SINERGI Vol. 23, No. 3, October 2019: 253-259
Accredited **SINTA 2** by KEMENRISTEKDIKTI, Decree No: 10/E/KPT/2019
http://publikasi.mercubuana.ac.id/index.php/sinergi
http://doi.org/10.22441/sinergi.2019.3.010 .

IMPROVEMENT OF NETWORK SURVIVABILITY USING THE EFFECTIVE REDUNDANCY DESIGN

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Abstract -- *Network survivability is a very important issue due to the sustainability of the network services. Failure in a network system conduce to disturbance of the network services and causes trouble to millions of applications. Implement an effective redundancy design is one of method to cope nuisance in terms of sustainability in a network. In this paper, there are two design networks with and without redundancy respectively by Metro Ethernet-based technique to support transmission of data and voice. Furthermore, there is a validation performance of networks by measuring and comparing the throughput, latency and jitter between the two network designs. The value of bandwidth capacity is 100 Mbps as plan bandwidth link. Measurements results denote that network with redundancy design is able to enhance performance of the network, the parameters are: the throughput on single link tends to moderate (25%-50%), on the other hand, the throughput values on the main link and back uplink are in accordance with very good condition (75%-100%). The values of frame loss ratio 69.979% - 56.679% (single link), 6.77% -9.999% (main link) and 6.676 %-9.999% (back uplink). The values of jitter and latency in network with redundancy design are much better than in single link network. The recovery time for each frame length is ranging from 48.999ms to 49.887ms, where it is still meet with the standard that must below 50ms. Finally, when the main link in the network topology with redundancy design undergo link fails condition, the backup link is able to maintain the quality of network throughout that time, on the contrary, network topology without redundancy design is unable.*

Keywords: *Redundancy; Networks; Bandwidth; Capacity; Survivability*

Received: May 24, 2019 Revised: October 10, 2019 Accepted: October, 16 2019

INTRODUCTION

Network survivability is a very important issue due to the sustainability of the network services. Davis (2019) stated that network communications could easily be disrupted by the failure of networking equipment, ranging from single accidental link cut, to a wide swath of links and nodes wiped out simultaneously by a natural disaster. Failure in a network system conduce to disturbance of the network services and causes trouble to millions of applications. On the other hand, Xu et al., (2018) stated that redundancy is vital for transportation networks to provide utility to users during disastrous events. In order to reduce effect of failures in the networks, survivability solutions involving pre-computed backup paths can be used to help maintain connectivity and reduce service downtime. One method to anticipated network failure is implementing an effective redundancy design in a network. It provides more ways to get the data to its destination although there is a link failure in the network (Sirait et al, 2019).

Bakhtiar (2017) employing information redundancy and hardware redundancy in order to reach reliable communications in Optical Networks on Chip (ONoC), where errors associated with SNR are able to detect using optical parity generators. Mal et al. (2018) propose a Mobility Robustness Optimization (MRO) mechanism that is based on radio link failure prediction, called MBRP, for dealing with Radio Link Failures (RFLs) during handover process. Kadri and Koudil (2019) explore reliability as a major concern in Networks-on-Chips (NoCs), and also proposed several techniques to deal with different types of faults at different levels of an NoC. In Kadri and Koudil (2019), a classification is proposed, based on the approaches adopted to recover from failures.

Techniques based on the combination of mapping and routing, techniques based on redundancy, and techniques based on task remapping are the main categories of the classification proposed. Rodriguez-Martin et al. (2016) presented a MIP formulation and valid inequalities for a complex two-level survivable network design problem by considering two survivable structures, two-edge-connected (2EC) networks and rings, in both levels of the networks. Shahriar et al. (2018) study the problem of jointly optimizing spare capacity allocation in a Virtual Network (VN) and embedding the VN to guarantee full bandwidth in the presence of multiple substrate link failures. Wong et al. (2017) propose two survivable schemes that exploit the inherent resiliency of the ring network, and the survivable schemes provide enhanced connection availability and power saving at less than 0.2% incremental network cost. Xu et al. (2018) develop two network-based measures for systematically characterizing the redundancy of transportation networks: travel alternative diversity dimension is to evaluate the existence of multiple modes and effective routes available for travelers or the number of effective connections between a specific origin-destination pair. Garcia-Magarino et al. (2018) propose using big data analytics techniques such as decision trees for detecting nodes that are likely to fail, and so avoid them when routing traffic. The method can improve the survivability and performance of networks. Liu et al. (2017) designed the method for service risk analysis and analyzed the probability of fiber link failure. The reliability loss caused by the single fiber link failure is evaluated.

In the end, the effectiveness of the service risk model is verified by exploiting the practical network model. Nugraha et al. (2016) implemented PVST+ (Per VLAN Spanning Tree Plus) to overcome the problem caused by broadcast storm attack on the Metro Ethernet Network. The PVST+ serves as redundant network management and it prevents looping on the network.

In this paper there are two designed network topologies, point to point network without redundant and point to point network with redundant. The use of redundancy design in this paper is to show the impact of the design on the improvement of network QoS. The effective redundant paths must be provisioned with a particular mechanism to switch between them if there is a disruption in the main link network, so that, the loss due to disruption in the network can minimize. There is Quality of Service (QoS) parameters that are tested in this paper, namely throughput utilization, jitter, latency, and recovery time. Those parameters are used to determine that the quality of a network with redundancy designed has better performance than the network without redundancy designed.

The remaining of this paper is organized as follows: Methodology is presented in Section 2; in Section 3 presents network impairment testing; Section 4 is described Results and Analysis; the conclusions are given in section 5.

METHOD

In this section, there are two design network topologies. The first is a point to point network topology without redundant, and the second one is a point to point network topology with redundant. It is urgent to design the effective redundancy in the network due to backup of the network system, or interchangeable of the network system so that the network system can be repaired quickly and without interruption.

Point to Point Network Without Redundant

In Fig. 1, it can be seen that there is a point to point network topology. There is a router HQL7-XTRA-CORE-01 that connected to branches-Router used link ISP1. The scenario of this part is the link between HQL7-XTRA-CORE-01 to ISP1 is disabled manually (indicated with blue x mark), then the packets will drop due to no backup link in this network. Then the link is enabled again, and the packets will travel as a normal way. The Quality of Services (QoS) before and during a disable network is measured using NMS that installed on the laptop.

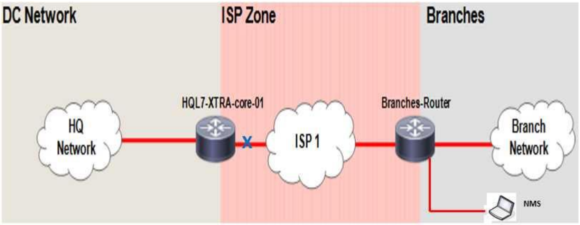

Figure 1. A scenario in Single Link Network Topology

Point to Point Network With Redundant

In Fig. 2, there are router HQL7-XTRA-CORE-01 and router HQL7-XTRA-CORE-02 that are connected to ISP 1 and ISP2 respectively. In this part, router HQL7-XTRA-CORE-01 that connected to ISP 1 as the main link. Otherwise, router HQL7-XTRA-CORE-02 that connected to ISP2 as a backup link.

The scenario in this section is the main link between HQL7-XTRA-CORE-01 and ISP1 is disabled manually (indicated with blue x mark), then the packets will travel on the backup network automatically. The NMS is used to measure the Quality of Services (QoS) in the networks.

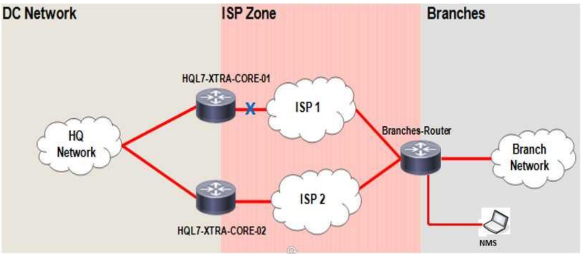

Figure 2. A scenario in Network Topology with Redundancy Design

Then, the main network is enabled again and the packets switched back to the main network. There is a recovery time needed for the packets to revert to the main network. In this part, jitter, latency, and recovery time are measured. The measurements are conducted in branches router.

Network Impairment Testing

In terms of validating network performance, we used the RFC 2544 Testing of Ethernet Services in this paper. RFC 2544 is a standard developed by the Internet international standards body, the Internet Engineering task Force (IETF), which contains the necessary testing methods to measure the quality of an Ethernet network. Agilent (2004) described the following parameters are tested to benchmark the network element: Throughput, Latency, Jitter, Frame Loss that listed from Table 1 to Table 9.

Table 1. Standard for Throughput

Category	Throughput
Very Good	75% - 100%
Good	50% - 75%
Moderate	25% - 50%
Bad	<25%

FRC 2544 requires the standard frame sizes (64,128, 256, 512, 1024, 1280 and 1518) to be tested based on the parameters. Agilent (2004) stated that all these frame sizes are used in the network and so the results for each must be known.

RESULTS AND ANALYSIS

In this section, there are two types of results and analysis provided. Those results were described on network topology without redundancy design and the other one described on a network topology with redundancy design. So, it can be seen the difference of performance improvement between two types of network topology that has been designed.

Table 2. Standard for Jitter

Category	Throughput
Very Good	0 ms
Good	0 – 75 ms
Moderate	75 – 125 ms
Bad	125 – 225 ms

Table 3. Standard for Latency

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

Results on Network Topology without Redundancy Design

The first testing process performed on the single link network topology as shown in Fig. 1. In Agilent (2004) there are seven different sizes of frame length that we used during the measurement process, which are 64, 128, 256, 512, 1024, 1280, and 1518 fit testing standard RFC 2544. The measurement results that we are obtained during the testing process are utilization of the throughput, frame loss ratio, jitter, and latency. All the results can be seen in Table 4 to Table 7.

Table 4. Results of Throughput Testing on Single Link Network Topology

Frame Length (Byte)	Plan Link		Single Link Network	
	Throughput (Mbps)	Utilization (%)	Throughput (Mbps)	Utilization (%)
64	100	100	30.021	30.021
128	100	100	30.834	30.834
256	100	100	35.323	35.323
512	100	100	33.366	33.366
1024	100	100	38.295	38.295
1280	100	100	43.321	43.321
1518	100	100	50.254	50.254

Table 5. Frame Loss Ratio on the Single Link Network Topology

Frame Length (Byte)	Plan Link		Single Link Network		Frame Loss Ratio (%)
	Throughput (Mbps)	Utilization (%)	Throughput (Mbps)	Utilization (%)	
64	100	100	30.021	30.021	69.979
128	100	100	30.834	30.834	69.166
256	100	100	35.323	35.323	64.677
512	100	100	33.366	33.366	66.634
1024	100	100	38.295	38.295	61.705
1280	100	100	43.321	43.321	56.705
1518	100	100	50.254	50.254	56.679

Table 4 present the measurement results of the throughput parameter values with different frame length sizes on single link network topology, which can be seen that the actual link for throughput is 100 Mbps for all frames. The throughput measurement results for single link network topology is varied from 30.021 Mbps to 50.254 Mbps for all frame sizes. Therefore, it concluded that the achieved throughput is in accordance with moderate condition (25% - 50%).

Furthermore, Table 5 illustrates the measurement results of frame loss on a single link network topology with different frame lengths. It can be seen that the frame loss for all frame sizes varies from 69.979% to 56.679%.

Table 6. The Value of Latency on the Single Link Network Topology

Frame Length (Byte)	Latency (ms)	Category
64	140	$t_{end\ to\ end} \leq 150\ ms$ (Very Good)
128	140	$t_{end\ to\ end} \leq 150\ ms$ (Very Good)
256	140	$t_{end\ to\ end} \leq 150\ ms$ (Very Good))
512	140	$t_{end\ to\ end} \leq 150\ ms$ (Very Good)
1024	140	$t_{end\ to\ end} \leq 150\ ms$ (Very Good))
1280	140	$t_{end\ to\ end} \leq 150\ ms$ (Very Good))
1518	140	$t_{end\ to\ end} \leq 150\ ms$ (Very Good)

Table 6 presents the latency values on single link network topology, where the latency values for single link network topology is 140 ms for all frame sizes. From these testing results we conclude that that the values of latencies for all frame sizes meet with the category very good (less than 150 ms).

Table 7. Jitter on Main Link Network Topology

Maximum (ms)	Maximum (ms)	Current (ms)	Average (ms)	Estimate (ms)	Category (ms)
200	200	200	2-00	72	125 - 225

Table 7 shows the result of measurements on Single Link Network Topology. The results showed that the jitters are matched with a defined category that is 125-225ms.

Results on Network Topology with Redundancy Design

The second testing process performed on the network topology with redundancy design as shown in Fig 2. The measurement results that we are obtained during the testing process are the utilization of the throughput, frame loss ratio, jitter, and latency. All the results can be seen in Table 8 to Table 16.

Table 8. Results of Throughput Testing on the Main Link Network Topology

Frame Length (Byte)	Plan Link		Main Link Network	
	Throughput (Mbps)	Utilization (%)	Throughput (Mbps)	Utilization (%)
64	100	100	93.230	93.230
128	100	100	93.124	93.124
256	100	100	93.230	93.230
512	100	100	93.421	93.421
1024	100	100	90.034	90.034
1280	100	100	91.002	91.002
1518	100	100	90.024	90.024

Table 9. Frame Loss Ration on Main Link Network Topology

Frame Length (Byte)	Plan Link		Single Link Network		Frame Loss Ratio (%)
	Throughput (Mbps)	Utilization (%)	Throughput (Mbps)	Utilization (%)	
64	100	100	93.230	93.230	6.770
128	100	100	93.124	93.124	6.876
256	100	100	93.230	93.230	6.770
512	100	100	93.421	93.421	6.770
1024	100	100	90.034	90.034	9.966
1280	100	100	91.002	91.002	8.998
1518	100	100	90.024	90.024	9.976

Table 8 present the measurement results of the throughput parameter values with different frame length sizes on single link network topology, which can be seen that the actual link for throughput is 100 Mbps for all frame sizes. The throughput measurement results for single link network topology is varied from 90.024 Mbps to 93.421 Mbps for all frame sizes. It means, the measurement results of throughput for all frame sizes are following very good condition (75% - 100%).

Table 10. The Value of Latency on Main Link Network

Frame Length (Byte)	Latency (ms)	Category
64	72	$t_{end\ to\ end} \le 150\ ms$ (Very Good)
128	80	$t_{end\ to\ end} \le 150\ ms$ (Very Good)
256	82	$t_{end\ to\ end} \le 150\ ms$ (Very Good))
512	81	$t_{end\ to\ end} \le 150\ ms$ (Very Good)
1024	87	$t_{end\ to\ end} \le 150\ ms$ (Very Good))
1280	86	$t_{end\ to\ end} \le 150\ ms$ (Very Good))
1518	88	$t_{end\ to\ end} \le 150\ ms$ (Very Good)

Table 9 illustrates the measurement results of frame loss on a single link network topology with different frame lengths. It can be seen that the frame loss for all frame sizes varies from 6.77% to 9.976%. From all the results it can be concluded that there is an improvement for the performance of the network on main Link network topology if we compare with single link network topology.

Table 10 presents the latency values on the main link network topology, where the latency values for single link network topology vary from 72 ms to 88 ms for all frame sizes. From those testing results we conclude that that the values of latencies for all frame sizes meet with the category very good (less than 150 ms), and it can be seen that there is an improvement in term of the value of latency on main link network topology compare with the value of latency on single link network topology.

Table 11. Jitter on Main Link Network Topology

Maximum (ms)	Maximum (ms)	Current (ms)	Average (ms)	Estimate (ms)	Category (ms)
72	72	72	72	72	0 - 75

Table 11 shows the result of measurements on Main Link Network Topology. The results showed that the jitters are matched with a defined category that is 0-75ms.

Table 12. Results of Throughput Testing on Backup Link Network Topology

Frame Length (Byte)	Plan Link		Backup Link Network	
	Throughput (Mbps)	Utilization (%)	Throughput (Mbps)	Utilization (%)
64	100	100	93.000	93.000
128	100	100	93.115	93.114
256	100	100	93.324	93.324
512	100	100	93.231	93.231
1024	100	100	91.243	90.243
1280	100	100	90.231	91.231
1518	100	100	90.001	90.001

Table 13. Results of Frame Loss Ratio on Backup Link Network Topology

Frame Length (Byte)	Plan Link		Single Link Network		Frame Loss Ratio (%)
	Throughput (Mbps)	Utilization (%)	Throughput (Mbps)	Utilization (%)	
64	100	100	93.000	93.000	7.000
128	100	100	93.114	93.114	6.886
256	100	100	93.324	93.324	6.676
512	100	100	93.231	93.231	6.769
1024	100	100	91.243	90.243	9.757
1280	100	100	90.231	91.231	8.769
1518	100	100	90.001	90.001	9.999

Table 12 present the measurement results of the throughput parameter values with different frame length sizes on backup link network topology, which can be seen that the actual link for throughput is 100 Mbps for all frames. The throughput measurement results for single link network topology is varied from 90.001 Mbps to 93.324 Mbps for all frame sizes. Therefore, it concluded that the achieved throughput is following very good condition (75% - 100%). Furthermore, Table 13 illustrates the measurement results of frame loss on backup link network topology with different frame lengths. It can be seen that the frame loss for all frame sizes varies from 7.00% to 9.999%.

Table 14 presents the latency values on backup link network topology, where the latency values for backup link network topology vary from 75 ms to 89 ms for all frame sizes.

Table 14. The Values of Latency on Backup Link Network Topology

Frame Length (Byte)	Latency (ms)	Category
64	75	$t_{end\ to\ end} \le 150\ ms$ (Very Good)
128	83	$t_{end\ to\ end} \le 150\ ms$ (Very Good)
256	82	$t_{end\ to\ end} \le 150\ ms$ (Very Good)
512	86	$t_{end\ to\ end} \le 150\ ms$ (Very Good)
1024	88	$t_{end\ to\ end} \le 150\ ms$ (Very Good)
1280	79	$t_{end\ to\ end} \le 150\ ms$ (Very Good)
1518	89	$t_{end\ to\ end} \le 150\ ms$ (Very Good)

From those testing results we conclude that that the values of latencies for all frame sizes meet with the category very good (less than 150 ms), and it can be seen that there is not much difference in term of the value of latency on the main link network topology compare with the value of latency on backup link network topology.

Table 15. Recovery Time

Frame Length (Byte)	Recovery Time (ms)	Category
64	48.999	$\le 50\ ms$ (Fit with the standard)
128	49.023	$\le 50\ ms$ (Fit with the standard)
256	49.054	$\le 50\ ms$ (Fit with the standard)
512	49.445	$\le 50\ ms$ (Fit with the standard)
1024	49.678	$\le 50\ ms$ (Fit with the standard)
1280	49.887	$\le 50\ ms$ (Fit with the standard)
1518	49.967	$\le 50\ ms$ (Fit with the standard)

In terms of recovery time testing, the packet data are routed from the main link network topology into a backup link network topology network due to the failure on the main link network. Table 14 shows that duration of recovery time on main link network varies from 48.999 ms to 49.967 ms. It can be concluded that the values of recovery time are accordance with the standard ITU-T G803.2, that all the values are less than 50 ms.

Table 16. Jitter on Backup Link Network Topology

Maximum (ms)	Maximum (ms)	Current (ms)	Average (ms)	Estimate (ms)	Category (ms)
72	72	72	72	72	0 - 75

Table 16 shows the result of measurements on Main Link Network Topology. The results showed that the jitters are matched with a defined category that is 0-75ms. From Table 11 and Table 16 can be concluded that the value of jitter for both Main Link Network Topology and Backup Link Network Topology is similar.

CONCLUSION

Based on results performed, it can be seen that when the main link in the network topology with redundancy design undergo link fails condition, the backup link is able to maintain the quality of network throughput that time, in contrary, network topology without redundancy design is unable. Furthermore, the throughput values on a single link network tend to moderate category (25% - 50%). On the other hand, the throughput values on main link network topology and backup link network topology are in accordance with very good conditions (75% - 100%). Furthermore, there is an improvement in terms of frame loss ratio, from the range of 69.979% to 56.679% on single link network reduce to 6.77% - 9.976% on main link network, on the other hand, the value of frame loss ratio on backup link network varies from 6.676% - 9.999%.

From measurement results, it can be seen that the values of jitter on main and backup network topology has much better than the values of jitter on single link network topology. The latency on the main link and backup link network has better performance compare with latency on single link network topology, but all of them are still categorized as very good (less than 150ms). The recovery time is the last parameter that is measured, there is the time needed to switch back from the backup network to the main network. The recovery time for each frame length is ranging from 48.999ms to 49.887ms, but, it is still in meet with the standard that must be below 50ms.

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