TELKOMNIKA, Vol.16, No.1, February 2018, pp. 200~209
ISSN: 1693-6930, accredited **A** by DIKTI, Decree No: 58/DIKTI/Kep/2013
DOI:10.12928/TELKOMNIKA.v16i1.7674

Capacity Improvement and Protection of LTE Network on Ethernet Based Technique

Fadli Sirait*, Akhmad Wahyu Dani, Triyanto Pangaribowo
Department of Electrical Engineering, Universitas Mercu Buana
Jakarta, Indonesia
*Corresponding author, e-mail: fadli.sirait@mercubuana.ac.id

Abstract

High demands for data rates in mobile communications is the reason for developing broadband wireless access technologies. Long Term Evolution (4G LTE) networks which offer significantly higher data rates and require suitably higher capacity backhaul networks. To prepare for the high data rates usage in 4G LTE, operators are using ethernet services in terms of backhaul connectivity. Protection packet switching developed to anticipated network failure on ethernet based network technology. The failures in the network include the link fails to connect to each network element, the network element fails to transfer the data to the destination, or the quality drops below the standard. In this paper we used two ethernet based technique, namely Ethernet over SDH and MPLS-TP with ring protection to anticipated network failure on these techniques. Furthermore, we measured performance of network by measuring and comparing the throughput, latency and jitter between Ethernet over SDH and MPLS-TP. We used bandwidth capacity 240 Mbps as plant bandwidth link and worked in MIMO 2 × 2. The results of measurements indicated that MPLS-TP with ring protection is the best technique to enhanced the performance of LTE network.

***Keywords**: LTE, MPLS-TP, Ethernet over SDH, Protection Switching, Ring Protection*

Copyright © 2018 Universitas Ahmad Dahlan. All rights reserved.

1. Introduction

The 4th Generation Long Term Evolution (4G LTE) is an emerging technology to address the needs of high demand for the data rate. LTE aims to offer a minimum of 100/50 Mbps DL/UL (Downlink/Uplink, 1 sector, 20MHz spectrum) and up to 1 Gbps DL (3 sectors, DL/UL of 300/150 Mbps per sector) per LTE Base Station (eNB) [1]. Moreover, there is a need in terms of very high link utilization (<<100 percent) to support the improvement of customer services such as multimedia distribution, e-Commerce, and cloud computing or gaming systems as a part of future converged Industrial Internet of Things (IIoT) [2]. Ethernet based technique is developing technology to support the backhaul capacity of LTE. Despite having such advantage, there is one big issue in ethernet networks in terms of survivability focusing on protection switching.

Aleksandra et al [3] have describe that Carrier Ethernet, one of the candidate technologies for mobile backhaul, protects the network from users that want to flood the network with their data and manages to keep the delay experienced by other users low. Andrei et al [4] have analyzed the impact of backhaul packet delay (latency) on the LTE S1-U interface, which provides user plane transport between the Core Network and the Evolved NodeBs. Andrei et al [5] have analyzed the impact of backhaul packet loss by focusing on the LTE S1-U interface, which provides user plane transport between the Core Network (CN) and the Evolved NodeBs (eNBs). Yi Shi et al [6] introduced a novel wireless backhaul framework for small cell networks by introducing a new backhauling component, which is referred to as Type-A relay in order to capable of communicating simultaneously with two macrocells by leveraging the downlink resource of one cell as well as the uplink resource of the other, which effectively operates in full-duplex mode without incurring additional costs to acquire carrier resources. Vijayalakshmy et al [7] presented the analyzing of convergence of 3G (3rd Generation), IEEE 802.16, IEEE 802.11 with an LTE backbone network for improving the network performance. Christian et al [8] reviews the use case for MPLS-TP ring protection switching, how one of the proposed mechanisms, namely MPLS-TP Ring Protection Switching (MRPS), can address the

Received October 26, 2017; Revised December 1, 2017; Accepted January 10, 2018

requirements to support the packet transport reliability and some possible enhancements to the MRPS base mechanism. Wenjun et al [9] have proposed a method of ring protection to reduce the amount of packet loss. Jeong-dong et al [10] have discussed a linear protection switching mechanism on a mesh-based MPLS-TP network and it is compatible to other types of network topologies. Chang-Gyu et al [11] have presented a finding that the rapidly developing computer networking technology, the Software Defined Networking (SDN), can be used to manage MPLS-TP by using Transport-SDN (T-SDN) controller. Shicheng et al [12] proposed a protection mechanism in Passive Optical Network (PON) to achieve high availability. Amra at al [13] presented the result of practical performance benchmark analysis of the state-of-the-art procedures for restoration and protection of Ethernet over SDH networks. Patteti et al [14] describe that in LTE there is 100.8 Mbps for single chain, therefore in this paper, we used LTE system with 2 2 MIMO (2T2R), then the throughput will be two times of single chain throughput. *i.e*. 2 x 01.6 Mbps. Patteti et al [13] also describe that there is 25% of overhead used for controlling and signaling. So the effective throughput will be 151.2 Mbps.

In this paper, we used Ethernet over SDH and MPLS-TP to describe performance of the LTE network. On the other hand, there is still problem exist in these technique in terms of network failure, therefore, to overcome this problem, we are implementing ring protection method on Ethernet over SDH and MPLS-TP based network and then analyzing and comparing performance of these network. There are four Quality of Service (QoS) parameters that are tested in this paper, namely throughput utilization, jitter, latency, and recovery time. We used these parameters to determine that the quality of these network with ring protection is not lower than the quality of the main network.

The rest of this paper is organized as follows: Ethernet Based Networks is presented in Section 2, in Section 3 Ring Protection on Ethernet Based Network is describe, in Section 4 Impairment Testing is described, in Section 4 the Results and Analysis are discussed, and in Section V the Conclusion of this paper is presented.

2. Ring Protection on Ethernet Based Networks

2.1. Ring Protection on Ethernet over SDH

In Figure 1, it can be seen that the ring protection is presented as a red ring. The ring protection is working when the main ring fails to work. The scenario in this section is the main link between MUX-SDH-1 and MUX-SDH-3 is disabled manually (indicated with red x marks), then the packets will travel on the ring protection network automatically. The BER Test Ethernet is used to measure the QoS on the ring protection network. Then the main ring is enabled again and the packets switched back to the main ring. The recovery time is the time needed for the packets to revert back to the main ring. In this step throughput, jitter latency and recovery time is measured.

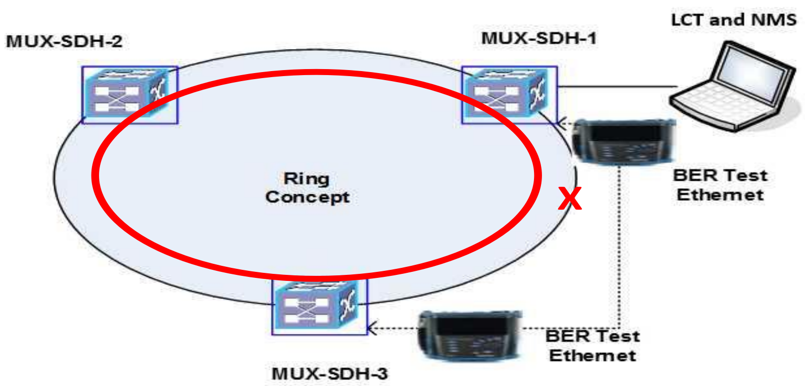

Figure 1. Ethernet over SDH with Ring Protection Topology

2.2. Ring Protection on MPLS-TP

In Figure 2 it can be seen that the ring protection is presented as a red ring. The ring protection is working when the main ring fails to work. The scenario in this section is the main link between NE_MPLS-TP_1 and NE_MPLS-TP_2 is disabled manually (indicated with red x marks), then the packets will travel on the ring protection network automatically. The BER Test Ethernet is used to measure the QoS on the ring protection network. Then the main ring is enabled again and the packets switched back to the main ring. The recovery time is the time needed for the packets to revert back to the main ring. In this step throughput, jitter latency and recovery time is measured.

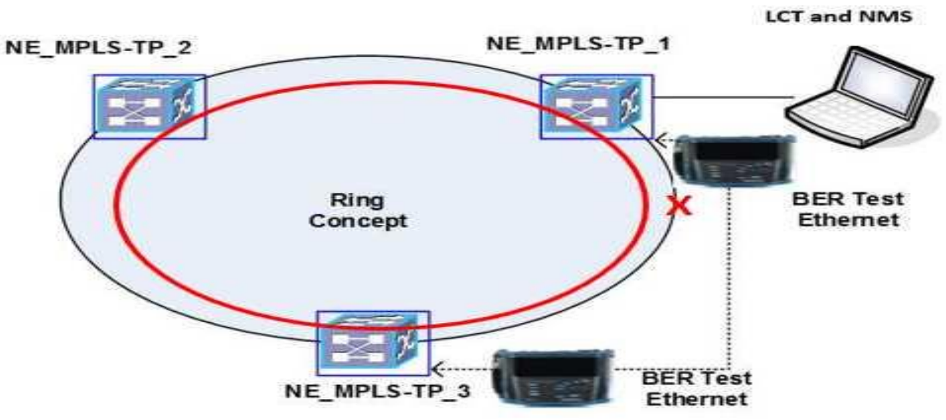

Figure 2. MPLS-TP with Ring Protection Topology

3. Impairment Testing for LTE Networks

Impairments is affecting to traffic packets traversing the LTE networks. The cause for these impairments are cumulative random events (e.g. busy hours, high profile events, panic usage, localized service disruptions, dynamic routes and paths for packets, faulty or overloaded network elements) [14]. RFC 2544 Standard testing are using to validate the Quality of Services (QoS) in LTE networks. The RFC 2544 is a standard developed by the Internet international standardization body, the Internet Engineering Task Force (IETF), which contains the necessary testing methods to measure the quality of an Ethernet network. The parameters that are testing in [16] are as shown in Tables 1, 2 and 3.

Table 1. Standard for Throughput

Category	Throughput
Very Good	76% - 100 %
Good	51% - 75 %
Modearte	25% - 50 %
Bad	< 25%

Table 2. Standard for Jitter

Category	Throughput
Very Good	0 ms
Good	0 – 75 ms
Modearte	76 – 125 ms
Bad	126 – 225 ms

Table 3. Standard for Latency

Category	Throughput
Very Good	$t_{\text{end to end}}$ < 150 ms
Good	150 ≤ $t_{\text{end to end}}$ ≤ 300 ms
Modearte Bad	$t_{\text{end to end}}$ > 450 ms

According to the ITU-T standard, the G 803.2, on Ethernet ring protection switching, the standard recovery time is less than 50ms.

4. Results and Analysis

In this section, we provide the measurements results to verify the performance of network quality for all the frame sizes measured. There are seven difference sizes of frame length that we used during measurement process, which are 64, 128, 256, 512, 1024, 1280, and 1518 fit to testing standard RFC 2544 [16].

4.1. Throughput on the Main Ring Network

Figure 3 presents the test results of throughput parameter values with different frame length on the main ring, which could be seen that the actual link plan for throughput is 240 Mbps for all frame sizes. The test results for Ethernet over SDH technique is varied from 224.94 Mbps to 225.2 Mbps for all frame sizes. Whereas, the test results for MPLS-TP technique is 240 Mbps for all frame sizes.

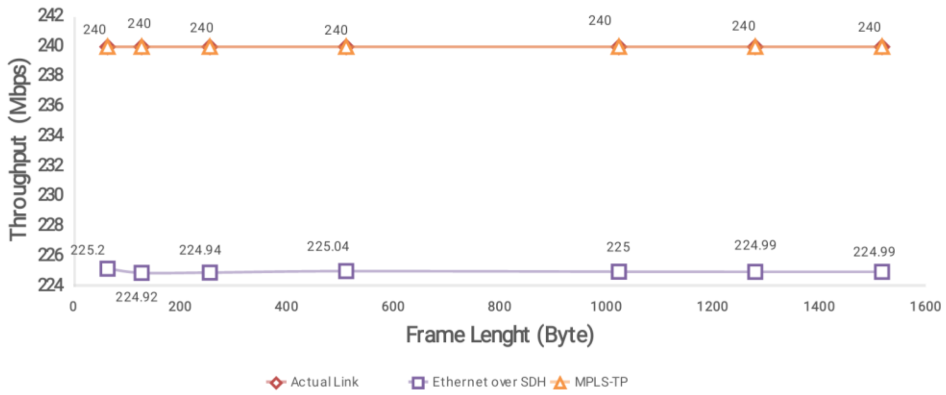

Figure 3. The Value of Throughput on the Main Ring for Actual Link Plan, Ethernet over SDH and MPLS-TP

Figure 4 indicated the throughput utilization of those techniques on the main ring, where the throughput utilization for Ethernet over SDH varied from 93.72 % to 93.83 % for all frame sizes, whereas the throughput utilization for MPLS-TP is 100 % for all frame sizes.

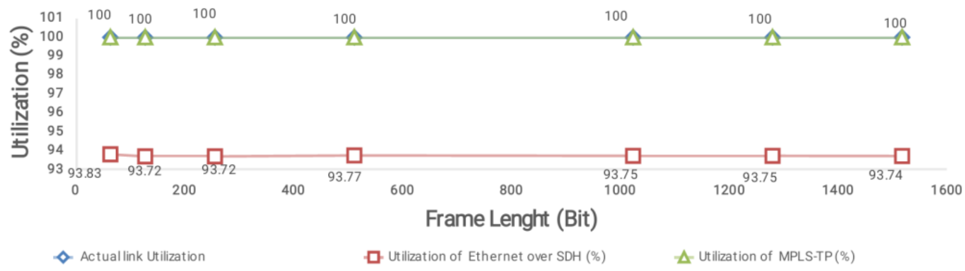

Figure 4. The Value of Throughput on the Main Ring in Terms of Utilization in Percentage from Actual Link Plan, Ethernet over SDH and MPLS-TP

From Figure 3 and Figure 4, we can see that there is gap between Ethernet over SDH technique and actual link plan in term of throughput values, where the value of throughput from the Ethernet over SDH technique didn't reach the defined value that is 240 Mbps. Whereas there is no gap between MPLS-TP technique and actual link plan.

4.2. Frame Loss on the Main Ring Network

Figure 5 shows the frame loss of Ethernet over SDH on the main ring and MPLS-TP on the main ring with different frame length. The results showed the frame loss values of Ethernet over SDH on the main ring varied from 14.8 Mbps to 15.08 Mbps for all frame sizes, whereas, there is no frame loss in MPLS-TP on the main ring.

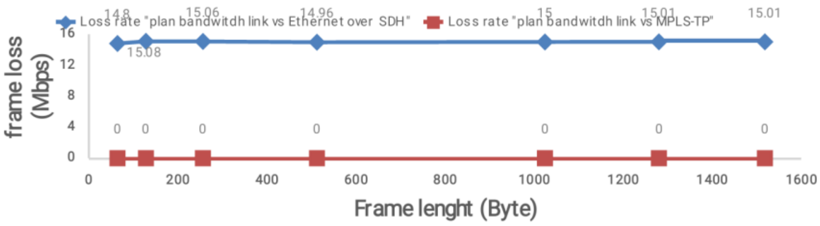

Figure 5. The Value of Frame Loss on the Main Ring Network from Actual Link Plan, Ethernet over SDH and MPLS-TP

In Figure 6 shows the values of frame loss in percentage, where the percentage values of frame loss in Ethernet over SDH on the main ring varied from 6.17 % to 6.28%, whereas, there is no frame loss in MPLS-TP on the main ring. All the results showed that on the main ring performance of MPLS-TP is better than Ethernet over SDH.

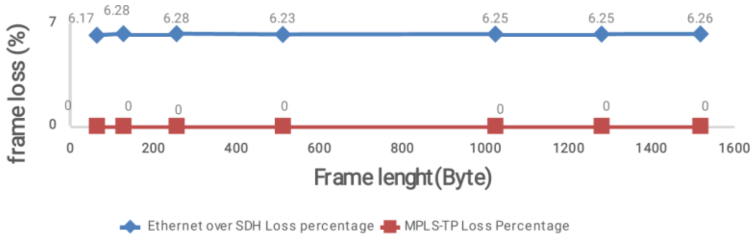

Figure 6. The Value of Frame Loss in Percentageon on the Main Ring Network from Actual Link Plan, Ethernet over SDH and MPLS-TP

4.3. Latency on the Main Ring Network

Figure 7 illustrates the results of measurements for latency values on the main ring of Ethernet over SDH and MPLS-TP with different frame length. Both of the results is kept below the standard QoS that is 150ms [17]. However, the results verify that MPLS-TP has better performance as compared to Ethernet over SDH.

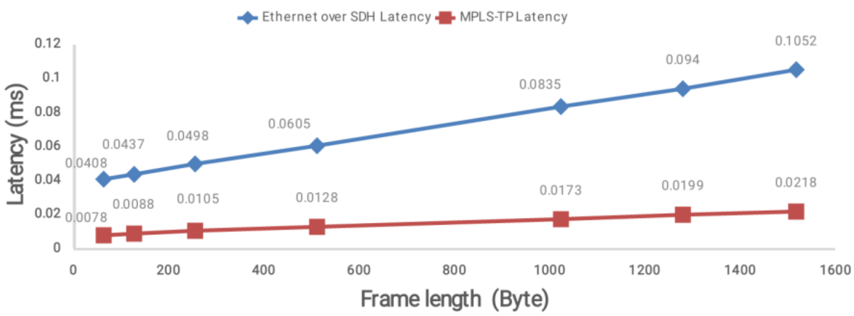

Figure 7. The Latency Values of Ethernet over SDH and MPLS-TP on the Main Ring Network

4.4. Jitter on the Main Ring Network

Table 4 shows the result of measurements on the main ring network for both Ethernet over SDH and MPLS-TP. The results showed that the jitter's values for both Ethernet over SDH and MPLS-TP is matched with defined category that us 0-75ms [17]. The values of latency Therefore, the value of jitter for both Ethernet over SDH and MPLS-TP are available to support LTE network.

Table 4. Jitter on the Main Ring Network

Maximum (ms)	Current (ms)	Average (ms)	Estimate (ms)	Category
0.015	0.015	0.015	0.015	0-75 ms

4.5. Throughput on the Ring Protection Network

Figure 8 presents the test results of throughput parameter values with different frame length, which could be seen that the actual link plan for throughput is 240 Mbps for all frame sizes. The test results for Ethernet over SDH technique is varied from 224.94 Mbps to 225.2 Mbps for all frame sizes. Whereas, the test results for MPLS-TP technique is 240 Mbps for all frame

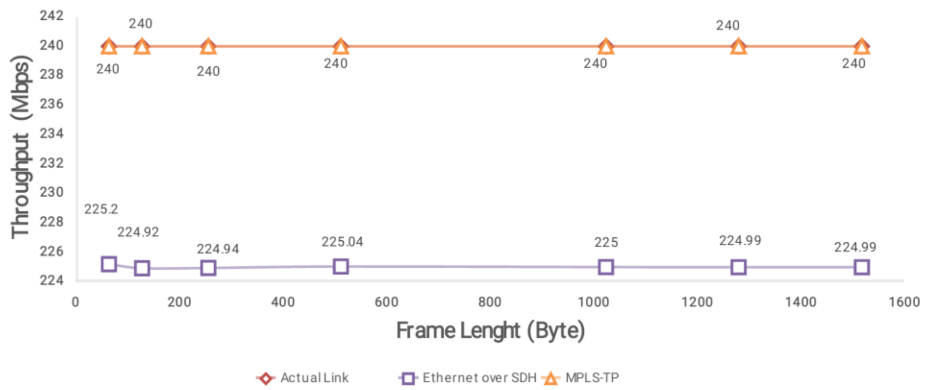

Figure 8. The Value of Throughput on the Protection Ring Network for Actual Link Plan, Ethernet over SDH and MPLS-TP

Figure 8 indicated the throughput utilization of those techniques on the protection ring, where the throughput utilization for Ethernet over SDH varied from 93.72 % to 93.83 % for all frame sizes, whereas the throughput utilization for MPLS-TP is 100 % for all frame sizes.

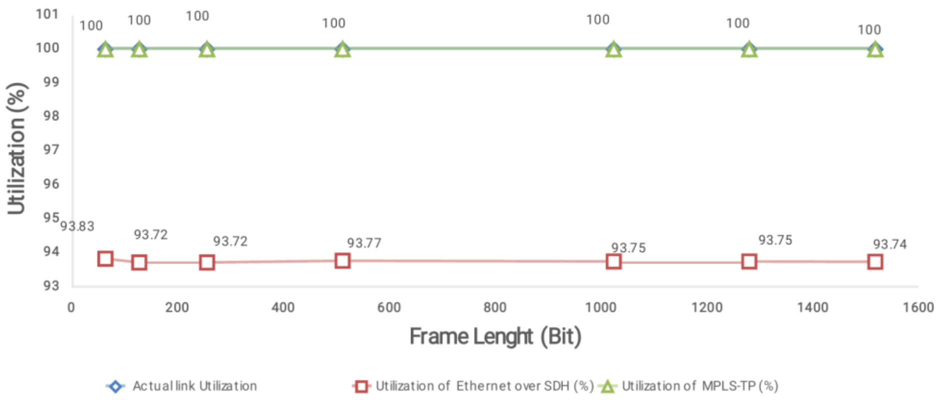

Figure 8. The Value of Throughput on the Protection Ring in Terms of Utilization in Percentage from Actual Link Plan, Ethernet over SDH and MPLS-TP

From Figure 8 and Figure 9, we can see that there is gap between Ethernet over SDH technique and actual link plan in term of throughput values, where the value of throughput from the Ethernet over SDH technique didn't reach the defined value that is 240 Mbps. Whereas there is no gap between MPLS-TP technique and actual link plan.

The results verify that MPLS-TP with ring protection has superior performance as compared to Ethernet over SDH with ring protection when the throughput values of MPLS-TP with ring protection meet to 240 Mbps as a defined value. However, since throughput values of MPLS-TP with ring protection meet to defined value, there is a greatly affect to performance of LTE network, that is no packet loss during transmission. Conversely, when the throughput values of Ethernet over SDH with ring protection below the defined value, therefore, it affected to reduce performance of LTE network lead to packet loss during transmission process.

4.6. Frame Loss on the Ring Protection Network

Figure 10 shows the frame loss on the ring protection network between Ethernet over SDH and MPLS-TP with different frame length. The results showed the frame loss values of Ethernet over SDH varied from 14.8 Mbps to 15.08 Mbps for all frame sizes, whereas, there is no frame loss in MPLS-TP.

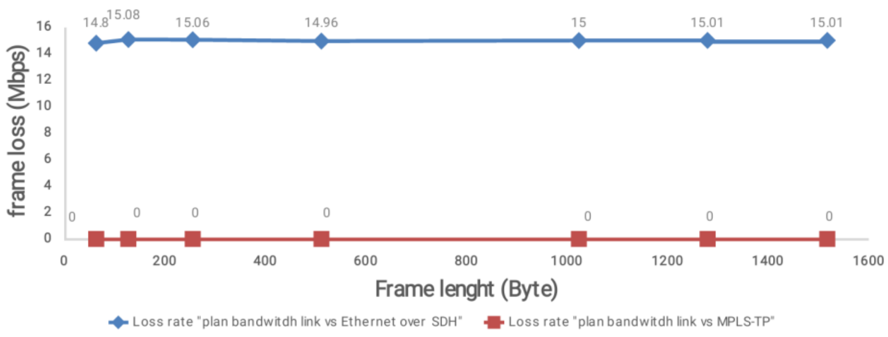

Figure 10. The Value of Frame Loss on the Ring Protection Network from Actual Link Plan, Ethernet over SDH and MPLS-TP

In Figure 11 shows the values of frame loss in percentage on the ring protection network, where the percentage values of frame loss in Ethernet over SDH varied from 6.17 % to 6.28%, whereas, there is no frame loss in MPLS-TP. All the results showed that MPLS-TP with ring protection provide better performance then Ethernet over SDH with ring protection.

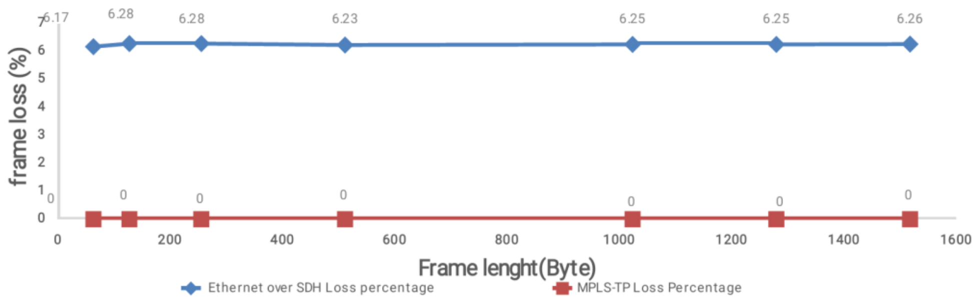

Figure 11. The Value of Frame Loss in Percentage from Actual Link Plan on the Ring Protection Network between Ethernet over SDH and MPLS-TP

4.7. Latency on the Ring Protection Network

Figure 12 illustrates the results of measurements for latency values of Ethernet over SDH with ring protection and MPLS-TP with ring protection with different frame length. Both of the results is kept below the standard QoS that is 150ms [16]. However, the results verify that MPLS-TP with ring protection has better performance as compared to Ethernet over SDH with ring protection.

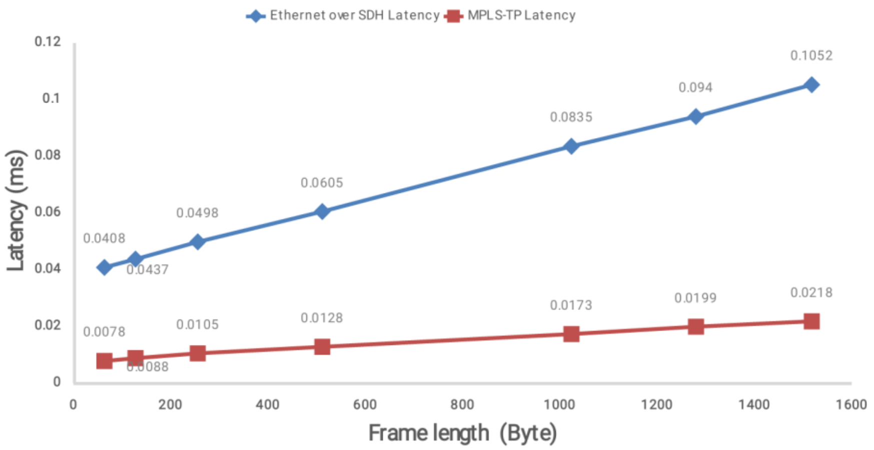

Figure 12. The Latency Values on the Ring Protection Network between Ethernet over SDH and MPLS-TP

4.8. Jitter on the Ring Protection Network

Table 5 shows the result of measurements for both Ethernet over SDH and MPLS-TP. The results showed that the jitter's values for both Ethernet over SDH with ring protection and MPLS-TP with ring protection is matched with defined category that us 0-75ms [16]. The values of latency Therefore, the value of jitter for both Ethernet over SDH with ring protection and MPLS-TP with ring protection are available to support LTE network.

Table 5. Jitter on the Ring Protection Network

Maximum (ms)	Maximum (ms)	Current (ms)	Average (ms)	Estimate (ms)	Category
0.015	0.015	0.015	0.015	0.015	0 – 75 ms

4.9. Recovery Time

In the testing for recovery time, the data packets are routed from the main ring network into the ring protection network due to the failure on the main ring network. Table 6 and Table 7 shows that the recovery time between Ethernet over SDH and MPLS-TP on the protection network does not have a significant difference. Table 6 and 7 indicated that the duration to switch back from the ring protection network to the main ring network is in accordance with the standard ITU-T G803.2, all the values are less than 50ms. From Figure 8 to Figure 12, it can be seen that the value of throughput, loss ratio, and jitter on the ring protection network between Ethernet over SDH and MPLS-TP indicated that MPLS-TP has better performance compare to Ethernet over SDH. Therefore, it can be concluded that the protection ring network is able to maintain network performance even though the main ring network is currently unavailable.

Table 6. Recovery Time on Ethernet Over SDH

Frame Length (Byte)	Recovery Time (ms)	Category
64	48.097	≤ 50 ms
128	48.320	≤ 50 ms
256	48.590	≤ 50 ms
512	48.887	≤ 50 ms
1024	48.970	≤ 50 ms
1280	49.178	≤ 50 ms
1518	49.397	≤ 50 ms

Table 7. Recovery Time on MPLS-TP

Frame Length (Byte)	Recovery Time (ms)	Category
64	48.091	≤ 50 ms
128	48.310	≤ 50 ms
256	48.578	≤ 50 ms
512	48.878	≤ 50 ms
1024	48.951	≤ 50 ms
1280	49.145	≤ 50 ms
1518	49.388	≤ 50 ms

5. Conclusion

Analyzing the results, we see that throughput values of MPLS-TP with ring protection reached 100% (240 Mbps), and throughput values of Ethernet over SDH with ring protection varying around 93% (224.92 Mbps – 225.2 Mbps). Refer to [17] both of values are able to support LTE network (MIMO 2 x 2) but MPLS-TP with ring protection has a better performance than Ethernet over SDH with ring protection. The latency values of MPLS-TP with ring protection in this paper is around 0.078ms – 0.0218ms, while the latency values of Ethernet over SDH with ring protection is around 0.048ms – 0.1502ms, both of values are consistent with latency standard (<150ms) [17]. From the latency values, we see that MPLS-TP with ring protection has better performance as compared to Ethernet over SDH with ring protection. Table 5 shows that the result of jitter measurements for both techniques are same, that is 0.015ms, this results are meet to latency standard in [17]. The last parameter that is measured is the recovery time, which is the time needed to switch back to the main ring network, there is no significant difference between Ethernet over SDH and MPLS-TP. The recovery time for Ethernet over SDH is ranging from 48.097ms – 49.397ms, while recovery time for MPLS-TP is ranging from 48.091 ms to 49.388 ms, however, it is still in accordance with the standard that must be below 50ms. From all the testing results, we see that MPLS-TP with ring protection has a better performance in the current assessment to satisfy LTE backhaul requirements. In terms of link utilization, the used of MPLS-TP are meeting to the requirements of backhaul technology that can support Industrial Internet of Things (IIoT) but need further research to improve the overall QoS.

References

[1] G Kalimani Venkatesan, Kishor Kulkarni. "*Wireless backhaul for LTE – requirements, challenges and options*". in Proc. ANTS'08. 2nd International Symposium. 2008: 1-3.

[2] Ted H Szymanski. "Supporting consumer services in a deterministic industrial internet core network". *IEEE Communications Magazine*. 2016; 54: 110-117.

[3] Aleksandra Checko, Lars Ellegaard, Michael Berger. "*Capacity planning for carrier ethernet LTE backhaul networks*". in Proc. Wireless Communications and Networking Conference (WCNC). 2012: 2741-2745.

[4] Andrei Rusan, Radu Vasiu. "*Assessment of packet latency on the 4G LTE S1-U interface: impact on end-user throughput*". in Proc. Software, Telecommunications and Computer Networks (SoftCOM). 2015: 305-309

[5] Andrei Rusan, Radu Vasiu. "*Emulation of backhaul packet loss on the LTE S1-U interface and impact on end user throughput*". in Proc. Intelligent Computer Communication and Processing (ICCP). 2015: 529-536.

[6] Yi Shi, Mingchao Li, Xin Xiong, Guanglin Han, Lei Wan, Xiaodai Dong, "*A Flexible Backhaul Architecture for LTE-Advanced*". in Proc. International conference on connected vehicles and expo (ICCVE). 2014: 1098-1105.

[7] G Vijayalakshmy, G Sivaradje. "*LTE backbone for heterogeneous architectures*". in Proc. International Conference on Circuit, Power and Computing Technologies [ICCPCT]. 2014: 1354 – 1359.

[8] Christian Addeo, Italo Busi. "*Protection switching in packet transport rings*". in Proc. Telecommunications Network Strategy and Planning Symposium (NETWORKS), XVth International. 2012: 1-6

[9] Wenjun Xie, Shanguo Huang, and Wanyi Gu. "*An improved ring protection method in MPLS-TP networks*". in Proc. Network infrastructure and digital content. 2010 2nd IEEE International Conference. 2010: 1056-1060.

[10] Jeong-dong Ryoo, Taesik Cheung, Daniel King, Adrian Farrel, Huub van Helvoort. "MPLS-TP linear protection for ITU-T and IETF". *IEEE Communications Magazine*. 2014; 52(12): 16-21.

[11] Chang-Gyu Lim, Soo-Myung Pahk, Young-Hwa Kim. "*Model of transport SDN and MPLS-TP for T-SDN controller*". in Proc. 18th International Conference on Advanced Communication Technology (ICACT). 2016: 522 – 526.

[12] Shicheng Zhang, Wei Ji, Xiao Li, Kangrui Huang, and Zenglu Yan. "Efficient and reliable protection mechanism in long-reach PON". *IEEE/OSA Journal of Optical Communications and Networking*. 2016; 8(1): 23 – 32.

[13] Amra Imamovic, Vlatko Lipovac. "*Practial benchmark analysis of traffic protection with ethernet-over-SDH transmission*". In Proc. Ultra Modern Telecommunications and Control Systems and Workshops (ICUMT), 3th International Congress. 2011: 1-7.

[14] Patteti Krishna, Tipparti Anil Kumar, Kalithkar Kishan Rao. "Throughput evaluation of downlink multiuser-MIMO OFDM-LTE System". *Int. J. Communications, Network and System Sciences*. 2015; 8: 58-61.

[15] IXIA. "Predicting and managing network impairments". *White paper*, rev. A. 2012.

[16] Nigel Burgess. "RFC 2544 Testing of Ethernet Services in Telecom Networks". *White Paper*, Agilent Technologies. 2004.

[17] NEC, "*SDH Transmission System*". 6^{th} ed, Japan. 1999.