QUALITY OF SERVICE (QoS) IN CAMPUS NETWORK: COMPREHENSIVE SURVEY

Khalid Hammouda[1], Zulkiflee M [1], Abdelrafe Elzamly[2] and Mohamed Doheir[3]

[1]Fakulti Teknologi Maklumat dan Komunikasi,
Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.

[2]Faculty of Information and Communication Technology,
Al-Aqsa University, Gaza, 4051, Palestine.

[3] University Malaysia of Computer Science and Engineering,
UNIMY University, Cyberjaya, 63000, Malaysia.

Corresponding Author's Email: [1]p032010010@student.utem.edu.my
khalid.hommouda@gmail.com

Article History: Received 11 September 2022; Revised 14 October 2022; Accepted 24 November 2022

ABSTRACT: The existing Internet architecture has many well-known features, which has made it extremely difficult to extend Internet services. Determining the factors and criteria that influence internet services, particularly QoS, and creating substantial solutions to them continue to be difficult tasks. Although many studies have proposed numerous solutions to solve the QoS drawbacks of recent networking, some of them are failed or were not implemented. The objective of this paper is to review the existing techniques of QoS in the campus network, which are related to targeted goals of QoS future development in the campus network. The analysis is extended by dividing the Hard QoS and Soft QoS solutions. Defining those parameters and causes which affect internet services, especially the QoS, and developing significant techniques to solve them is continued to be a major challenge. The result shows the Hard QoS method mostly used the bandwidth while the Soft QoS methods bandwidth and delay factor to evaluate the performance of QoS along with other factors. In the future, more work and focus are needed toward an efficient QoS in the campus network and related applications is manageable.

KEYWORDS: Campus Network, QoS

1.0 INTRODUCTION

Nowadays, the explosive growth of real-time applications that require stringent Quality of Service (QoS) guarantees, brings network programmers to design network protocols that deliver certain performance guarantees. While, with the huge and rapid advance of a computer network, the structure of the campus network is the inescapable choice for the improvement of the information network. The campus network framework is quite large and complicated system. It is not only for modern teaching, integrated information management, and office automation series of applications to provide a basic operating platform but also to provide a variety of application services, so that information can be timely and accurate delivery. The campus network construction in the application of network technology is an important branch of technology to build and manage [1].

The capacity of the current Internet with rapid growth is becoming insufficient to carry the large volumes of traffic patterns delivered by the new services and modalities, where new types of networking services are appeared and generated for a huge number of end users. Specifically, the currently utilized infrastructure system of the network has been preserved almost in the same structure for decades, while technology continues to evolve. Resource management is of paramount importance in network scenarios, and it is a long-standing and still open issue. The existing networks built with multiple stages of static Ethernet switches organized in a tree structure are not sufficient for the dynamic computing and storage needs of today's carrier environments and future developments. The improvement of the network speedup, scalability, and robustness with the effective creation and delivery of versatile digital services that provide stringent Quality of Service (QoS) guarantees is a key demand.

However, all of these services and applications require different treatments to make the delivery successful over a network as some applications such as video conferencing require a certain bandwidth for their flow, other applications are sensitive to the delay over a network, and other specific requirements. Thus, defining these needs as a well-understanding Quality of Service (QoS) mechanism(s) in a network is a unique term [2]. One significant solution that has been paid attention to until recent time is SDN.

The SDN isolates network control from data and information transfer. As a result, filtering, routing algorithms, firewalls, and other algorithms utilized in various elements of the network are transferred to switches and controllers of data transfer. Therefore, with help of this architecture, the networks become more controllable and smarter, their dependence on hardware is decreased and their management will become simpler and more flexible, while their Quality of Service (QoS) guarantees. Eventually, the objective of the present paper is to get a clear understanding of the Quality of Service (QoS) in campus network obstacles which is necessary to address the multiple challenges realizing the QoS future development for campus network uses. The effect is represented by attention to the architecture of these networks in which control and the Service (QoS) in the campus network.

2.0 RELATED WORKS

Several studies have been done in prior works on Quality of Service (QoS) in the campus network. A novel approach to stream video over OpenFlow networks with QoS has been investigated and contacted by [2], [3], it fulfilled end-to-end QoS support which is possible with OpenFlow's centralized control capabilities over the network. New scheduling and channel allocation mechanisms have been proposed that ensure QoS for IMM applications over WCNs is introduced by [4]. The proposed mechanism delivers QoS with the least handoff delay and minimizes the call-dropping probabilities. A QoS-based Network Virtualization technique has been presented by [4]. The technique is based on constraint placement language used when mapping virtual network (node and links) over the substrate infrastructure which significantly ensures the QoS requirements of application flows. Another approach of the new mechanism (WiFi AP) has been developed by [5]. The mechanism based on (WiFi AP) has been studied in different protocols in wireless networks and focused on the WLAN IEEE 802.11. The problem associated with current WiFi is too much delay and loss of packets. The proposed (WiFi AP) has been conducted to enhance the QoS of the wireless network including delay and loss. However, this study does not provide sufficient results and evaluation

to support system performance which is left as future work. Another performed work on using SDN for video flow handling can be seen in [6], where a QoS Controller (Q-Ctrl) system is used to control and allocate bandwidth for the virtual machines supporting video streaming in a cloud infrastructure. The proposed approach aims to achieve QoS in an SDN-based cloud infrastructure. While it is more efficient in wide-area and WAMI data visualization. A mobile application which developed to gather the metrics necessary to evaluate QoE in a mobile environment over the network on campus is presented by [7]. This prototype application is able to evaluate the user's perceived QoE in various Internet services. However, the mean opinion score (MOS) of the proposed approach does not consider the jitter, packet loss and signal strength. A new mechanism to improve the QoS by reducing the IP packet delay is proposed by [8]. The mechanisms are analyzed through a simple packet transfer simulator that offers different combinations of mechanisms to be used in the simulation,
allowing different packet transfer scenario setups. However, the proposed approach comes with a simple design that needs to be improved by adding new QoS mechanisms to show the individual and combined effects of QoS on packet transfer.
A distributed QoS-oriented model for the improvement of network performance for fixed WiMAX using QoS parameters is introduced by [9]. The method improved the point-to-point system of delivering bandwidth from the central server to WiMAX BSs and SSs. However, the coverage area of WiMAX needs to be increased. A campus SWAN architecture to provide quality of service (QoS) guarantees to the campus WLAN users is presented by [10]. The SWAN is divided into control and data plane because the admin has to control a large number of Aps. In [11] a QoS of video conferencing between the main campus and sub-campus as the implementation of a distance learning system is presented.
The outcomes result show that the system can achieve sufficient results of bandwidth, jitter, and packet loss. While it does not consider the QoS in the access, distribution, and core levels where video/audio traffic passes through. A new technique to provide a scalable yet efficient solution to distributed SDN network management is proposed by [12] .It is an architecture as a collaborative multi-domain to load balancing and network performance enhancement in software-defined networks. The author also introduced a distributed machine learning agent to allow controllers to evaluate which brokers are more advantageous than others. While it is

required to modify the Flow Broker to provide better scalability and to avoid the scenario in which a single layer of brokering actually increases overhead. A role-based SDN campus network slicing approach has been proposed by [13] . The approach involves with authentication controller and the virtualization technology of Flow-Visor which led to reducing the flow setup latency by 14% to 60% compared to that of MAC-based slicing. While the proposed approach is required to be applicable in real campus networks to efficiently manage them. A technique for stitching inter-domain paths under the control of centralized routing brokers which known as IXPs has been introduced by [14], it allows for providing paths with end-to-end guarantees for mission-critical applications. A new technique which known as an open northbound API has been proposed by [15]. The method enables streaming video applications to easily enforce Quality of Service (QoS) requirements in a high-level fashion, without incurring any controller's code coupling or network operator intervention. However, the approach needs to be integrated with other OpenFlow controllers to better support its communication between a single streaming video application and disparate SDN controllers. Another technique of Bandwidth-allocation controller which called (NN-SPID) is developed by [16]. The proposed technique is based on a PID control strategy to control QoS requirements relying on an auto-adaptive neural network to ensure the minimum guaranteed bandwidth levels to users according to their contracted SLA, and it also shows more stability and robustness than GA-SPID. However, the proposed technique does not consider on controlling other QoS parameters such as jitter, packet delay of sensitive traffic, or packet loss ratio. In [17] new Scheduling algorithms for evaluating the performance of QoS over MPLS/VPN/WiMAX networks have been presented. Based on the proposed scheduling algorithms, it is clearly observed that MWRR has the lowest delay in both VPN and WiMAX. However, the long-term Evolution of advanced (LTE-adv) networks have not been achieved yet.

3.0 ANALYSIS AND RESULTS

In this section, the analysis of proposed technique from previous studies were conducted. The analysis can be found in Table 1.

Table 1: QoS Techniques

Technique	Contribution and drawbacks	Reference
An OpenFlow controller design	A novel approach to streaming video over OpenFlow networks with QoS, it fulfilled end-to-end QoS support which is possible with OpenFlow's centralized control capabilities over the network.	[19]
Scheduling mechanism for IMM applications	A new scheduling and channel allocation mechanism that ensures QoS for IMM applications over WCNs. It delivers QoS with the least handoff delay and minimizes the call-dropping probabilities.	[18]
QoS-based Network Virtualization	A constraint placement language is used when mapping the virtual network (node and links) over the substrate infrastructure to ensure the QoS requirements of application flows.	[3]
Optimized Routing in OpenFlow Networks	Streaming setup that utilizes the flexible routing possibilities provided by an SDN implemented with OpenFlow. It improves the QoS by changing the metric model of the Dijkstra algorithm.	[4]
QoS control and SRTP for real-time multimedia streaming	Quality of Service (QoS) control and Secure Real-time Transport Protocol (SRTP) approach to provide smooth streaming under various network bandwidths, while maintaining effective security.	[5]
A novel SHRP strategy	A novel QoS routing strategy called Swarm-based Hybrid Routing Protocol (SHRP) which able to select the minimum delay path with the maximum available bandwidth at nodes	[6]
A new mechanism of (WIFI AP)	Enhance the QoS of the wireless network including delay and loss. However, the study does not conduct clear results and evaluation to support system performance which left as future work.	[7]
Q-Ctrl system for video flow handling	Achieving high QoS in an SDN based cloud infrastructure. While it is more efficient in wide-area and WAMI data visualization.	[8]
A (QoE) evaluation model	A prototype application that evaluates the user perceived QoE in various Internet services over a mobile network in the campus. While its mean opinion score (MOS) does not consider the jitter, packet-loss and signal strength parameters.	[9]
A new QoS mechanisms	A new mechanism to improve the QoS by reducing the IP packet delay. While the proposed approach comes with a simple design which needs to be improved by adding new QoS mechanisms to show the individual and combined effects QoS on packet transfer.	[10]
Distributed QoS-oriented model	Improvement of network performance for fixed WiMAX using QoS parameters. the method improved the of the point-to-point system of delivering bandwidth from central server to WiMAX BSs and SSs. However, the coverage area of WiMAX needs to be increased.	[11]
A new campus SWAN architecture	A new campus WLAN architecture based on the concept of SDN called as SWAN. The SWAN is decoupled into a control plane and data plane which led to network control for a large number of APs	[12]
Real-time QoS-Aware video streaming	Performance evaluation for video transmission over LAN using Data Distribution Service (DDS). The proposed DDS consumes low bandwidth, has low jitter and causes lesser packet loss. While the examination for the QoS parameters to come up with the best configuration has not been contacted.	[13]
Allocation algorithm with Xen and Linux QoS	An allocation algorithm combined with Xen and Linux QoS which able to achieve the dynamic control of network bandwidth and flexibility to adjust the allocation scheme.	[14]
Flow Broker architecture	Multi-domain approach to load balancing and network performance enhancement in software-defined networks. It minimizes the maximum link utilization that leads to link saturation and significant packet loss. While it needs to be modified for Flow Broker to provide better scalability.	[15]
A fine granular API for QoS configuration	A QoS configuration API at the SDNC approach, its outcomes demonstrate the efficient capabilities of the QoS Config AP and give an indication about its significant performance. however, the SDNC needs to be extended with higher level abstractions.	[16]
A novel software-defined automatic QoS management	This model provides a universal scheme for autonomic network management in SDN with high effectiveness. The model does not other QoS parameters including jitter and loss.	[17]
Trust DSCP model for QoS evaluation	A video conference system testing for distance learning between two campuses with achieving sufficient results of bandwidth, jitter, and packet loss. While it doesn't consider the QoS in the access, distribution, and core levels where video traffic pass-through.	[18]

Open Cache API	An interface for developers and users which uses SDN-based technology to provide the redirection functionality necessary for a cache to perform effectively.	[19]
Role-based SDN campus network slicing	Involves with authentication controller and the virtualization technology of Flow-Visor which led to reduce the flow setup latency. While the proposed approach is required to be applicable in real campus networks to efficiently manage them.	[20]
IXPs	Technique for stitching inter-domain paths under the control of centralized routing brokers, which provide paths with end-to-end guarantees for mission-critical applications.	[21]
Bandwidth-allocation controller (NN-SPID)	Ensures the minimum guaranteed bandwidth levels to users depending on their service level agreement. However, the proposed technique does not consider on controlling other QoS parameters such as jitter, packet delay, or packet loss ratio.	[22]
Open northbound API	Enables streaming video applications to easily and achieving QoS goals without having to struggle with low-level OpenFlow instructions. However, it needs to be integrated with other OpenFlow controllers beyond to better support its communication.	[23]
New scheduling algorithms	Scheduling algorithms for evaluating the performance of QoS over MPLS/VPN/WiMAX networks. While long-term Evolution advanced (LTE-adv) networks have not been achieved.	[24]
Flexible 5G architecture for network slicing	Extensions for NFV orchestration that provide network slice tailored support for mobility and QoS, while ensuring efficient utilization of the substrate network resources. However, there are still open points in the algorithm definitions.	[41]

Table 1 show the analysis of the QoS techniques which were proposed by previous studies. The analysis focus on the advantage and disadvantage of each technique. Later, the analysis of a suitability of a technique related to the QoS model was conducted as in Table 2.

Table 2: Proposed QoS technique for Campus Network

QoS models / Technique	Hard Quality of Service (QoS)				Soft Quality of Service (QoS)			
	Bandwidth	**Delay**	**Jitter**	**Loss**	**Bandwidth**	**Delay**	**Jitter**	**Loss**
New (WIFI AP) mechanism						√		√
Bandwidth controller (NN-SPID)	√				√			
Q-Ctrl system for video flow handling	√				√			
Open northbound API	√	√						
Flow Broker architecture	√	√		√	√	√		√
Role-based SDN campus network slicing						√		
IXPs					√	√		
A (QoE) evaluation model					√	√		
Trust CoS model and Trust DSCP for QoS evaluation					√		√	√
A new QoS mechanisms						√		
Distributed QoS-oriented Model					√	√		
A fine granular API for QoS configuration						√		
A novel software-defined automatic QoS management model	√	√			√	√		
Scheduling mechanism for IMM applications					√	√		
New scheduling algorithms						√	√	
A new campus SWAN architecture					√			
QoS-based Network Virtualization					√	√		
Real-time QoS-Aware video streaming					√		√	√

A framework for automatic QoS control	√				√			
Open Cache API					√	√		
Optimized Routing in OpenFlow Networks					√	√		
QoS control and SRTP for multimedia streaming					√	√		
Allocation algorithm with Xen and Linux QoS					√			
Flexible 5G architecture for network slicing					√	√		
A novel SHRP strategy					√	√		

Table 2 shows the analysis of the facctor used by techniques proposed by previous researchers to evaluate their QoS performance and quality. From the table, the analysis shows that for Hard QoS solutions mostly are using bandwidth as its evaluation factor. Meanwhile, the Soft QoS solutions mostly prefer to use the bandwidth and delay factor to evaluate the performance of the Soft QoS solutions.

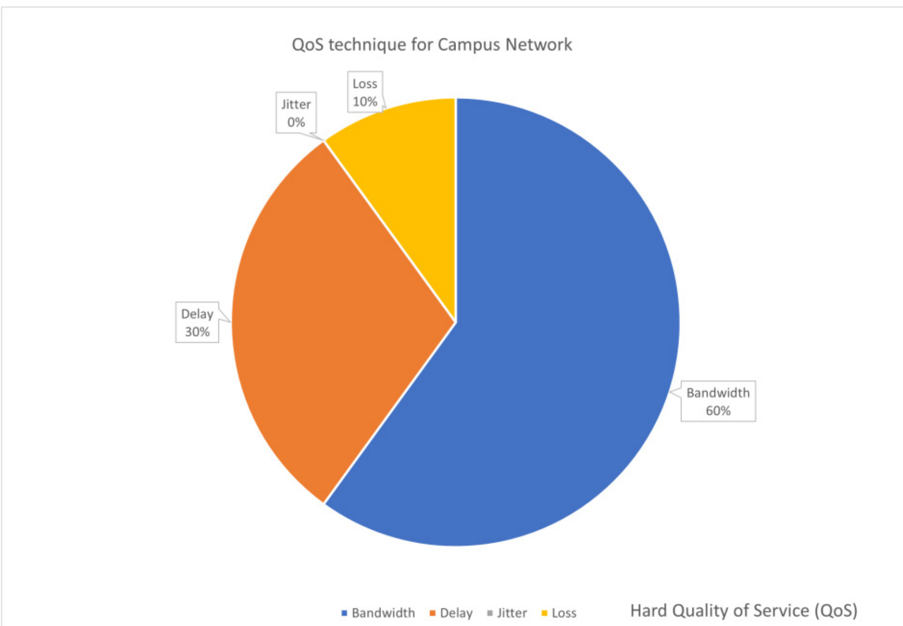

Figure 1: Hard QoS

Figure 1 shows the Hard QoS, the factor analysis used by the techniques proposed by previous researchers to evaluate the performance and quality of service quality. From the ratio in the graph, the analysis shows that Hard QoS solutions mostly use bandwidth as their evaluation factor.

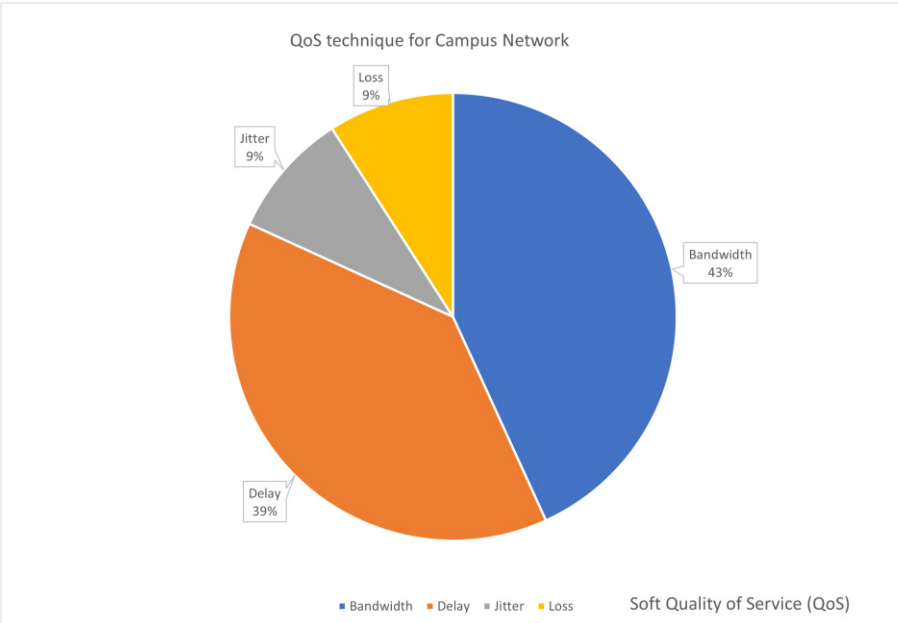

Figure 2: Soft QoS

Figure 2 Soft QoS, shows the factor analysis used by the techniques proposed by previous researchers to evaluate the performance and quality of service quality. From the ratio in the graph, the analysis shows that Soft QoS solutions mostly prefer to use bandwidth and delay factors to evaluate the performance of Soft QoS solutions.

4.0 DISCUSSION

Based on the evaluations of techniques, methods, and algorithms detailed in this paper, one could conclude that most of the solutions involving network applications, software-defined networks with Quality of Service (QoS) guaranty for campus network and other related areas contribute to the quality of service significantly. The effect of software-defined networks on quality of service of applications is inevitable. The considering the routing methods and metrics used in each of them, one may infer that some novel software techniques and other methods based on Flow Broker architectures are suitable for Quality of Service (QoS) guarantees in networks. In addition, tables above offer a comparison between the most significant methods suggested in the present paper for use of campus networks and other related applications that could be adopted.

5.0 CONCLUSION

One of the problems of today networks is the ability to manage differentiating services guaranteeing the various QoS requirements. Thus, in this paper, recent architectures and methods for offering the required Quality of Service (QoS) in campus networks and other related applications in current networks are reviewed. Then, these contributions, benefits and drawback problems of these methods were discussed. The effect performance is represented by attention to the architecture of these networks in which control and guaranty the Quality of Service (QoS) in the campus network. We can conclude that SDN and OpenFlow is the most likely become pervasive technologies in the future networks since they have an enormous potential contribution in a large number of different applications and fields. In addition, for QoS in networks, the lack of sufficient bandwidth, as well as high packet loss or delay, impact very negatively on the quality of service. Finally, more work and focus is needed toward an efficient Quality of Service (QoS) in campus network and related applications is control and guaranty.

REFERENCES

[1] M. Rahouti, K. Xiong, Y. Xin, and N. Ghani, “A priority-based queueing mechanism in software-defined networking environments,” 2021 IEEE 18th Annual Consumer Communications and Networking Conference, CCNC 2021, Jan. 2021, doi: 10.1109/CCNC49032.2021.9369614.

[2] M. Broadbent, D. King, S. Baildon, N. Georgalas, and N. Race, “OpenCache: A software-defined content caching platform,” 1st IEEE Conference on Network Softwarization: Software-Defined Infrastructures for Networks, Clouds, IoT and Services, NETSOFT 2015, Jun. 2015, doi: 10.1109/NETSOFT.2015.7116129.

[3] S. Rathee, S. Tiwari, K. Haribabu, and A. Bhatia, “qMon: A method to monitor queueing delay in OpenFlow networks,” *Journal of Communications and Networks*, vol. 24, no. 4, pp. 463–474, Jul. 2022, doi: 10.23919/JCN.2022.000023.

[4] P. Kujur and S. Patel, “Network Functions Virtualization and SDN,” *Software Defined Networks*, pp. 191–229, Jul. 2022, doi: 10.1002/9781119857921.CH7.

[5] E. Ak and B. Canberk, “Forecasting Quality of Service for Next-Generation Data-Driven WiFi6 Campus Networks,” IEEE Transactions on Network and Service Management, vol. 18, no. 4, pp. 4744–4755, Dec. 2021, doi: 10.1109/TNSM.2021.3108766.

[6] L. Jorge, P. Melo, and T. Gomes, “Multiclass data plane recovery using different recovery schemes in SDN: a simulation analysis,” *Procedia Comput Sci*, vol. 204, pp. 305–314, Jan. 2022, doi: 10.1016/J.PROCS.2022.08.037.

[7] C. Tsiaras *et al.*, “Towards evaluating type of service related quality-of-experience on mobile networks,” 2014 7th IFIP Wireless and Mobile Networking Conference, WMNC 2014, 2014, doi: 10.1109/WMNC.2014.6878848.

[8] H. Kozačinski and P. Kneževic, “Configuration of Quality of Service Parameters in Communication Networks,” *Procedia Eng*, vol. 69, pp. 655–664, Jan. 2014, doi: 10.1016/J.PROENG.2014.03.039.

[9] I. A. , S. A. M. , N. K. and M. Lawal, “A distributed QoS-oriented model to improve network performance for fixed WiMAX,” *International Journal on Recent Trends in Engineering & Technology*, vol. 10, p. 186, 2014.

[10] A. A. M. Ibrahim A. Lawal, “Design and Performance Analysis of Wireless Campus Network Using Delay Parameter,” *Sule Lamido University Journal of Science and Technology (SLUJST)* , vol. 2. pp. 107–115, 2021. Accessed: Dec. 07, 2022. [Online]. Available: https://www.academia.edu/44935322/Design_and_Performance_Analysis_of_Wireless_Campus_Network_Using_Delay_Parameter

[11] S. A. L. and M. H. M. J. S. Yalli, “An improved QoS in the architecture, model and huge traffic of multi-media applications under high speed wireless campus network,” IEEE Symp, 2014. https://www.researchgate.net/publication/281705500_An_improved_QoS_in_the_architecture_model_and_huge_traffic_of_multi-media_applications_under_high_speed_wireless_campus_network (accessed Dec. 06, 2022).

[12] D. Marconett and S. J. B. Yoo, “FlowBroker,” *Journal of Network and Systems Management*, vol. 23, no. 2, pp. 328–359, Apr. 2015, doi: 10.1007/S10922-014-9325-5.

[13] C. H. Chen, S. H. Lu, C. C. Tseng, and C. Chen, “Role-based campus network slicing,” Proceedings - International Conference on Network Protocols, ICNP, vol. 2016-December, Dec. 2016, doi: 10.1109/ICNP.2016.7785315.

[14] M. Karl, J. Gruen, and T. Herfet, “Multimedia optimized routing in OpenFlow networks,” IEEE International Conference on Networks, ICON, 2013, doi: 10.1109/ICON.2013.6781969.

[15] C. Caba and J. Soler, “APIs for QoS configuration in Software Defined Networks,” 1st IEEE Conference on Network Softwarization: Software-Defined Infrastructures for Networks, Clouds, IoT and Services, NETSOFT 2015, Jun. 2015, doi: 10.1109/NETSOFT.2015.7116157.

[16] T. Docquier, Y.-Q. Song, V. Chevrier, L. Pontnau, and A. Ahmed-Nacer, “Performance evaluation methodologies for Smart Grid Substation Communication Networks: A survey,” *Comput Commun*, Nov. 2022, doi: 10.1016/J.COMCOM.2022.11.005.

[17] H. E. Egilmez, S. T. Dane, K. T. Bagci, and A. M. Tekalp, “OpenQoS : An OpenFlow Controller Design for Multimedia Delivery with End-to-End Quality of Service over Software-Defined Networks,” Signal & Information processing association annual summit and conference (APSIPA ASC), 2012 Asia-Pacific. IEEE, 2012.

[18] K. Alam, S. A. Latif, M. H. Masud, M. Akter, F. Anwar, and J. S. Yalli, “An Analysis of Scheduling Scheme for QoS Guaranteed Interactive Multimedia over High Speed Wireless Campus Networks,” Artificial Intelligence, Modelling and Simulation (AIMS), 2013 1st International Conference on. IEEE, 2013.

[19] I. Ayadi and G. Diaz, “QoS-based Network Virtualization to Future Networks: An approach based on network constraints,” Fourth International Conference on the, 2013.

[20] M. Karl, S. Member, J. Gruen, T. Herfet, and S. Member, “Multimedia Optimized Routing in OpenFlow Networks,” Networks (ICON), 2013 19th IEEE International Conference on IEEE, 2013.

[21] J. Kim, H. Choi, S. Lee, and S. Park, “Implementation of quality of service control and security based on real-time transport protocol,” Broadband Network & Multimedia Technology (IC-BNMT), 5th IEEE International Conference on. IEEE, 2013.

[22] S. K. Nivetha, R. Asokan, and N. Senthilkumaran, “A swarm-based hybrid routing protocol to support multiple Quality of Service (QoS) metrics in mobile ad hoc networks,” Computing, Communications and Networking Technologies (ICCCNT), 2013 Fourth International Conference on. IEEE, 2013.

[23] J. S. Yalli, S. A. Latif, and M. H. Masud, “A Comprehensive Analysis of Improving QoS and IMM Traffic of High Speed Wireless Campus Network,” Computer Applications and Industrial Electronics (ISCAIE), 2014 IEEE Symposium on. IEEE, 2014.

[24] K. Govindarajan, K. C. Meng, H. Ong, and W. M. Tat, “Realizing the Quality of Service (QoS) in Software-Defined Networking (SDN) Based Cloud Infrastructure,” Information and Communication Technology (ICoICT), 2014 2nd International Conference on. IEEE, 2014.

[25] C. Tsiaras, A. Sehgal, S. Seeber, D. Dönni, and B. Stiller, “Towards Evaluating Type of Service Related Quality-of-Experience on Mobile Networks,” Wireless and Mobile Networking Conference (WMNC), 2014 7th IFIP. IEEE, 2014.

[26] H. Kozačinski and P. Knežević, “Configuration of Quality of Service Parameters in Communication Networks,” *Procedia Eng*, vol. 69, pp. 655–664, 2014.

[27] I. A. Lawal, A. Said, K. Nisar, and A. Aminu, “A Distributed QoS-Oriented Model to Improve Network Performance for Fixed WiMAX,” *International Journal on Recent Trends in Engineering & Technology*, vol. 10, no. 1, 2014.

[28] T. Lei, Z. Lu, X. Wen, X. Zhao, and L. Wang, “SWAN : An SDN Based Campus WLAN Framework,” Wireless Communications, Vehicular Technology, Information Theory and Aerospace & Electronic Systems (VITAE), 2014 4th International Conference on. IEEE, 2014.

[29] B. Al-madani, A. Al-roubaiey, and Z. A. Baig, “Real-Time QoS-Aware Video Streaming : A Comparative and Experimental Study,” *Advances in Multimedia*, 2014.

[30] S. Mingsong, “Optimization in dynamic allocation of network bandwidth campus based on Xen,” Strategic Technology (IFOST), 2014 9th International Forum on. IEEE, 2014.

[31] D. Marconett and S. J. B. Yoo, “FlowBroker : A Software-Defined Network Controller Architecture for Multi-Domain Brokering and Reputation,” *Journal of Network and Systems Management*, vol. 23, no. 2, pp. 328–359, 2015, doi: 10.1007/s10922-014-9325-5.

[32] C. Caba and J. Soler, “APIs for QoS configuration in Software Defined Networks,” Network Softwarization (NetSoft), 2015 1st IEEE Conference on. IEEE, 2015.

[33] W. Wang, Y. Tian, X. Gong, Q. Qi, and Y. Hu, “Software defined autonomic QoS model for future Interne,” *J Syst Softw*, vol. 110, pp. 122–135, 2015.

[34] A. Sudarsono, A. Siswanto, H. Iswanto, and Q. Setiawan, “Traffic Analysis of Quality of Service (QoS) for Video Conferencing between Main Campus and Sub Campus in Laboratory Scale,” *EMITTER International Journal of Engineering Technology*, vol. 3, no. 2, pp. 1-17., 2015.

[35] M. Broadbent, D. King, S. Baildon, N. Georgalas, and N. Race, “OpenCache : A Software-defined Content Caching Platform,” Network Softwarization (NetSoft), 2015 1st IEEE Conference on. IEEE, 2015.

[36] C. Chen, C. Chen, S. Lu, and C. Tseng, “Role-based Campus Network Slicing,” Network Protocols (ICNP), 2016 IEEE 24th International Conference on. IEEE, 2016.

[37] V. Kotronis, R. Klöti, M. Rost, and P. Georgopoulos, “Stitching Inter-Domain Paths over IXPs,” Proceedings of the Symposium on SDN Research. ACM, 2016.

[38] N. Merayo et al., “PID Controller Based on a Self-Adaptive Neural Network to Ensure QoS Bandwidth Requirements in Passive Optical Networks,” *Journal of Optical Communications and Networking*, vol. 9, no. 5, pp. 433–445, 2017.

[39] C. R. Vasconcelos, R. C. M. Gomes, A. F. B. F. Costa, D. Dias, and C. Silva, “Enabling High-Level Network Programming : A Northbound API for Software-Defined Networks,” Information Networking (ICOIN), 2017 International Conference on. IEEE, 2017.

[40] H. H. Elkarash, N. M. Elshennawy, and E. A. Sallam, “Evaluating QoS using Scheduling Algorithms in MPLS / VPN / WiMAX Networks,” In Computer Engineering Conference (ICENCO), 2017 13th International , IEEE, 2017.

[41] F. Z. Yousaf, M. Gramaglia, V. Friderikos, B. Gajic, D. Von Hugo, and B. Sayadi, “Network Slicing with Flexible Mobility and QoS / QoE Support for 5G Networks,” Communications Workshops (ICC Workshops), 2017 IEEE International Conference on. IEEE, 2017.