QoS management for performance analysis of switched Ethernet networks

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Abstract: This research provides a simulation scenario for testing the efficacy of switched Ethernet as a controller network's communication medium. Ethernet has become the standard LAN technology due to its cheap cost and ease of implementation. When developing software, using Ethernet rather of a specialized industrial protocol for communication might save time and effort. Some of the most significant issues with utilizing Ethernet in controller networks have been eradicated with the advent of Fast Ethernet and micro-segmentation. This opens the door for interoperability between controller networks and larger corporate and international infrastructures. Queue management as a subject reveals several openings for satisfying needs for various service varieties. Simulation analysis using the NS2 network simulator is used for the assessment. The findings are put to use in analyzing and enhancing the communication performance of the multi-tier paradigm utilized in distributed automation. In the multi-tier concept, several suggested classes are utilized to prioritize various types of CNDEP traffic.

Keywords: : High-Speed Ethernet, Embedded Communication, and Modeling Simulations

Introduction

Among LAN protocols, Ethernet has the widest level of support. The widespread uptake that has resulted in its cheap cost and strong deployment has sparked a movement toward increasing its usage in manufacturing settings. When developing software, using Ethernet rather of a specialized industrial protocol for communication might save time and effort.

Embedded systems may be made available across WANs when an industry-standard TCP/IP stack is implemented atop Ethernet. This lays the groundwork for connecting the production floor to the company's internal network. Despite these perks, however, there are conditions that must be met. The control loop traffic is time-sensitive and must be given top priority.

There are several published publications that try to assess the usefulness of Ethernet in control networks. Most of them are focused on the communication channel that was established in the first implementations of the standards. Fast Ethernet has surpassed Shared Ethernet as the standard for business networking, and Gigabit Ethernet is quickly becoming the new standard. These norms not only facilitate speedier communication, but also enable switching-based isolation of collision areas and the imposition of full-duplex connections. According to, the shift in the scientific landscape has opened up new avenues of inquiry. Through simulation utilizing the NS2 network simulator as an assessment tool, this research aims to demonstrate the performance characteristics of switched Ethernet as a communication

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medium in controller networks. The widespread use of Internet technology across all spheres of human endeavor and the internationalization of trade and commerce have given rise to a new category of widely dispersed applications.

The tendency is also shared by embedded systems. Newly created software aims to better connect items to the internet. The systems installed in factories are linked to the corporate network and software. Using a multi-tiered architecture [7] is one technique to connect the automation systems on the manufacturing floor with the corporate information systems. Business logic is abstracted away from presentation logic and data storage, a technique borrowed from database systems' multi-tier design. The data layer is replaced by a controller network in the multi-tier architecture described in [7]. As long as functionality is kept separate, this improves availability and security. In this intricate distributed design, the network controllers only talk to the upper-tier (service) server, which acts as an adaptor for them. The implementation of a multi-tier architecture necessitates an analysis of the communication between and within the different levels of the structure. In this study, we suggest an assessment of the data tier's (the controller network's) interaction and communication. The controller network employs CNDEP [6] as its upper-layer communication protocol. This is an UDP-based application layer protocol. Ethernet is a nondeterministic technique for media access (CSMA/CD) that has been developed for usage in office networks.

This 1-persistent media access technique strives to provide all nodes "fair" use of the channel in terms of statistics. Ethernet's non-deterministic behavior in the event of collision is a major issue for control networks. Each node must pause transmission for a certain amount of time once a collision is detected. Using micro-segmentation, this problem may be effectively controlled. When devices are very micro-segmented, each one has its own "collision domain" where collisions never take place. Full-duplex channels further remove media concurrency, allowing for unrestricted transmission from any and all connected devices. Only the switch's internal fabric is used by both sides simultaneously. In addition, the standards have been updated to account for the fact that real-time traffic necessitates the use of channel scheduling algorithms, which were not originally enabled by early implementations of Ethernet. It's possible that cut-through and store-and-forward are the two default settings for most LAN switches. In the first setting, commutation occurs dynamically, meaning that a packet is transmitted as quickly as feasible. The second option waits for the whole packet to arrive before deciding whether to send it or discard it.

There is no need for the higher-level transport for the 802.1p standard to function [1, 5, 13]. The 802.3x standard has techniques for regulating data transfer rates. Real-time communication performance may be very important and may suffer without proper flow management. However, when used in the controller network, flow control may ensure the delivery of critical frames while also preventing frame loss. All the devices on the channel may decrease the quantity of data they receive with the help of flow control, which can be applied either link by link or end to end. Unlike other methods of regulating traffic, link-by-link analysis focuses on a single connection between nodes.

When the receiver's time is at a premium, it will notify the sender through the direct connection. If the signal's source is not the same as the transmitter, the signal must be sent back across each connection until it reaches the source. To implement end-to-end flow control, switches on both ends of the connection must coordinate to reduce throughput to the source end stations. Since packets must be kept or deleted until this information is broadcast, flow control lessens, but does not do away with, the need for buffers. [1, 5]

Commercial off-the-shelf (COTS) Ethernet switches prevented their usage in time-critical applications due to their unpredictable behavior. If packets are arriving at the switch ports at an unpredictable rate, the queues may fill up and packets may be dropped. Additionally, most COTS switches use First In First Out (FIFO) queues, which may cause significant delays for time-sensitive packets. The latter issue may be alleviated to some extent by establishing traffic priorities and implementing priority queues. However, only 8 priority levels are taken into account, which is insufficient to provide efficient priority scheduling, according to the IEEE 802.1D standard. To get around these restrictions, many Real-Time Ethernet (RTE) protocols have been developed, all of which use the strengths of the original Ethernet standard. There are two major families of RTE protocols. In the first category, superior Ethernet switches are used. Among them are TTEthernet [7] [8] and PROFINET IRT [9], both of which were designed with time-triggered operations in mind. Overlay protocols, which govern the traffic sent to COTS switches, have also been the subject of much study and subsequent commercialization as a second class of RTE protocols. Ethernet POWERLINK [10], which has a master-slave architecture, is a good example for this category. Unfortunately, it was discovered that most RTE protocols available in the literature suffer from serious shortcomings when it comes to handling dynamic real-time applications. These applications are characterized by volatile needs that are also subject to high timeliness requirements (for example, message streams may be added, withdrawn, and altered during run-time). Static scheduling is often used in RTE protocols that guarantee strong determinism, which hinders their ability to effectively adapt to changing communication needs in real time. To address the need for real-time networked embedded systems to be adaptable, dynamic, and have efficient resource allocation, two methods have been proposed. The first, known as Flexible Time-Triggered Switched Ethernet (FTT-SE) [11], was designed to work with commercial off-the-shelf (COTS) Ethernet switches, while the second, known as Hard Real-Time Ethernet Switching architecture (HaRTES) [12] [13], makes use of specially equipped Ethernet hubs. The master-slave approach lies at the foundation of both suggested systems, which were first developed for a network with a single switch. Both the FTT-SE and HaRTES designs can accommodate non-real-time, periodic, and ad hoc traffic in real time. To further facilitate dynamic reconfiguration, middleware [14] was created by using an online admission control [15] with linear time complexity. These two architectural types are what we've been working on.

Need for Ethernet QoS.

Priority Marking [15] is the current method through which QoS is supported in native Ethernet. The three Class of Service (CoS) bits in the VLAN header are used by Priority Marking to give certain packets of data higher priority. While priority marking helps to distinguish between various forms of traffic, it does not provide equal access to bandwidth or ensure that all users are treated equally. Existing Ethernet QoS mechanisms are node-specific and spatially-dependent. Therefore, a distributed QoS mechanism is necessary to guarantee fairness and bandwidth in Ethernet, improving the current level of quality of service. One such method is discussed in this paper.

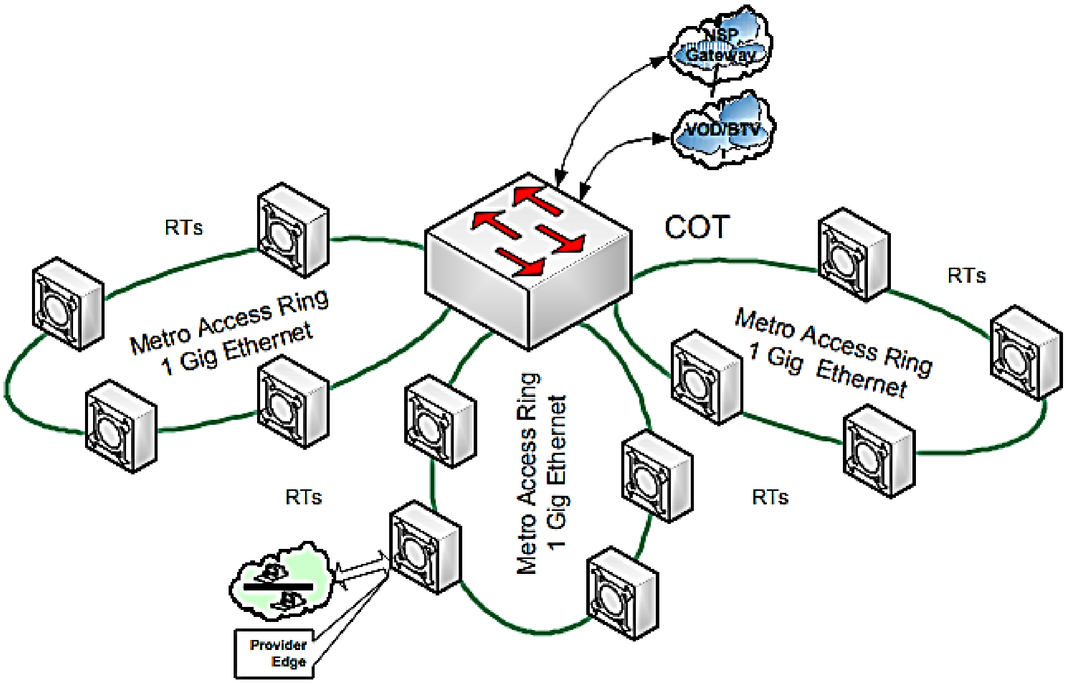

Figure 1 Metro Ethernet Network with RT's connected to COT

When Ethernet is extended into the access network using a ring topology, there are a number of potential quality-of-service problems that must be addressed. For its protection and fault tolerance features, the Ring topology is selected, as well as its current widespread usage in metro networks. Rings' multicasting capabilities outperform those of other topologies, such as mesh, in terms of throughput.

Literature Review

Chisa Kobayashi et.al.,(2020) This research investigates a technique for SPQ-based QoS estimation for vehicular Ethernet. Despite being the most basic kind of control, SPQ has yet to have its estimate technique of QoS clarified for a multi-switch in-vehicle Ethernet. Through simulation, the writers assess SPQ's quality of service. The authors prove the efficacy of their equation for calculating QoS by adjusting the regression analysis to fit the data.

Pablo Fondo-Ferreiro et.al.,(2018) In this article, we'll go through how to deploy an ONOS application that uses Energy-Efficient Ethernet connections between two switches to load-balance incoming traffic and reduce power consumption. To accommodate the needs of real-time traffic coming to the link aggregate, we provide two alternatives to the plain technique, which might cause excessive traffic latency. Providing time-sensitive traffic does not account for an excessive percentage of total traffic demand, our final application maintains low energy consumption, as shown by our experiments.

Inés Álvarez et.al.,(2016) An increasing number of people are working to perfect embedded technologies that can be used in unexpected, ever-evolving settings. The network is only one more component of the design that has to be adaptable in distributed embedded systems (DESs). However, there is a noticeable shift in the business world toward using Ethernet-based protocols for DES networks. However, Ethernet does not provide sufficient help for RT communications, including the mixing of various RT traffic and the online control of the Quality of Service (QoS). Multiple Flexible Time-Tiggered (FTT) protocol over Ethernet solutions were developed to address these issues. Since FTT is a master/multi-slave protocol, it can efficiently carry both real-time and non-real-time data, and it also includes tools for dynamically adjusting the network's quality of service, such as Admission Control (AC). The AC is a crucial aspect of managing a network online since it ensures that all users have access to the necessary quality of service. This article details the development of an AC simulation model for the FTT HaRTES switch and its subsequent implementation in OMNeT++, along with an initial performance analysis.

Switched Ethernet Technology

Ethernet was first created as a means of connecting computers to one another. These days, IEEE has a set of standards outlining the many levels of a network that may be used with Ethernet. Ethernet has progressed from a bus architecture to a star topology with switching hubs (sometimes called Ethernet switches) in addition to improvements in transmission speed. Ethernet generates a single collision domain since it employs a common media for communication. When a message is broadcast in the medium, it is received by every node. Additionally, the collision issue is dealt with by using an arbitration technique known as Carrier Sense Multiple Access with Collision Detection (CSMA/CD). A node acts as a buffer for the message until the shared media is free to receive new information. Because every node is acting in accordance with the same principle, a collision is unavoidable. In the event of a collision, all associated transmissions are cancelled, the nodes wait for a predetermined length of time, and then begin retransmitting the messages. This process will keep repeating itself until a collision-free transmission has occurred. The primary impetus for deploying Ethernet switches was to solve the issue of message retransmission, which results in inefficient bandwidth use. Since a switch isolates each of its ports into its own collision domain, it mitigates the effect of the original Ethernet's non-deterministic CSMA/CD arbitration. The fundamentals of switched Ethernet are outlined, and then real-time protocols for using switches are discussed.

The prevailing standard for switches, IEEE 802.1D, implements FIFO queues for each output port. When a packet is received by a switch, it checks the destination address and, if it matches, places the packet in a queue for later transmission. For as long as it takes to send the messages ahead of it in the line, the message will remain in the queue. For each output port, IEEE 802.1D takes into account a certain number of parallel queues with varying degrees of priority. Priority queued messages are delivered in order of priority, beginning with the highest priority queue. Figure 2 shows the fundamental design of an Ethernet switch.

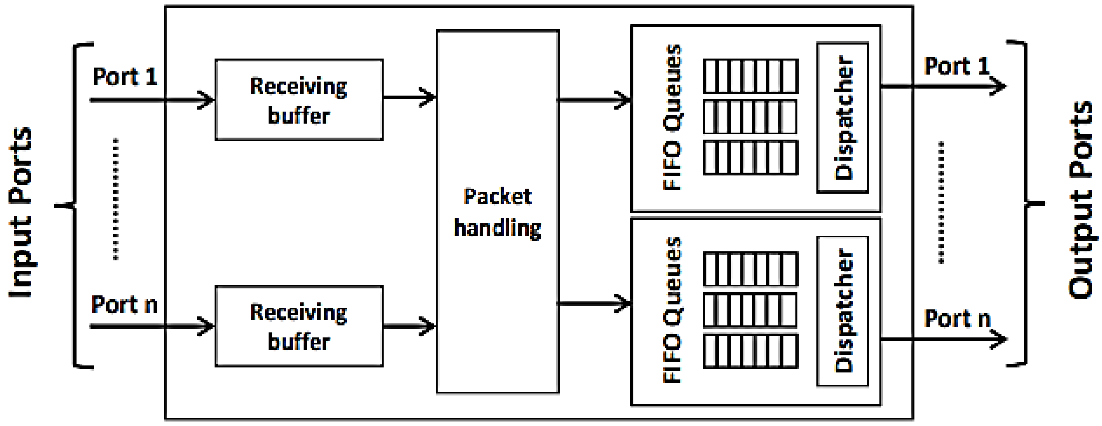

Figure 2: The Switch Internal Structure

The IEEE 803.2 working group defines Ethernet as part of the LAN family of network protocols. With the development of network technologies, various extensions have been established since the standard's publication in 1985 [1] [2] to accommodate new network media and increased data rate compatibilities. These days, most LAN settings make extensive use of optical fiber networks, as shown by Ethernet's capacity for transmission distances of up to 150 kilometers. Ethernet networks simultaneously use the physical and data connection layers to transmit packets and frames [3]. Ethernet nodes exchange information by transmitting packets, with the Ether-Type field in the frames used by the receiving node's operating system to choose which protocol module to use [4].

Ethernet's performance is the primary concern in every local area network (LAN). Deliveries per second, throughput, latency, collision probability, bandwidth efficiency, packet loss ratio, bit error rate, queuing delay, and jitter are all examples of network characteristics used to determine quality of service in the telecommunications industry [5]. Ethernet's maximum transmission unit (MTU) is 1500 bytes, which is substantially larger and has the potential to decrease network performance [6]. Congestion and packet loss become more likely, however, as packet sizes get larger during transmission. Congestion and its associated effects on the quality of service (QoS) in an Ethernet network may be mitigated by segmenting the bigger packets into smaller ones. Queuing in the Ethernet's switch and router's buffer is affected by the packet's size as it travels between nodes. This affects the rate at which packets are received and sent, and hence the pace at which they are processed [7]. When packets become too large for the maximum transmission unit (MTU), they cause delays in the transmission from beginning to finish [7]. Segmentation slows down the data transfer rate and lowers the network's quality of service. As a result, packets that are too big cause delays in the network, while those that are too little cause more errors and take longer to send [8]. This research simulates an Ethernet network with bigger packets and analyzes the impact on quality of service and network performance.

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Previous research in [9] shows that bigger packet size reduces the network's energy efficiency by slowing down the data throughput of the application. Optimal packet size enhances performance across a wireless LAN's error-prone channel, according to another research [10]. Prioritization of traffic, as shown by Carmo et al. in [2], may impact network performance as a whole. Therefore, reducing the amount of data packets being sent between Ethernet nodes may have an effect on the efficiency of the network as a whole [11].
Based on previous studies' results, this study assesses the quality of service (QoS) of an Ethernet network simulated using Riverbed modeler, which shows the effects of altering packet size on the network's QoS and performance characteristics. The goal of this segmentation procedure is to compare the transmission performance of bigger packets than the maximum transmission unit (MTU) to that of smaller packets, taking into account factors such as throughput, bit error rate, and latency.

Methodology

After reviewing the research on how Ethernet LANs have been implemented in various scenarios, we can calculate its latency, efficiency, loss of packets ratio, bit error rates, and queuing delay. Real-time simulation of the network's creation based on the literature review requires an appropriate simulation tool.

OMNET++, NS-2, NS-3, Riverbed [16], and MATLAB were only few of the network modeling tools we used to perform qualitative analysis in this study. Riverbed molder 17.5 was chosen for this simulation [17] because to its popularity and ease of use in the development environment. The simulation was executed on a Core i3-powered computer. The Fast-Ethernet protocol is used in the examined Ethernet network. Fast Ethernet is being considered because of its broad usage in optical communication and the need for speeds of up to 10 Gbit/s [18] in a laboratory environment. The elements of an Ethernet LAN testbed are a switch, two hubs, and sixteen client stations. In this setup, two hubs are connected to a total of eight clients through a fast Ethernet link running at 10 Mbps over a full duplex 10BASE_T connection. In a full duplex setup, the hub and switch may be used by both the sending and receiving clients to send and receive multiple packets. If a packet's data payload is too large for a single unit of transmission, it is split into a sequence of fragments. Larger packets need segmentation to ensure they get at their destination in a timely manner with all of the required data. In this proposed network, the larger packets are broken down into two halves of 1500 and 1024 bytes. Network performance is evaluated by simulating real-world use cases, which might vary widely in terms of throughput, latency, packet loss ratio, queuing delay, and bit error rate. In this testbed, we send packets of varied sizes and run several Riverbed simulations to see how they perform.

Finally, thorough information has been collected from an Ethernet network simulator. When the simulation is executed, the appropriate graphs are produced for analysis. With the aid of the graphs, the effect of changing Gigabit network properties may be measured.

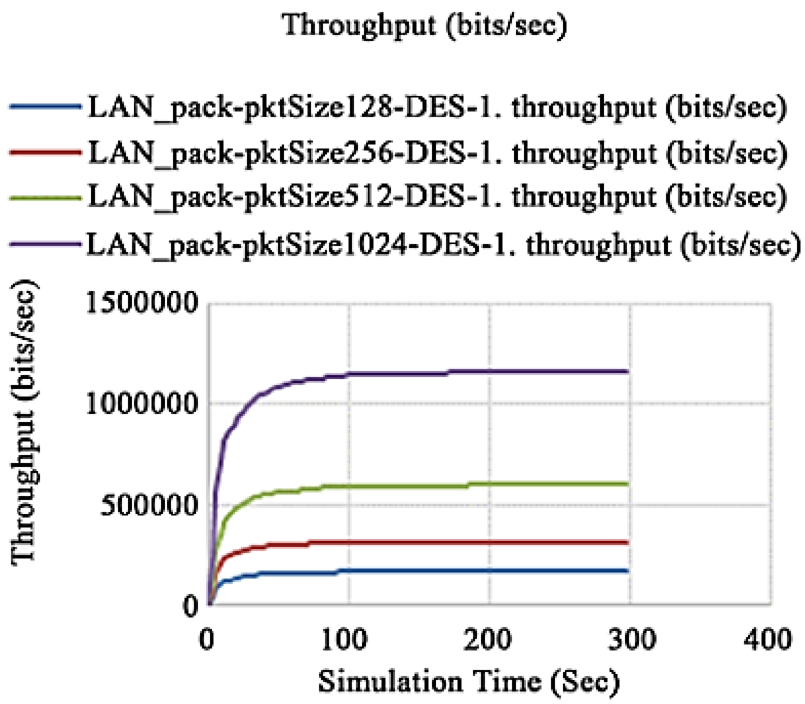

Figure 1. Throughput (bits/sec) at switch.

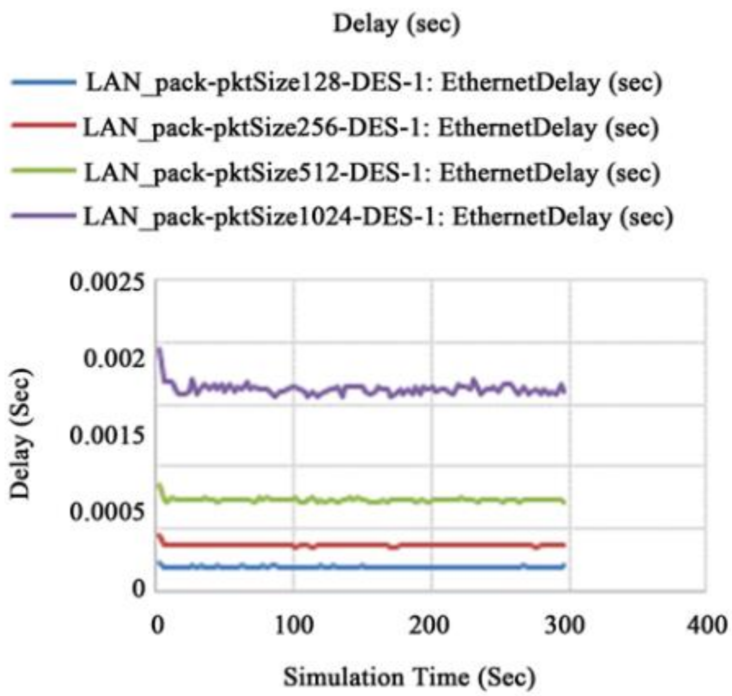

Figure 2. Network delay (sec) for 128, 256, 512 and 1024 Bytes packet size.

Conclusion

The provided simulated scenarios evaluate Fast Ethernet's viability as a communication channel for geographically scattered embedded devices. Each case study is grounded on the specifics of a real-world, distributed automation system with many tiers. The results show that 802.1p-enabled fast Ethernet switching are a worthwhile investment for setting up controller networks. Priority queues and dedicated bandwidth allow time-sensitive traffic to meet its strict deadlines. It is expected that latency and jitter for high-priority traffic will be sufficiently low to support real-time applications. UDP is suitable for these applications because to its low rate of error for high as well as moderate priority traffic, which negates the need for more complex transport. Besides revealing the bounds of specific characteristics for the examined network, like the number of managers in just one network into the queue buffer size, the results may be used as a basis for calculating the quantity of priority subclasses and mappings of traffic and classes..

References

1. C. Kobayashi and Y. Ito, "Study on a Method of Estimations QoS for In-vehicle Network with SPQ of IEEE802.1," *2020 IEEE 9th Global Conference on Consumer Electronics (GCCE)*, Kobe, Japan, 2020, pp. 684-685, doi: 10.1109/GCCE50665.2020.9291855.
2. P. Fondo-Ferreiro, M. Rodríguez-Pérez and M. Fernández-Veiga, "QoS-aware Energy-Efficient Algorithms for Ethernet Link Aggregates in Software-Defined Networks," *2018 26th International Conference on Software, Telecommunications and Computer Networks (SoftCOM)*, Split, Croatia, 2018, pp. 1-5, doi: 10.23919/SOFTCOM.2018.8555789.
3. I. Álvarez, M. Knezic, L. Almeida and J. Proenza, "A first performance analysis of the Admission Control in the HaRTES Ethernet switch," *2016 IEEE 21st International Conference on Emerging Technologies and Factory Automation (ETFA)*, Berlin, Germany, 2016, pp. 1-4, doi: 10.1109/ETFA.2016.7733688.
4. T. Kikuchi and R. Kubo, "Variable gain PI-based cyclic sleep control with anti-windup technique for QoS-aware and energy-efficient Ethernet PONs," *2016 21st OptoElectronics and Communications Conference (OECC) held jointly with 2016 International Conference on Photonics in Switching (PS)*, Niigata, Japan, 2016, pp. 1-3.
5. "IEEE Approved Draft Standard for Service Interoperability in Ethernet Passive Optical Networks (SIEPON)," in *IEEE P1904.1/D3.1, December 2016* , vol., no., pp.1-886, 1 Jan. 2016.
6. A. Gomez-Sacristan, V. M. Sempere-Paya and M. A. Rodriguez-Hernandez, "Virtual Laboratory for QoS Study in Next-Generation Networks With Metro Ethernet Access," in *IEEE Transactions on Education*, vol. 59, no. 3, pp. 187-193, Aug. 2016, doi: 10.1109/TE.2015.2498120.
7. B. N. Amel, B. Rim, J. Houda, H. Salem and J. Khaled, "Data distribution service timing and buffering management for Ethernet," *2015 2nd World Symposium on Web Applications and Networking (WSWAN)*, Sousse, Tunisia, 2015, pp. 1-6, doi: 10.1109/WSWAN.2015.7209087.
8. P. Sanmartin, J. Cardona and D. Jabba, "QoS in heterogeneous networks based on DWDM technology," *2015 CHILEAN Conference on Electrical, Electronics Engineering, Information and Communication Technologies (CHILECON)*, Santiago, Chile, 2015, pp. 339-344, doi: 10.1109/Chilecon.2015.7400399.

9. J. C. Moon, B. M. Cheon, J. D. Park and J. W. Jeon, "Comparison of IEEE802.1Q and IEEE802.1AVB in in-vehicle network implemented in embedded system," *2015 IEEE International Conference on Information and Automation*, Lijiang, China, 2015, pp. 1491-1496, doi: 10.1109/ICInfA.2015.7279521.
10. A. Dixit, B. Lannoo, D. Colle, M. Pickavet and P. Demeester, "Delay models in ethernet long-reach passive optical networks," *2015 IEEE Conference on Computer Communications (INFOCOM)*, Hong Kong, China, 2015, pp. 1239-1247, doi: 10.1109/INFOCOM.2015.7218499.
11. I. -S. Hwang, A. Nikoukar, A. T. Liem and K. -C. Chen, "A new architecture for multicasting live IPTV traffic in ethernet passive optical network," *2013 International Conference on Electronics, Computer and Computation (ICECCO)*, Ankara, Turkey, 2013, pp. 60-63, doi: 10.1109/ICECCO.2013.6718228.
12. Y. Chen and I. Darwazeh, "Quality of service (QoS) analysis of an Internet traffic trace over gigabit Ethernet," *ICT 2013*, Casablanca, Morocco, 2013, pp. 1-4, doi: 10.1109/ICTEL.2013.6632116.
13. A. T. Liem, "P2P locality awareness architecture in Ethernet Passive Optical Networks," *2013 International Conference on QiR*, Yogyakarta, Indonesia, 2013, pp. 111-115, doi: 10.1109/QiR.2013.6632547.
14. A. Dixit, B. Lannoo, G. Das, D. Colle, M. Pickavet and P. Demeester, "Dynamic bandwidth allocation with SLA awareness for QoS in ethernet passive optical networks," in *Journal of Optical Communications and Networking*, vol. 5, no. 3, pp. 240-253, 1 March 2013, doi: 10.1364/JOCN.5.000240.
15. Hui-Tang Lin, Chia-Lin Lai and Yu-Chih Huang, "Dynamic bandwidth allocation with QoS support for integrated EPON/WiMAX networks," *2013 IEEE 14th International Conference on High Performance Switching and Routing (HPSR)*, Taipei, 2013, pp. 74-79, doi: 10.1109/HPSR.2013.6602293.