Networks (ICCCN'07), August 13-16, 2007, IEEE, Honolulu, Hawaii, ISBN:978-1-4244-1250-1, pp: 675-680.

Fadlullah, Z.M., A.V. Vasilakos and N. Kato, 2012. A game theoretic approach to integrate security with quality of service. Proceedings of the 2012 IEEE International Conference on Communications (ICC'12), June 10-15, 2012, IEEE, Ottawa, Canada, ISBN:978-1-4577-2052-9, pp: 4965-4969.

Frinkle, K. and M. Morris, 2015. Developing a hands-on course around building and testing high performance computing clusters. Procedia Comput. Sci., 51: 1907-1916.

Kothari, C.R., 2010. Research Methodology Methods and Techniques. New Age International Publishers, New Delhi, India.

Liu, F., W. Huang, P. Wang and L. Zhang, 2012. Assistant decision system for optimization of private communication network. Proceedings of the 2012 International Conference on Computational Problem Solving (ICCP'12), October 19-21, 2012, IEEE, Leshan, China, ISBN:978-1-4673-1696-5, pp: 490-494.

Mouton, J., 1996. Understanding Social Research. Van Schaik Bookstore, Pretoria, South Africa, ISBN:9780627021633, Pages: 272.

Oppenheimer, P., 2004. Top-Down Network Design. 2nd Edn., Cisco Press, Indianapolis, Indiana, Pages: 579.

Tariq, B.M., A. Mansy, N. Feamster and M. Ammar, 2009. Characterizing VLAN-induced sharing in a campus network. Proceedings of the 9th ACM SIGCOMM Conference on Internet Measurement, November 04-06, 2009, ACM, Chicago, Illinois, ISBN:978-1-60558-771-4, pp: 116-121.

Villa, A.H. and E. Varki, 2011. The feasibility of moving terabyte files between campus and cloud. Netw., 21: 22-30.