Lecture Notes in Electrical Engineering 739

Hyuncheol Kim
Kuinam J. Kim
Suhyun Park *Editors*

Information Science and Applications

Proceedings of ICISA 2020

Springer

Lecture Notes in Electrical Engineering

Volume 739

The book series *Lecture Notes in Electrical Engineering* (LNEE) publishes the latest developments in Electrical Engineering - quickly, informally and in high quality. While original research reported in proceedings and monographs has traditionally formed the core of LNEE, we also encourage authors to submit books devoted to supporting student education and professional training in the various fields and applications areas of electrical engineering. The series cover classical and emerging topics concerning:

- Communication Engineering, Information Theory and Networks
- Electronics Engineering and Microelectronics
- Signal, Image and Speech Processing
- Wireless and Mobile Communication
- Circuits and Systems
- Energy Systems, Power Electronics and Electrical Machines
- Electro-optical Engineering
- Instrumentation Engineering
- Avionics Engineering
- Control Systems
- Internet-of-Things and Cybersecurity
- Biomedical Devices, MEMS and NEMS

For general information about this book series, comments or suggestions, please contact leontina.dicecco@springer.com.

To submit a proposal or request further information, please contact the Publishing Editor in your country:

China

Jasmine Dou, Editor (jasmine.dou@springer.com)

India, Japan, Rest of Asia

Swati Meherishi, Editorial Director (Swati.Meherishi@springer.com)

Southeast Asia, Australia, New Zealand

Ramesh Nath Premnath, Editor (ramesh.premnath@springernature.com)

USA, Canada:

Michael Luby, Senior Editor (michael.luby@springer.com)

All other Countries:

Leontina Di Cecco, Senior Editor (leontina.dicecco@springer.com)

**** This series is indexed by EI Compendex and Scopus databases. ****

More information about this series at http://www.springer.com/series/7818

Hyuncheol Kim · Kuinam J. Kim ·
Suhyun Park
Editors

Information Science and Applications

Proceedings of ICISA 2020

Springer

Editors
Hyuncheol Kim
Namseoul University
Cheonan-si, Korea (Republic of)

Kuinam J. Kim
Kyong-gi University
Suwon-si, Gyeonggi-do, Korea (Republic of)

Suhyun Park
Department of Computer Engineering
Dongseo University
Busan, Korea (Republic of)

ISSN 1876-1100 ISSN 1876-1119 (electronic)
Lecture Notes in Electrical Engineering
ISBN 978-981-33-6384-7 ISBN 978-981-33-6385-4 (eBook)
https://doi.org/10.1007/978-981-33-6385-4

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

Organizing Committee

General Chairs

Suhyun Park, Dongseo University, Republic of Korea
Hyeunchul Kim, Namseoul University, Republic of Korea

Steering Committee

Nikolai Joukov, New York University and modelizeIT Inc, USA
Borko Furht, Florida Atlantic University, USA
Bezalel Gavish, Southern Methodist University, USA
Kin Fun Li, University of Victoria, Canada
Kuinam J. Kim, Institute of Creative Advanced Technologies, Science and Engineering, Korea
Naruemon Wattanapongsakorn, King Mongkut's University of Technology Thonburi, Thailand
Xiaoxia Huang, University of Science and Technology Beijing, China

Publicity Chairs

Minsu Kim, Kyonggi University, Republic of Korea
Hongseok Jeon, ETRI, Republic of Korea
Suresh Thanakodi, National Defence University of Malaysia, Malaysia

Financial Chair

Jongmin Kim, Kyonggi University, Republic of Korea

Publication Chair

Hyeunchul Kim, Namseoul University, Republic of Korea

Program Chairs

Kuinam J. Kim, Institute of Creative Advanced Technologies, Science and Engineering, Korea
Nakhoon Baek, Kyungpook National University, Republic of Korea

Organizers and Supporters

Institute of Creative Advanced Technologies, Science and Engineering (iCatse)
Korean Industry Security Forum (KISF)
Korea Convergence Security Association (KCSA)
Hongik University, Republic of Korea
Kyonggi University, Republic of Korea
Kyungpook National University, Republic of Korea
Namseoul University Wellness Institute
Korea Institute of Science and Technology Information (KISTI)
Electronics and Telecommunications Research Institute (ETRI)
BPU Holdings Inc.

Program Committee

Dr. Mohd Ashraf Ahmad, University Malaysia Pahang, Malaysia
Dr. Siti Sarah Maidin
Wing C. Kwong, Hofstra University, USA
Dr. Christof EBERT, Vector Consulting Services
Marco Listanti, DIET Department, University of Roma Sapienza, Italy
Pr. Pascal LORENZ, University of Haute Alsace, France

Assistant Dr. Somlak Wannarumon Kielarova, Faculty of Engineering, Naresuan University, Thailand
Zeyar Aung, Khalifa University of Science and Technology, UAE
Xiaochun Cheng, Middlesex University, London, UK
Vasco N. G. J. Soares, Instituto de Telecomunicações / Instituto Politécnico de Castelo Branco, Portugal
Pavel Loskot, Swansea University, UK
Luca Piras, University of Brighton, UK
José Manuel Matos Ribeiro da Fonseca, NOVA University of Lisbon, Portugal
Sangseo Park, The University of Melbourne, Australia
Robert S Laramee, University of Nottingham, UK
Bok-Min Goi, Universiti Tunku Abdul Rahman, Malaysia
Tommaso Zoppi, University of Florence, Italy
Prof. Baojun MA, Shanghai International Studies University, School of Business and Management, China
Johann Marquez-Barja, University of Antwerp—imec, Belgium
Shimpei Matsumoto, Hiroshima Institute of Technology, Japan
Hyunsung Kim, Kyungil University, Korea
Zbigniew Leonowicz, Wroclaw University of Science and Technology, Poland
William Emmanuel Yu, Ateneo de Manila, Philippines
Dr. Shitala Prasad, Scientist, I2R, A*Star, Singapore
Dr. Chittaranjan Pradhan, KIIT University, Bhubaneswar, India
IICKHO SONG, Korea Advanced Institute of Science and Technology, Korea
Dr. Terje Jensen, Telenor, Norway
Pao-Ann Hsiung, National Chung Cheng University, Taiwan
Pr Naoufel Kraiem, RIADI Lab—Tunisia, North Africa
MAINGUENAUD Michel, Institut National des Sciences Appliquées—Rouen, France
Nguyen Dinh Cuong, Nha Trang University, Vietnam
Maicon Stihler, Centro Federal de Educação Tecnológica de Minas Gerais—CEFETMG, Brazil
Oscar Mortagua Pereira, University of Aveiro, Portugal
Dr. Bernd E. Wolfinger, University of Hamburg, Germany
Michalis Pavlidis, University of Brighton, UK
Ad Lalit Prakash Saxena, Combo Legal Consultancy, Obra India
Dr. James Braman, Community College of Baltimore County, USA
Ljiljana Trajkovic, Simon Fraser University, Canada
Bongkyo Moon, Dongguk University, Korea
Mauro Gaggero, National Research Council of Italy, Italy
Ong Thian Song, Multimedia University Malaysia, Malaysia
Yanling Wei, KU Leuven, Belgium
Harikumar Rajaguru, Bannari Amman Institute of Technology, Sathyamangalam India
Dr. Ahmad Kamran Malik, COMSATS University Islamabad (CUI), Pakistan
Etibar Seyidzade, Baku Engineering University, Azerbaijan

Lorenzo Ricciardi Celsi, Consel – Consorzio ELIS & Dipartimento di Ingegneria Informatica, Automatica e Gestionale, Università di Roma "La Sapienza", Italy
Sira Yongchareon, Auckland University of Technology, New Zealand
David Liu, Purdue University Fort Wayne, USA
Wun-She Yap, Universiti Tunku Abdul Rahman, Malaysia
Mohd. Saifuzzaman, Daffodil International University, Dhaka, Bangladesh
Daniel Bo-Wei Chen, Princeton University, USA
Dr. Ng Hui Fuang, Universiti Tunku Abdul Rahman, Malaysia
Min-Shiang Hwang, Asia University, Taiwan
Maurantonio Caprolu, Hamad Bin Khalifa University, Doha, Qatar
Sandro Leuchter, Mannheim University of Applied Sciences, Germany
Azeddien M. Sllame, University of Tripoli, Tripoli, Libya
Wg. Cdr. Tossapon Boongoen, Mae Fah Luang University, Chiang Rai, Thailand

Preface

This LNEE volume contains the papers presented at the iCatse International Conference on Information Science and Applications (ICISA2020) which was held in Zoom event platform (virtual Conference) during December 16–18, 2020.

ICISA2020 will provide an excellent international conference for sharing knowledge and results in information science and application. The aim of the conference is to provide a platform to the researchers and practitioners from both academia as well as industry to meet the share cutting-edge development in the field.

The primary goal of the conference is to exchange, share, and distribute the latest research and theories from our international community. The conference will be held every year to make it an ideal platform for people to share views and experiences in information science and application-related fields.

On behalf of the Organizing Committee, we would like to thank Springer for publishing the proceedings of ICISA2020. We also would like to express our gratitude to the 'Program Committee and Reviewers' for providing extra help in the review process. The quality of a refereed volume depends mainly on the expertise and dedication of the reviewers. We are indebted to the Program Committee members for their guidance and coordination in organizing the review process and to the authors for contributing their research results to the conference.

Our sincere thanks to the Institute of Creative Advanced Technology, Engineering and Science for designing the conference web page and also spending countless days in preparing the final program in time for printing. We would also like to thank our organization committee for their hard work in sorting our manuscripts from our authors.

We look forward to seeing all of you next year at ICISA.

Suwon-si, Korea (Republic of) Kuinam J. Kim
Busan, Korea (Republic of) Suhyun Park
Cheonan-si, Korea (Republic of) Hyuncheol Kim

Contents

Experience and Prospects of Tele-health Technologies

Valery Stolyar, Anastasiia Goy, and Maya Amcheslavskaya

Abstract The article describes the concept of modern telemedicine, and deals with basic directions of using tele-health technologies in clinical practice and the educational process. Particular attention is paid to such areas as remote video consultation and master classes, tele-mentoring. To conclude, the prospects of new technological solutions for telemedicine are estimated.

Keywords Informatics · Digital health · Telemedicine · Video consultation · Tele-lecture · Tele-mentoring

1 Introduction

An unprecedented leap in the development of information, multimedia and telecommunication technologies that took place at the turn of the twentieth and twenty-first centuries has had a significant impact on all spheres of our daily life. Computer technologies is so deeply rooted in everyday activities that human functioning without them seems impossible. The education and health care systems were also influenced by them, as a result of which the telemedicine direction was founded.

The subject of telemedicine is the transfer of medical information between points that are distant from each other (for example, between individual medical institutions). Telemedicine involves the use of telecommunications to connect healthcare professionals with clinics, hospitals, physicians, remote patients for diagnosis, treatment, consultation and continuing education.

V. Stolyar · A. Goy (✉) · M. Amcheslavskaya
Medical Informatics and Telemedicine Department, Peoples' Friendship University of Russia, RUDN University), Miklukho-Maklaya str.6, 117198 Moscow, Russia
e-mail: goy.telemed@yahoo.com

V. Stolyar
e-mail: v_stolyar@yahoo.com

M. Amcheslavskaya
e-mail: telemed@ntt.ru

H. Kim et al. (eds.), *Information Science and Applications*, Lecture Notes in Electrical Engineering 739, https://doi.org/10.1007/978-981-33-6385-4_1

The communication of doctors in the framework of medical consultations, medical education had reached a new qualitative level by telemedicine technologies. Such terms as remote video consultations «Doctor-Doctor» and «Doctor-Patient», interactive master classes and tele-mentoring are now in common parlance, in our vocabulary. However, there are unrealistic expectations in the medical community of using telemedicine. Therefore, we deemed it necessary to consider the possibilities, limitations and prospects of telemedicine technologies in this article.

2 Main "Vectors" of Modern Telemedicine

Put simply, telemedicine is medicine at a distance. It involves diagnostic consultations, managerial, educational, scientific and enlightenment activities in the field of health implemented with the use telecommunication technologies.

To date, the main application areas of telemedicine technologies are remote video consultations, interactive distance education, remote master classes, tele-mentoring, «Doctor-Patient» video consultations.

During a *remote video consultation* (scheduled or emergency) doctors from several clinics can jointly review and discuss patient information in order to clarify the diagnosis, treatment method, and indications for surgery. Patient participation and researching is also possible at the consultation. The attending physician reports on the patient's condition to the consultants, thereby turning for help to the experience and knowledge of senior colleagues from leading clinics. In some cases, remote video consultations are much more convenient than face-to-face consultations in these clinics, and help save the patient's time and energy (Fig. 1).

An up-to-date interactive distance education allow participate in lectures and seminars by the best professors from leading Russian and foreign universities, with

Fig. 1 Remote video consultation

studio audio and video quality, take a part in clinical discussions or scientific-practical conference. This technology allows to collect training courses for doctors and students from building blocks—from individual lectures by leaders in their fields [1]. Having extensive experience in this area, we regularly organize tele-lectures for RUDN University students with the participation of famous professors from Russia, India and Germany. Thus we are providing learners to receive knowledge from top professionals, which greatly improves the quality of education (Fig. 2).

Remote master classes based on modern video conferencing systems, and could get us into the operating room of leading clinics. A contemporary high-tech developments allow to connect to multiple cameras in the operating room simultaneously (to cameras on the surgeon's helmet, in the operating lamp, on the ceiling of the operating room, operational monitors, medical equipment), and display qualitative images on large monitors. Trainees have the opportunity to seeing an operation from different positions. Most cameras have remote control (for example, zoom, rotate), so that listeners can observe in detail the work of the operating surgeon and team members, to conduct a dialogue with them while in the classroom. A similar technology is adapted for interactive distance learning of diagnostic procedures and manipulations (ultrasound diagnostics of the heart, endoscopic procedures, etc.) when the full-time presence of students is undesirable (Fig. 3).

A tele-mentoring is the inverse task of remote master classes. A tele-mentoring make it possible to control the operation of young surgeons and diagnosticians with an option of remote consulting support in complex cases by more experienced colleagues based on video conferencing. This technology has already shown to be effective in the learning of new surgical and diagnostic methods and medical equipment (Fig. 4).

The stereoscopic complex can be used as an instrument of tele-mentoring. Stereoscopic technologies develop spatial thinking and make it possible to present a detailed model of any object. It is important to understand the implementation of one or another stereoscopic content is aimed at solving a narrow range of tasks for specific areas of activity. Great value stereoscopic technologies are presented in the task of

Fig. 2 The distance lecture from India

Fig. 3 Remote interactive master classes in ophthalmology and cardiac surgery

Fig. 4 Examples of tele-mentoring in ultrasound heart diagnosis and dentistry

improving the qualifications of already established surgeons in the course of interactive master classes and are successfully used in such areas as neurosurgery, oncology, maxillofacial surgery, laser surgery.

3 Future Developments and Expectations

When considering the possibility of using telemedicine technologies in the curative process and medical education, it is important to understand objectively both the possibilities and limitations (technical, organizational, economic, psychological etc.) of modern telemedicine. There will be fewer restrictions as technology develops, but they will never disappear in principle.

What should we expect from telemedicine in the next five years?

Firstly, it is dynamic transmission of a stereoscopic image of the operating field (for example, for maxillo-facial operations in addition to static images of 3D scanners) with spatial image processing to improve the effectiveness of remote interactive master classes, or issuing recommendations to the operating surgeon from an experienced colleague.

Secondly, remote transmission of tactile sensations during teleconsultation for palpation, percussion, assessment of skin areas surface problem using a remote «hand-glove».

Thirdly, remote transmission of smell during teleconsultation. Electronic dog nose created, and it is important to learn how correctly generate sets of smells on the receiving side. This technology will be in demand for a whole range of medical specialties (for example, dentistry, purulent surgery, etc.).

Fourthly, use of artificial intelligence (AI) technologies during emergency video consultations for rapid analysis of patient information and presentation of effective recommendations to the doctor based on available databases. At the current stage of development of digital medicine, it is extremely important to support medical decisions in emergency situations using intelligent systems located on the servers of large medical organizations or in "cloud" data centers. The appeal to these decision support systems (DSS) should be provided by calling the AI system by the doctor directly in the process of working in the electronic medical record system. The corresponding intelligent system will analyze the signs noted in the patient's card and form hypotheses of the differential diagnostic series, the possible prognosis of complications and recommendations for treatment.

Fifthly, use of augmented reality (AR) methods in conducting video conferences and educational process (tele-mentoring, master classes). AR considered one of the variations of virtual reality (VR). The main difference is that VR technology completely immerses the user in the virtual world. AR brings 3D virtual objects in real time into a 3D real environment. Thus, due to the possibility of generating any 3D-objects and their further integration into the real environment, augmented reality technologies are widely used in surgical practice, namely in training future surgeons. With the help of augmented reality, it has become possible to simulate various surgeries online, which greatly facilitates, for example, the practical part of the training of future surgeons [2].

Sixthly, the emergence of a whole range of implanted and pasted sensors connected by a single digital platform with pre-processing and analysis of data, for monitoring the condition of chronic patients and patients during long-term rehabilitation after complex operations. Currently available services, gadgets and medical devices for home use will remind the patient of the need to take medications on time, conduct research, fill out a diary about their condition, track the dynamics of indicators and automatically transmit them to the attending doctor. In this way, the doctor can fully assess the patient's condition by the time of the teleconsultation. Despite the fact that a remote appointment takes an amount of time equal to a face-to-face appointment, it is always less informative for the doctor, and the psychological burden for specialist is significantly higher.

4 Conclusion

Telemedicine services are actively developing all over the world, involving Телемедицинские сервисы активно развиваются во всем мире, involving the best minds of doctors and programmers, implementing artificial intelligence and the latest computer technologies. Success achieved only where they based on knowledge and experience of skilled doctors and diagnosticians, who should be involved as analysts at the stage of setting the task. We actively cooperate with Russian and foreign developers of new technologies and equipment for telemedicine, taking part in the search for ideas, formulating new tasks, creating and testing prototypes. We are optimistic about the prospects for the development and practical use of telemedicine, given the presence of strong medical schools in Russian.

Reference lists

1. At'kov O, Stolyar V (2001) Interaktivnoe teleobuchenie vrachej na osnove sistem videokonferencsvyazi. Vizualizaciya V Med 18:34–40
2. Namiot E (2019) Augmented reality in medicine. Int J Open Info Technol 7(11):94–98

Exploring the Effects of Network Topology Layers on Quality of Service Mechanisms in the Context of Software-Defined Networking

Josiah Eleazar T. Regencia and William Emmanuel S. Yu

Abstract The separation of the control plane and the data plane in the Software-Defined Networking (SDN) architecture makes it easier and more feasible to implement per-flow Quality of Service (QoS) provisioning in the network which is beneficial for flows that require special QoS handling such as VoIP and video streaming. Applying QoS mechanisms to a distributed single-layered set of switches in the context of SDN has shown promise in previous studies. Using a test framework that was previously developed for QoS algorithms and networking topologies in SDN, this study explored how layers in the network topology affect the performance of QoS in the network. This is in order to replicate real-world networking scenarios where packets travel through layers of networking equipment. Generally, results have shown that having less layers in the network means better performance. However, this does not mean that adding layers creates a material disadvantage. Results also show that despite adding layers to the networking topology, the SDN distributed Leaf-enforcement of QoS performed better or as good as compared to the traditional centralized Core-enforcement of QoS. This is despite having leaf-enforced environments have more points of enforcement as layers are added.

Keywords Software-defined networking · Quality of service · Class-based queueing

1 Introduction

The emergence of Software-Defined Networking (SDN) provides dynamic, flexible and scalable—all of which are weaknesses of traditional networks—control and management for networks. The separation of the control plane and the data plane

J. E. T. Regencia (✉) · W. E. S. Yu
Ateneo de Manila University, Loyola Heights, 1108 Quezon City, Philippines
e-mail: josiah.regencia@obf.ateneo.edu

W. E. S. Yu
e-mail: wyu@ateneo.edu

H. Kim et al. (eds.), *Information Science and Applications*, Lecture Notes in Electrical Engineering 739, https://doi.org/10.1007/978-981-33-6385-4_2

enables flow-management and resources to be dynamically optimized. In addition, this makes it easier and more feasible to implement per-flow Quality of Service (QoS) provisioning in the network which is beneficial for flows that require special QoS handling such as VoIP and video streaming [7].

Multiple studies have explored QoS in the context of SDN. Chato and Yu [2, 3] explored Class-Based Queuing (CBQ) QoS algorithms (Basic CBQ and Source CBQ) in a virtual network topology implemented inside the Mininet emulator [4] using a custom POX OpenFlow Controller to in terms of throughput, bandwidth, and latency. The Basic CBQ algorithm was a protocol-based classification queuing and the Source CBQ algorithm was a classification queuing based on source IP addresses. Results showed that QoS algorithms applied to the distributed nature of SDN have better performance in terms of bandwidth and decreased latency. In 2020, Regencia and Yu [8] introduced a testing framework for QoS algorithms and network topologies in the context of Software-Defined Networking. As an anchor to test the framework, Destination IP address based CBQ and Source-Destination IP addresses CBQ algorithms are introduced and compared against the CBQ algorithms in the Chato and Yu [2, 3] inside the test framework. The test framework has two test cases for each QoS algorithm: the traditional centralized Core-enforcement where QoS is only enforced in a centralized core switch and the SDN distributed nature Leaf-enforcement where QoS is distributedly enforced to switches that are closer to the edge called the client leaf switches. The test framework introduced by Regencia and Yu [8] has been submitted to the CANDAR'20 Conference and is currently awaiting paper acceptance notification.

In the previous 2020 study by Regencia and Yu [8], Leaf-enforcement is only applied to a single-layered set of client-leaf switches where results showed that Leaf-enforcement generally showed better performance compared to Core-enforcement. In this study, the test framework introduced by Regencia and Yu [8] is used to test how layers in the network topology affect QoS in both Core-enforced and Leaf-enforced test cases of QoS algorithms. The addition of layers is an experiment to replicate a real-word scenario networking topologies.

2 Related Literature

The flexibility and programmability of SDN has been seen as an answer to the issues traditional networks continue to face when it comes to QoS especially as standard QoS policies have become no longer capable of supporting today's complex networks due to the rapid increase of network applications and devices [7].

Applying proper QoS mechanism is a difficult task due to different needs of different types of flows. For example, multimedia flows from applications such as video conferences or video streaming require steady network resources and as much as possible, little to no packet drop and delay. In designing frameworks for such flows, prioritization and classification are both key factors [7]. Queuing is a common QoS mechanism. QosFlow [6] provides flexible control mechanisms by manipulating multiple packet schedulers such as Hierarchical Token Bucket (HTB), Random Early Detection (RED), and Stochastic Fairness Queuing (SFQ) schedulers. Chato and Yu [2, 3] also explored use of queuing QoS mechanisms by applying two (2) algorithms Class-Based Queuing (CBQ): Basic CBQ and Source CBQ. Each algorithm is tested on both centralized Core-enforcement and distributed Leaf-enforcement.

In 2020, Regencia and Yu [8] introduced a testing framework for QoS algorithms and network topologies in the context of Software-Defined Networking. As an anchor to test the framework, Destination IP address based CBQ and Source-Destination IP addresses CBQ algorithms are introduced and compared against the CBQ algorithms in the Chato and Yu [2, 3] inside the test framework. As shown in Fig. 1, the key component of the test framework is the separation of the SDN Controller, the Topology which is software simulated using Mininet, the Test Simulator, and the implementations of QoS algorithms. In addition, generator scripts create configuration files that define features of networking devices in the virtual topology. The test framework has two test cases for each QoS algorithm: Core-enforcement where QoS is only enforced in a centralized core switch and Leaf-enforcement where QoS is distributedly enforced to switches that are closer to the edge called the client leaf switches. In this study, the test framework introduced by Regencia and Yu [8] is used to test how layers in the network topology affect QoS in both Core-enforced and Leaf-enforced test cases of QoS algorithms. The addition of layers is an experiment to replicate a real-word scenario networking topologies.

3 Framework

This study was performed using an Amazon Web Services (AWS) EC2 m5.xlarge Ubuntu 18.04 environment with 40GB storage size. The implementation of the network topology was performed using Mininet version 2.3 [5] along with a custom Ryu OpenFlow 1.3 Controller [1]. The type of network topology used in this study is a fat-tree topology. Figure 2 shows two examples of how the topology looks when the number of client leaf switch layers is 2(a) and 3(b). Switches encompassed within the bracket are all called the client leaf switches. Quality of Service (QoS) is enforced in these switches if the test case is Leaf-enforcement. If the test case is Core-enforcement, QoS is enforced in the core switch. Switch 7 in the case of (a) and Switch 15 in the case of (b).

In the experiments performed, the network also had a total of 70 client hosts divided as equally as possible across the client leaf switches in the first layer. All client hosts run both Apache Bench and VLCt. The network also has six (6) server hosts connected to server aggregate switch, Switch 8 in the case of (a) and Switch 16 in the case of (b). Three (3) servers function as HTTP servers running Python3 simple.http server inside them. The other three (3) function as Video on Demand (VOD) servers running VLC Streaming Media using VLC version 3.8. All links in the network run at the default 10Gbps of Mininet.

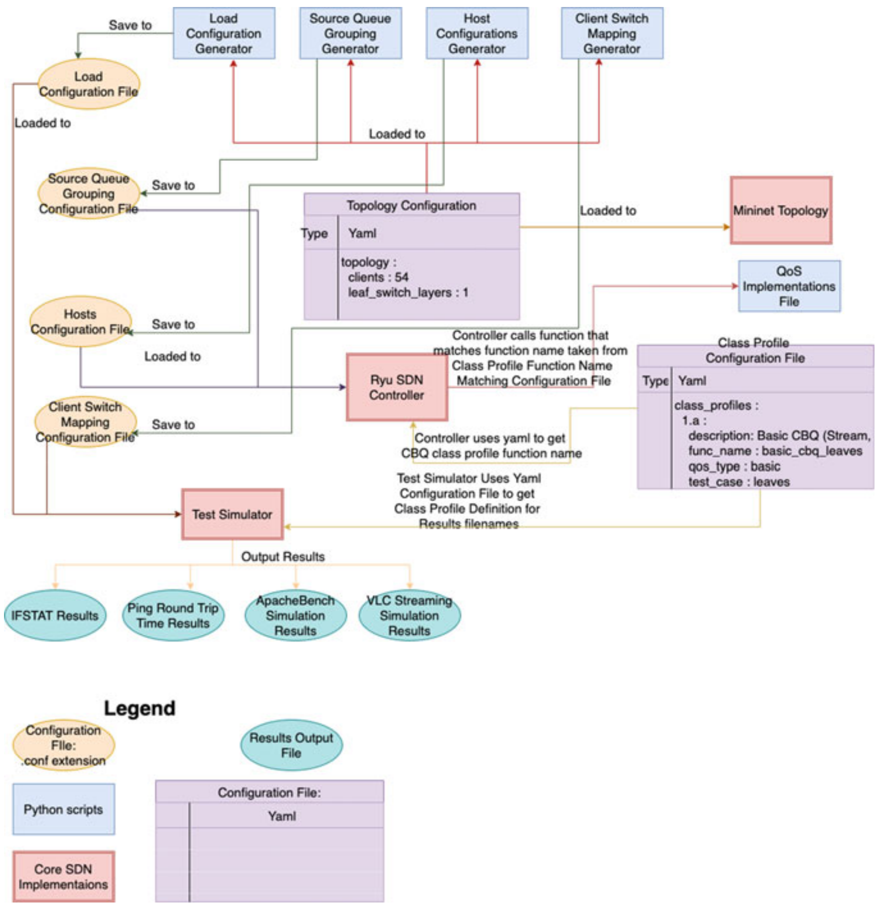
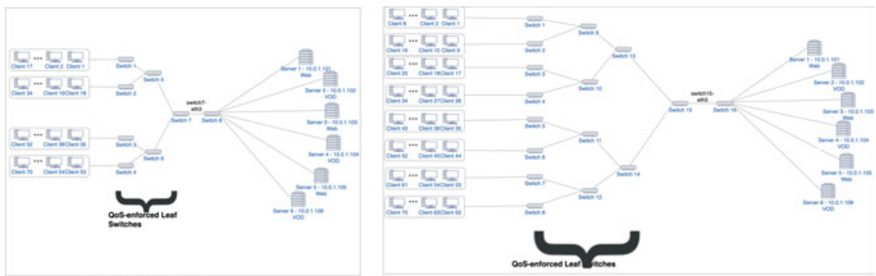


Fig. 1 Test framework architecture



(a) Network topology with 2 layers of client leaf switches

(b) Network topology with 3 layers of client leaf switches

Fig. 2 Sample virtual network topology used

4 Methodology

In this study, Quality of Service (QoS) mechanisms are tested in order to answer how layers in the topology affect their performance. QoS mechanisms used are all listed in Table 1. The experiments in this study focused on testing from 2 layers up to 6 layers of client leaf switches. This is mainly due to computational constraints. For every layer test case, the number of first layer switches is always 2^{layers}. The number of switches in the following layers will then only be half of the number of switches from its previous layer.

The simulations in this study follow the same simulations from Chato and Yu [3]. This simulation is also adapted in the test framework introduced by Regencia and Yu [8]. Each Class Profile listed in Table 1 is executed one at a time through the process shown in Fig. 3. Each Class Profile in this study was given a 5-min window to perform test simulations. The following tools were used to perform the simulations and get data results concurrently:

- Ifstat Bandwidth results—This tool is used to get Bandwidth In and Bandwidth Out for every second during the 5-min window. This was performed and executed at the Core Switch for all Class Profiles
- Ping Round Trip Time—Round Trip Time (RTT) was measured in milliseconds (ms) by sending Ping packets to all destination servers from each of the 70 client hosts. Each destination server has its own measurement but the overall result was calculated by getting the mean results of all destination servers.
- ApacheBench HTTP Results—ApacheBench was used to simulate the HTTP traffic to web servers. The data taken from this tool were the transfer rate, mean time per request in ms, and total data transferred.
- VLC Streaming Media statistics results—VLC Streaming Media software client take both De-multiplexer (Demux) Bytes Read (KB) and Demux Bitrate (in Kbps). The De-multiplexer takes feeds from disparate and separate streams and assembles them into a single coherent media stream for playing.

Table 1 Class profiles

CBQ class profile	CBQ class grouping	Switch QoS
Basic at leaf	Traffic protocol	Client leaf switches
Basic at core	Traffic protocol	Core switch
Source at leaf	Source IP address	Client leaf switches
Source at core	Source IP address	Core switch
Destination at leaf	Destination IP address	Client leaf switches
Destination at core	Destination IP address	Core switch
Source-destination at leaf	Source-destination IP address	Client leaf switches
Source-destination at core	Source-destination IP address	Core switch

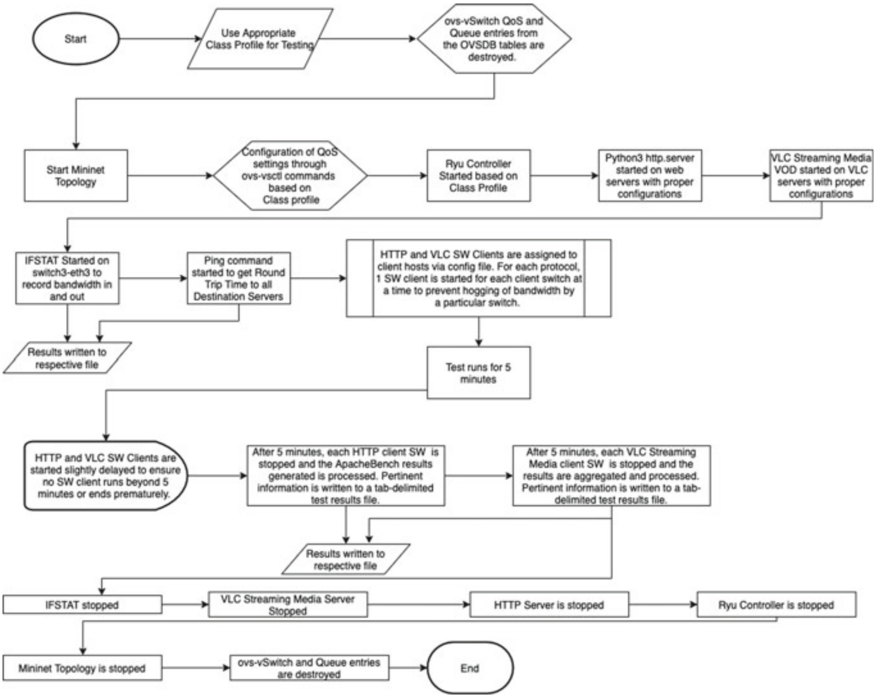


Fig. 3 Methodology flowchart based on Chato and Yu [3]

5 Results

The mean Quality of Service (QoS) performance results from layer 2 up to layer 6 can be found in Figs. 4, 5, 6, 7 and 8 respectively. Generally, it can be observed from the charts that for both Leaf-enforcement and Core-enforcement test cases, having less layers in the topology results to better performance. However, with regards to video streaming, the charts from Figs. 4, 5, 6, 7 and 8 show that layering does not have substantial impact to its performance. This is likely because the protocol is quite heavy and the additional switching enforcement is not too material.

For Apache Bench Transfer Rate, Figs. 4, 5, 7, and 8 show that when the network has 2, 3, 5, or 6 layers respectively, Leaf-enforcement of QoS performed better than Core-enforcement where we can conclude that in this aspect, the distributed nature of Software-Defined Networking is better than the traditional centralized enforcement of QoS. IFSTAT Bandwidth In and Bandwidth Out can also be generally observed to have similar results.

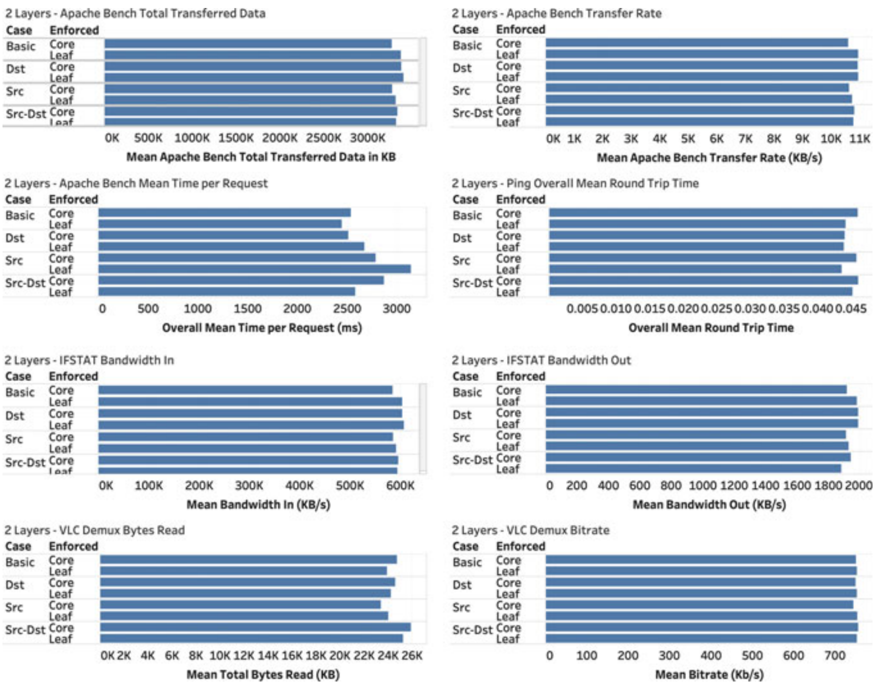


Fig. 4 2 layer results

For the latency tests, Destination Class-Based Queueing (CBQ) at the Leaf showed to have performed best as can be seen where 3 out 5 layer cases Destination CBQ at the Leaf performed best latency while in the other 2 layer cases, Destination CBQ at the Leaf performed second best latency.

However, it should also be noted that some tests indicate that the Core-enforcement algorithm performed better than the Leaf-enforcement algorithm. In order to test the significance of the result, a student's t-test was performed comparing both algorithms with significant level is set to $\alpha = 0.05$. If the p-value is less than $\alpha = 0.05$, then the difference will be considered as statistically significant. Otherwise, the difference will be considered as statistically insignificant.

The following instances show examples when Core-enforcement performed better than Leaf-enforcement and what the t-tests conclude with regards to the comparison.

- For VLC Demux Bitrate in 3 layer test case, Source CBQ at the Core (3rd) performed better than Source CBQ at the Leaf (5th). However, the t-test shows that its p-value is 0.9312 which is greater than $\alpha = 0.05$. Hence, the performance advantage of Source CBQ at the Core over Source CBQ at the Leaf for VLC Demux Bitrate in the 3 layer test case is statistically insignificant.

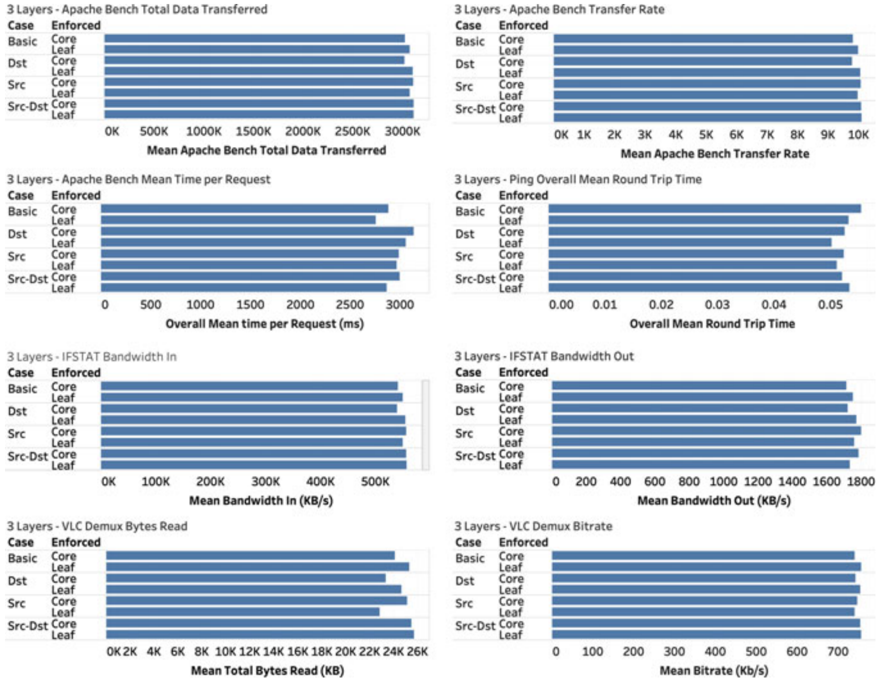


Fig. 5 3 layer results

- For VLC Demux Bitrate in 5 layer test case, Source CBQ at the Core (best) performed better than Source CBQ at the Leaf (3rd). However, the t-test shows that its p-value is 0.9522 which is greater than $\alpha = 0.05$. Hence, the performance advantage of Source CBQ at the Core over Source CBQ at the Leaf for VLC Demux Bitrate in the 5 layer test case is statistically insignificant.
- For Ping Round Trip Time latency test in 4 layer test case, Basic CBQ at the Core (4th) performed better than Basic CBQ at the Leaf (5th). However, the t-test shows that its p-value is 0.8851 which is greater than $\alpha = 0.05$. Hence, the latency advantage of Basic CBQ at the Core over Basic CBQ at the Leaf for VLC Demux Bitrate in the 4 layer test case is statistically insignificant.
- For Ping Round Trip Time latency test in 5 layer test case, Basic CBQ at the Core (3rd) performed better than Basic CBQ at the Leaf (7th). However, the t-test shows that its p-value is 0.4169 which is greater than $\alpha = 0.05$. Hence, the latency advantage of Basic CBQ at the Core over Basic CBQ at the Leaf for VLC Demux Bitrate in the 5 layer test case is statistically insignificant.

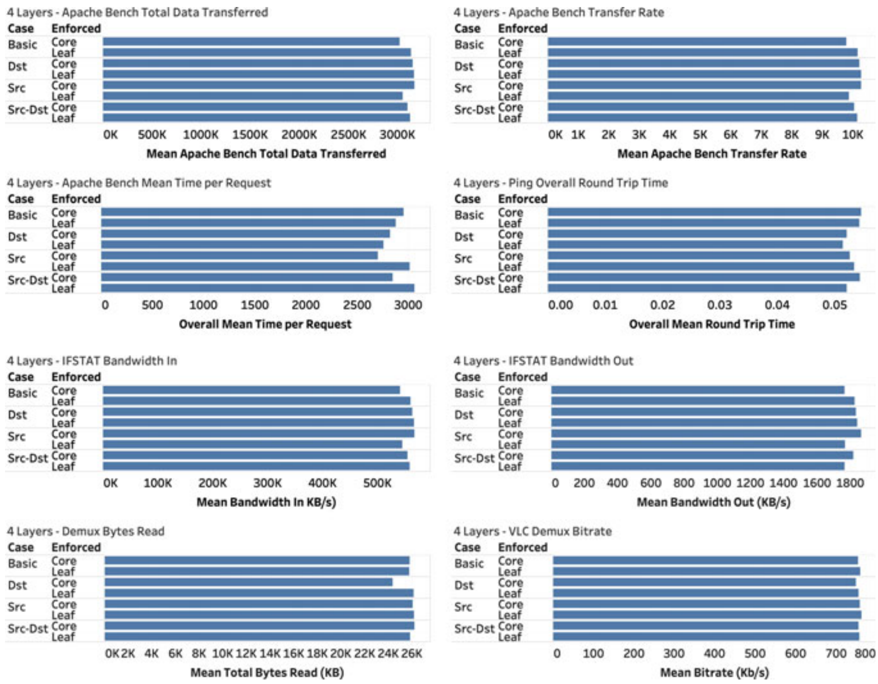


Fig. 6 4 layer results

- For Ping Round Trip Time latency test in 6 layer test case, Basic CBQ at the Core (3rd) performed better than Basic CBQ at the Leaf (7th). However, the t-test shows that its p-value is 0.1008 which is greater than $\alpha = 0.05$. Hence, the latency advantage of Basic CBQ at the Core over Basic CBQ at the Leaf for VLC Demux Bitrate in the 6 layer test case is statistically insignificant.

6 Conclusion

This study uses the testing framework for Quality of Service (QoS) algorithms and network topologies in order to test how layers in a network affect the performance of QoS which was introduced by Regencia and Yu [8] and is submitted to the CANDAR'20 Conference awaiting paper acceptance notification. The purpose for testing layers in the topology is to replicate a real-world networking scenario. Two types of QoS enforcements were tested and compared: Leaf-enforcement which is a distributed enforcement of QoS and Core-enforcement which is a centralized enforcement of QoS at the core switch. Having less layers in the network topology resulted to better performance in QoS for both Leaf-enforcement and Core-enforcement. How-

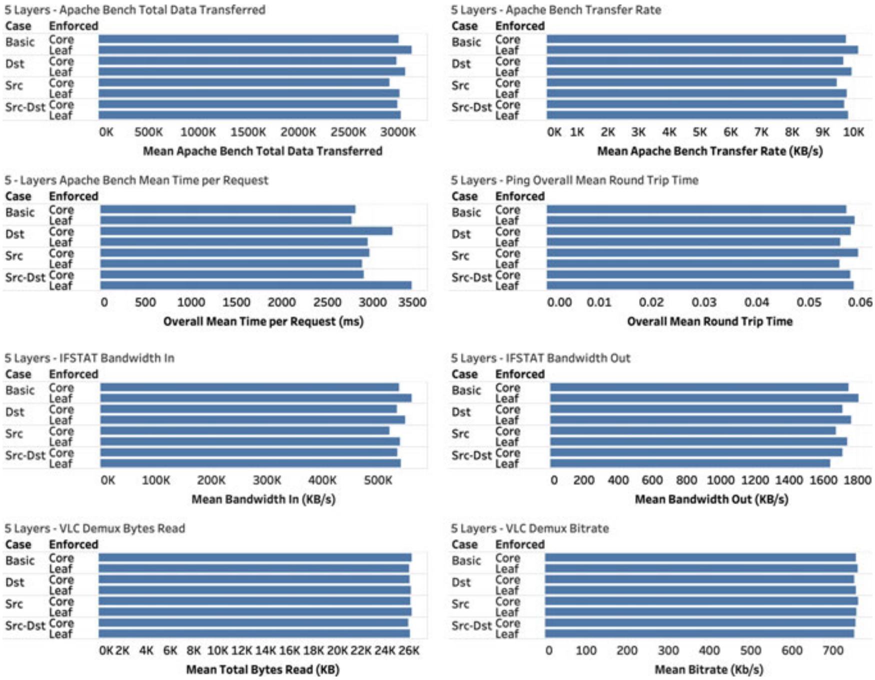


Fig. 7 5 layer results

ever, adding layers to the network topology does not create material disadvantage as can be seen from the results where Leaf-enforcement of QoS performed better or as good as Core-enforcement of QoS despite adding layers to the topology. Therefore, Software-Defined Networking logic has to be applied in many devices. This is despite the fact that enforcement in an SDN topology adds logic in more switches as the layers increase. Although it is noted that there were instances were Core-enforcement performed better than Leaf-enforcement, the student t-test results have shown that the difference in performance is not material and considered as insignificant.