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Comparative Performance Evaluation Of Open Shortest Path First, OSPF And Routing Information Protocol, RIP In Network Link Failure and recovery cases

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Abstract—The effect of Network link failure is undesirable which necessitated redundant links for reliability. This implies that operations are switched between links in case of failure. In the modern world where speed matters, it is important to investigate how quickly different routing protocols, in this case, Open Shortest Path First, OSPF and Routing Information Protocol, RIP recovers in case of link failure in a mesh topology. The research was simulated using OPNET. It was modelled after the University of Salford main campus, using three of its building, Newton, Peel and CW library. There were several links in between the buildings. The network was configured for the two routing protocols in different scenarios to test for their performance in case of single and multiple link(s) failure and recovery. It was observed that RIP converges faster (11.21s) than OSPF (53.06s) at the initial stage of the network in all cases. However, OSPF converges faster (Average of 5s – link failure, Average of 15s – Link recovery) than RIP (Average of 18.57s- link failure, Average of 18.28s – link recovery) in both single and multiple link(s) failure/recovery scenarios. Therefore, based on the performance comparison, OSPF should be used in a network prone to frequent link failure as it performs better in this situation. However, RIP would be preferred if the network is not prone to frequent network failure.

Keywords-- Campus Area Network, Mesh topology, Network link failure/recovery, Open Shortest Path First, OPNET, Routing Information Protocol, Simulation.

I. INTRODUCTION

Reliability and speed are one of the major features of today's Campus Network. The campus network is of great importance as it plays a vital role in administration, research, teaching and assessment. It simply cut across all the aspects of Campus operations[1]–[4]. Mesh topology is one which offers reliability as there are redundant links which can be used in case of link failure[3], [5]–[7]. Switching between the

links in terms of failure and recovery takes a period of time depending on the routing protocol employed[8]–[11]. According to[8]–[11], routing protocols see to how packets are being sent across the network through their IP (source and destination) addresses. This can either be static or dynamic. A static routing protocol needs manual set up and update of information and not suitable as the network grows while Dynamic routing protocol automatically learns about the network using an algorithm and does not need to be manually updated. Thus, the latter is being preferred in present networks. Dynamic routing protocols can be categorized into Distance vector routing protocols and Link state protocols based on the algorithm used. Distance vector routing protocols usually calculate the cost of reaching a destination based on the number of routers the path passes through. It uses the lowest number of router number (hop counts). Example of this includes RIP (Routing Information Protocol) and EIGRP (Enhanced Interior Gateway Routing Protocol). Link state protocol uses the calculated metrics of the path in reaching the destination using the most cost effective. Example of this includes OSPF (Open Shortest Path First) and BGP (Border Gateway Protocol). Hence, this research investigated the performance of OSPF (Link state protocol) and RIP (Distance vector protocol) in terms of their convergence time in case of link (s) failure and recovery.

II. RELATED WORK

The work in [12] presented the method for choosing between protocols that involve distance vector or link state. They compared between EIGRP, RIP and OSPF in terms of Network convergence activity, Network convergence duration, Routing protocol traffic, CPU utilization, Network bandwidth utilization, throughput and queuing delay. The

study was simulated in OPNET Modeler. In their result, EIGRP provided a better network convergence time, fewer bandwidth requirements and better CPU and memory utilization compared to OSPF and RIP.

The work in [8] examined the network performance using three routing protocols, RIP, OSPF and EIGRP. They configured Video, HTTP and Voice application for network transfer. They also examined the behaviour under link failure/recovery conditions. They opined that RIP is slower to converge because routes changes are propagated at regular intervals and not in an instant. They also demonstrated that in network convergence activity, EIGRP provide the best conversion duration, having the best reaction time to link failure and being more reliable for real time applications. However, OSPF provided security facilities, multipath facilities, integrated support for both routing unicast and multicast to a rapid convergence

The authors in [13] did a comparative study of RIP and OSPF dynamic routing protocols. RIP had a high latency value than OSPF. RIP also had higher convergence time than OSPF and hence it is suitable only for smaller networks. OSPF, on the other hand, had faster convergence and efficiently uses the bandwidth. They also opined that reliability and efficiency of OSPF are more than RIP. OSPF is the best choice for larger networks and RIP can be limited to simple and small networks.

the work in [11] investigated the performance of voice and video traffic in RIP, OSPF and EIGRP for flapping unstable links. They used OPNET simulation tool to analyze the performance of the routing protocols. They investigated the impact of flapping links on convergence time, packet end-to-end delay, packets drop in IP network, voice jitter, video packet delay variation and HTTP page response time is considered. The simulated results showed that flapping links had a significant impact on the overall performance of IP based networks affecting especially the network convergence time and packet drops in the network.

Their result showed that RIP performed better when there was single instability but OSPF did better when the link instability increased.

They also observed that OSPF outclassed EIGRP and RIP in link utilization. They concluded that OSPF performance was improved when there were more flapping links in the network and that as the network grows the performance of RIP becomes worst with respect to convergence time.

The work in [14] analyzed and evaluated which routing protocols used for Dual Hub Dual DMVPN hub-to-spoke connection ensures the least delay and jitter value, convergence time and link utilization using OPNET Modeler 16.1. Their result showed that OSPF and EIGRP are the best routes to implement secure enterprise network based on Dual Hub Dual DMVPN hub-to-spoke topology. Also, they showed that the protocol with lowest and more stable convergence times is OSPF. By contrast, RIP had an irregular and slow convergence. The simulations have revealed that EIGRP and OSPF are the two dynamic routing protocols to implement large-scale hub-to-spoke Dual hub dual DMVPN because of their fast convergence and link utilization.

III. METHODOLOGY

The research has been simulated because of the usage restriction of the University's network. However, there were network details available to simulate the real campus network. This design simulates a part of University of Salford network (a typical campus network), making use of her three (3) major buildings (Newton, Peel and CW library). Each building represents a Local Area Network, LAN while the interconnection of the LAN is the focus area of this research. Each LAN has its own router which serves as their gateway for external connection. Two extra routers are introduced to create alternative links in case failure or damage of links and or any of the routers. The two routing protocols, OSPF and RIP were configured on these routers that made up the entire network. The choice of RIP and OSPF is because they both fit into the size of the network as against EIGRP and BGP which are better suited for Wide Area Networks, WANs[10]. The simulator used was OPNET 6.2 because it has all the features necessary for evaluation of the two routing protocols and it is widely used by related work like [11], [12], [14]. The design has 5 routers (R1, R2, R3, R4 and R5) and 3 LANs (CW Library, Peel Building and Newton Building) in a mesh topology.

There were four pairs of scenarios, one each for the routing protocols being evaluated. The first pair was used for verification and validation. This is to ensure the design works and its result makes sense with the existing facts. The other three pairs were used for the comparative performance analysis of the two routing protocols (OSPF and RIP) under the following three conditions; no failure/recovery condition; single link failure/recovery condition; and multiple links failure/recovery condition.

A. Description of Parameters Used in the Simulation

The parameters used in this research are defined below:

- 1) Metric cost: This is the overhead cost of the path. This is inversely proportional to the bandwidth.
- 2) Hop counts: This is the number of routers IP traffic will have to pass through from the source to the destination.
- 3) Router Convergence Activity: This is the process by which all the routers in a network learn about the topology of the network. It is either '0' or '1' with '1' indicating the presence of convergence activity.
- 4) Router Convergence Duration: This is the time it takes for the routers in a network to reach a state of convergence that has full information about the topology. This is measured in seconds.
- 5) Routing Traffic sent: This is the amount of routing protocol traffic sent in bits/seconds by all the network nodes using either the RIP/OSPF routing protocol in their IP interfaces. This traffic is necessary for all the nodes to periodically advertise the up to date network topology. This, however, uses bandwidths of the network which implies the lower this traffic the more the bandwidth

available for the other network traffic between the nodes and vice versa. This is measured in bits per seconds (bps).

B. Description of different network Scenarios simulated in OPNET 6.2

1) Verification and Validation Scenario

The designed network was configured and tested using OPNET 6.2. In this scenario, data traffic was created from CW Library to Peel Building. Figures 1 and 2 showed that there were connection and data transfer between the two LANs. As highlighted earlier, RIP transmits packet along the path with the lowest hop counts while OSPF uses the cheapest metrics.

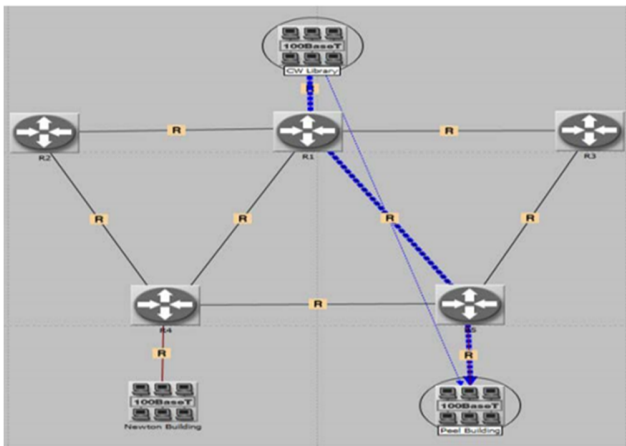


Figure 1. Verification and validation scenario for RIP

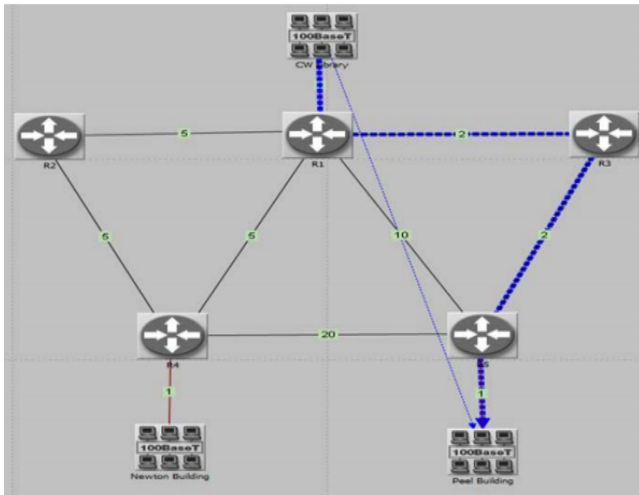


Figure 2. Verification and validation scenario for OSPF

Analysis of the entire different possible routes between CW and Peel are as follows:

Route 1 CW > R1 > R2 > R4 > R5 > Peel Building (Cost: 32, Hop Counts: 4)

Route 2 CW > R1 > R4 > R5 > Peel Building (Cost: 27, Hop Counts: 3)

Route 3 CW > R1 > R5 > Peel Building (Cost: 12, Hop Counts: 12)

Route 4 CW > R1 > R3 > R5 > Peel Building (Cost: 6, Hop Counts: 6)

Thus, RIP is expected to take the route with the lowest hop counts which is route 2 with a hop count of 3 while OSPF is expected to take the cheapest route which is Route 4 with the cost of 6. These were the routes taken in the simulation as shown in Figures 1 and 2. This shows the simulation conforms with the existing facts.

2) No Failure / Recovery Condition

The next pair of scenarios was used to investigate the performance of the routing protocols under no failure or recovery condition. New traffic was created between CW Library and Newton building.

Analysis of the entire different possible route between CW and Newton are as follows:

Route 1 CW > R1 > R2 > R4 > Newton Building (Cost: 12, Hop Counts: 3)

Route 2 CW > R1 > R4 > Newton Building (Cost: 6, Hop Counts: 2)

Route 3 CW > R1 > R5 > R4 > Newton Building (Cost: 32, Hop Counts: 3)

Route 4 CW > R1 > R3 > R5 > R4 > Newton Building (Cost: 26, Hop Counts: 4)

The best route for both protocols was Route 2 having the cheapest cost of 6 and lowest hop counts of 2. Figures 3 and 4 showed that they both followed Route 2.

The convergence activity and the traffic sent were compared for both protocols. The values of the convergence duration and traffic sent were exported to table form for analysis.

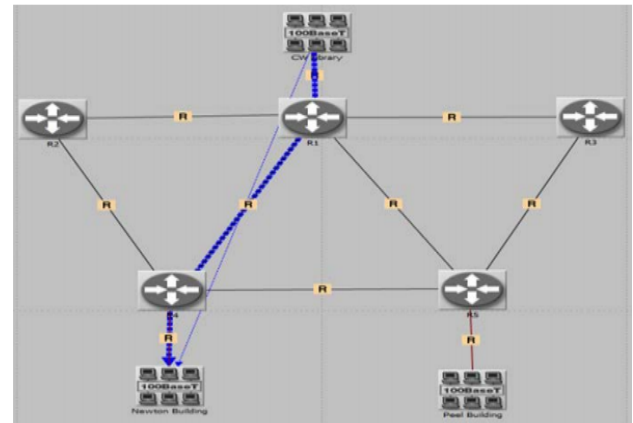


Figure 3. No failure/recovery scenario for RIP

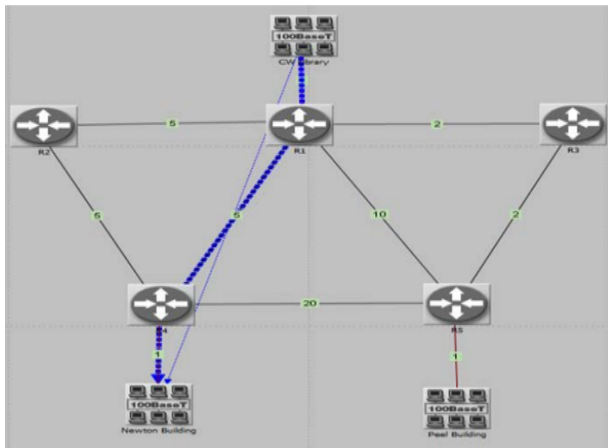


Figure 4. No failure/recovery scenario for OSPF

3) Single Link Failure/Recovery Scenario

This pair of scenarios investigates the performance of the routing protocols when a single link fails and recovers. The scenarios from the last session were duplicated and the chosen link ($R1 > R4$) in the previous condition was failed in 200 seconds and recovered in 500 seconds. The traffic between CW and Newton was made to start at 320 seconds which is between the failure time (200 seconds) and recovery time (500 seconds). This will help show the effect of link failure as the two protocols will choose the next best route (Route 1, Cost: 12, Hop Counts: 3) for their traffic. Route 1 was chosen as the best route for both protocols due to a link failure in Route 2 at the time of traffic. This is as shown in Figures 5 and 6.

The convergence activity and the traffic sent were compared for both protocols. The values of the convergence duration and traffic sent were exported to table form for analysis.

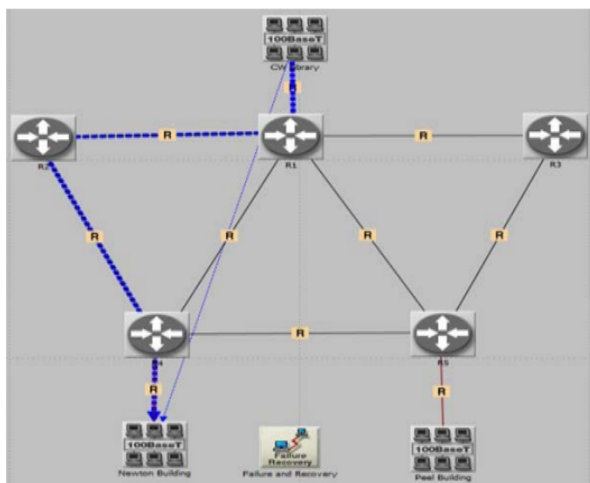
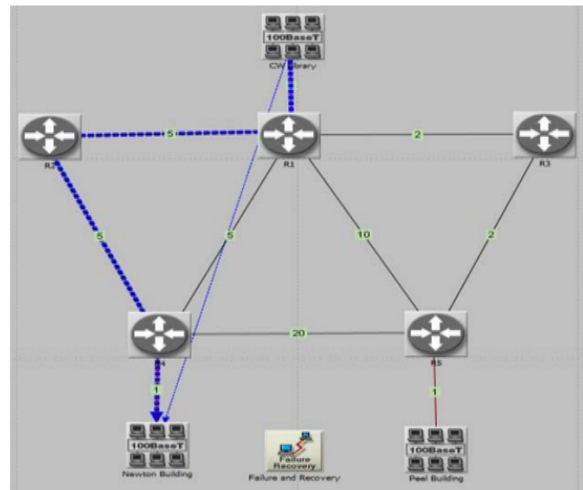


Figure 5. Single link failure/recovery scenario for RIP



Figure

6. Single link failure/recovery scenario for OSPF

4) Multiple Link Failure/Recovery Scenario

These two scenarios investigate the performance of the routing protocols when multiple links failed and recovered. The scenarios from the last session were duplicated with the link ($R1 > R4$) failed. More links ($R1 > R2$ and $R3 > R5$) were failed and recovered at different times summarized as follows;

$R1 > R2$ was failed in 300 seconds and recovered in 500 seconds and

$R3 > R5$ was failed in 200 seconds and recovered in 350 seconds

The traffic between CW and Newton was made to start at 320 seconds which is between the latest failure time (300 seconds) and the earliest recovery time (350 seconds). This will help show the failure of the link diagrammatically as the two protocols will choose the next best route (Route 3, Cost: 32, Hop Counts: 3) which is the only available route for their traffic as other two routes have failed link. This is as shown in Figures 7 and 8.

The convergence activity and the traffic sent were compared for both protocols. The values of the convergence duration and traffic sent were exported to table form for analysis.

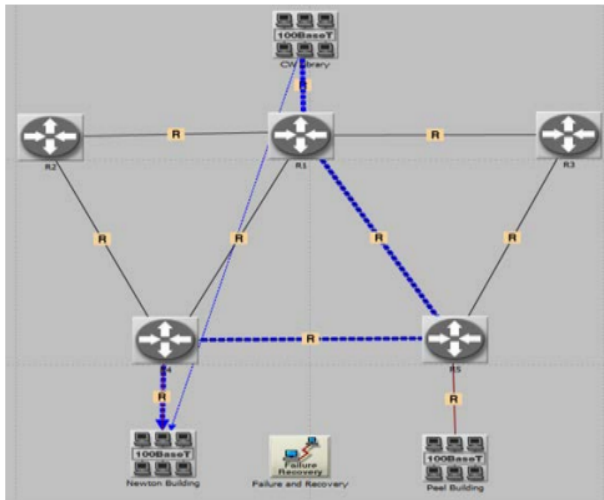


Figure7. Multiple links failure/recovery condition (RIP)

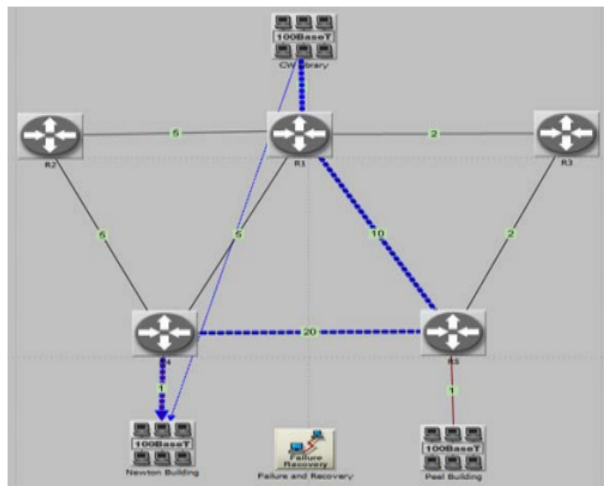


Figure 8. Multiple links failure/recovery condition (OSPF)

IV. RESULTS AND DISCUSSION

The convergence and the routing traffic activities are represented in Figures 9 to 11 and Figures 12 to 14 respectively. The exported values for discussion are also presented in Tables I to VI.

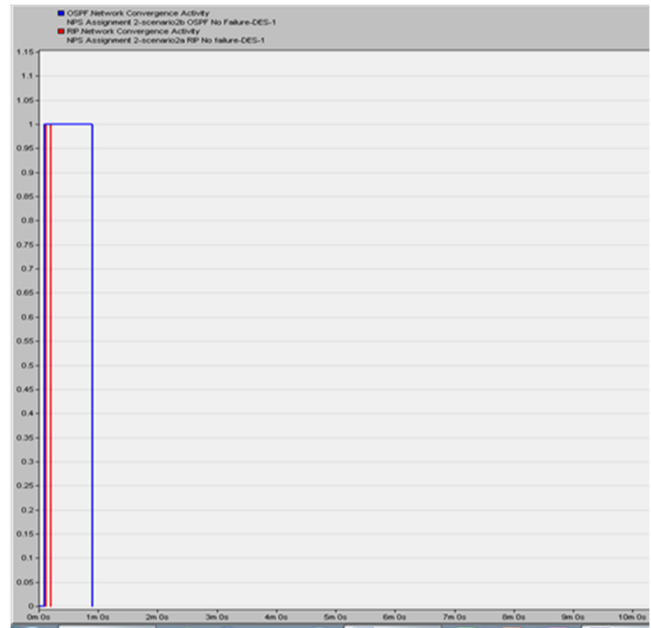


Figure9. Convergence activity for no link failure/recovery scenario

TABLE I COMPARISON OF CONVERGENCE ACTIVITY FOR NO LINK FAILURE/RECOVERY SCENARIOS

	RIP	OSPF
Event Time (s)	0	0
Start time of Convergence (s)	7.19	5.85
Duration of Convergence (s)	3.59	47.21
Total convergence duration (s)	10.78	53.06

The no failure/recovery scenario was run between 0s and 600s. RIP and OSPF started converging at 7.19 and 5.85s respectively while 10.78s and 53.06s were the RIP and OSPF total convergence period respectively.

The following was noted as shown in Figure 10 in the Single failure/recovery scenario:

- 0s was the beginning of the simulation.
- 200s was when the single link failed
- 201.2s and 200s were the RIP and OSPF start time of convergence respectively after a single link failure.
- 211.21s and 205s were the RIP and OSPF convergence time respectively after a single link failure.
- 500s was when the single failed link was recovered.
- 500s and 500s were the RIP and OSPF start time of convergence respectively after single link recovery.
- 500s and 517.19s were the RIP and OSPF convergence time respectively after single link recovery.

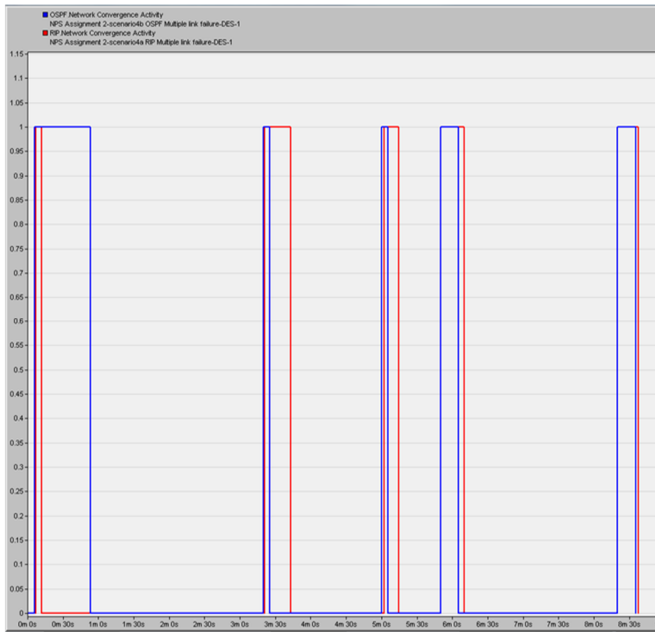


Figure 10. Convergence activity for single link failure/recovery scenario

TABLE II COMPARISON OF CONVERGENCE ACTIVITY FOR SINGLE LINK FAILURE/RECOVERY SCENARIOS

	RIP	OSPF
Event Time (s)	0	0
Start time of Convergence (s)	7.19	5.85
Duration of Convergence (s)	4.02	47.21
Total convergence duration (s)	11.21	53.06
Event Time (seconds)	200	200
Start time of Convergence (s)	201.02	200
Duration of Convergence (s)	18.34	5.00
Total convergence duration (s)	19.36	5.00
Event Time (s)	500	500
Start time of Convergence (s)	500	500
Duration of Convergence (s)	17.19	15.00
Total convergence duration (s)	17.19	15.00

The summary of the notable events in the Multiple links failure/recovery scenario is has given below:

- 0s was the beginning of the simulation.
- 200s was when two links failed simultaneously.
- 201.2s and 200s were the RIP and OSPF start time of convergence respectively after adouble link failure.
- 222.43s and 205s were the RIP and OSPF convergence time respectively after adouble link failure.
- 300s was when another single link failed
- 302.58s and 300s were the RIP and OSPF start time of convergence respectively after the single link failure.
- 314.17s and 305s were the RIP and OSPF convergence time respectively after the single link failure.

- 350s was when a single link was recovered.
- 350s and 350s were the RIP and OSPF start time of convergence respectively after single link recovery.
- 369.36s and 365s were the RIP and OSPF convergence time respectively after single link recovery.
- 500s was when the two-failed links were recovered.
- 500s and 500s were the RIP and OSPF start time of convergence respectively after two links were recovered.
- 500s and 517.19s were the RIP and OSPF convergence time respectively after two links were recovered.

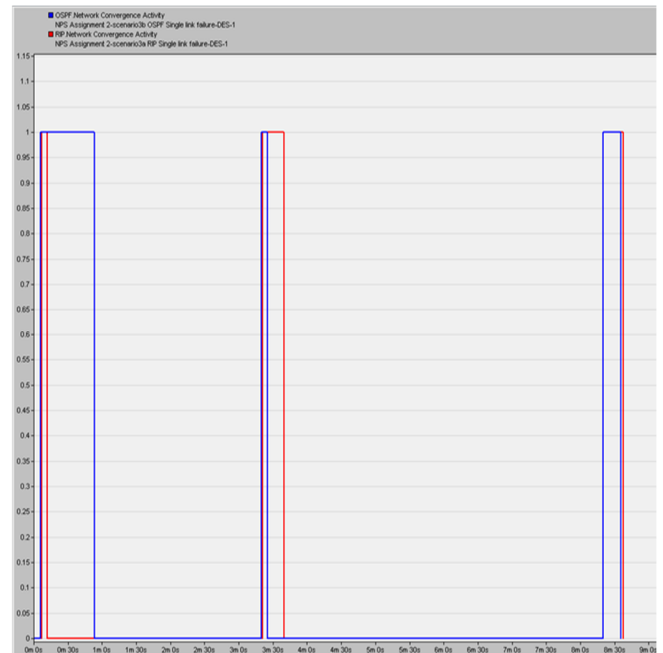


Figure 11. Convergence activity for multiple link failure/recovery scenario

TABLE III COMPARISON OF CONVERGENCE ACTIVITY FOR MULTIPLE LINK FAILURE/RECOVERY SCENARIOS

	RIP	OSPF
Event Time (s)	0	0
Start time of Convergence (s)	7.19	5.85
Duration of Convergence (s)	4.02	47.21
Total convergence duration (s)	11.21	53.06
Event Time (seconds)	200	200
Start time of Convergence (s)	201.02	200
Duration of Convergence (s)	21.41	5.00
Total convergence duration (s)	22.43	5.00
Event Time (s)	300	300
Start time of Convergence (s)	302.08	300
Duration of Convergence (s)	12.09	5.00
Total convergence duration (s)	14.17	5.00
Event Time (seconds)	350	350
Start time of Convergence (s)	350	350
Duration of Convergence (s)	19.36	15.00
Total convergence duration (s)	19.36	15.00

Event Time (s)	500	500
Start time of Convergence (s)	500	500
Duration of Convergence (s)	17.19	15.00
Total convergence duration (s)	17.19	15.00

The convergence activity revealed that it takes OSPF longer time to converge at the beginning of the simulation. However, OSPF converges faster after link failure and recovery in both single and multiple cases. OSPF also shows faster response than RIP as it starts its convergence earlier than RIP in all the conditions. RIP shows longer convergence duration during double link failure as compared to its single link failure/recovery. OSPF maintained the same convergence duration for single and multiple failure (5s) as well as recovery (15s). This result correlates with the result of [14] who also concluded that OSPF performs better in unstable conditions while RIP is only good when there is no failure. This comparison of convergence activity is as documented in Table I to III.

The routing traffic sent by OSPF is usually high with the peak of 9994.667Bps before its convergence. The OSPF traffic sent after convergence is the usually very low with around average of 600Bps. RIP routing traffic sent normally has a periodic pair value. The first value is usually less than 1000Bps and the other value in excess of 4000Bps. RIP, however, maintained a pattern pair of 544Bps and 4080Bps every 30 seconds. During the event of link failure and recovery, OSPF sends more routing traffic than RIP but the reverse is the case after the convergence from the event as RIP adjusting to its pair pattern and OSPF traffic sent dropping significantly.[13] also opined that OSPF bandwidth utilization is better than RIP. Tables IV to VI show the comparison of routing traffic sent for all the conditions.

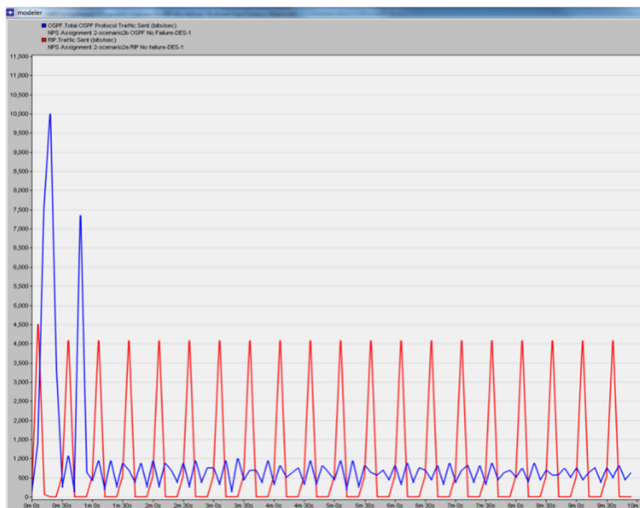


Figure 12. Traffic sent for no link failure/recovery scenario

TABLE IV
COMPARISON OF ROUTING TRAFFIC SENT
FOR NO LINK FAILURE/RECOVERY SCENARIOS

RIP	OSPF
-----	------

Event Time (s)	Simulation Time (s)	Traffic sent (bps)	Event Time (s)	Simulation Time (s)	Traffic sent (bps)
0	0	117.33	0	0	117.333
7.19	6	4512	5.85	6	1418.667
10.78	12	64		12	7514.667
	18	0		18	9994.667
	24	0	53.06	48	7344
	30	544		54	640
	36	4080			

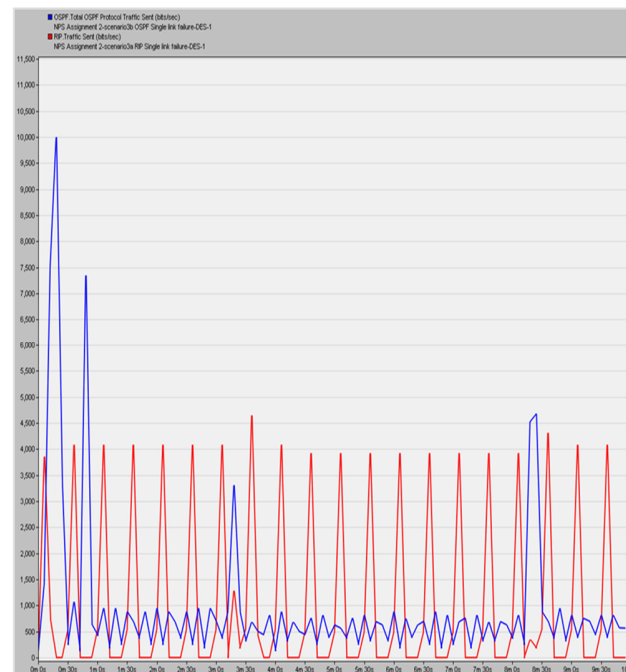


Figure 13. Traffic sent for single link failure/recovery scenario

TABLE V
COMPARISON OF ROUTING TRAFFIC SENT FOR SINGLE
LINK FAILURE/RECOVERY CONDITION

RIP			OSPF		
Event Time (s)	Simulation Time (s)	Traffic sent (bps)	Event Time (s)	Simulation Time (s)	Traffic sent (bps)
200 & 201.2	198	1285.33	200	198	3306.67
	204	192		204	880
211.2	210	544	205	210	320
	216	4645.33		216	688
	222	426.66	500	498	4528
	228 & 234	0		504	4672
	240	544	515	510	880

	246	4080		516	698		336	3626	500	498	4826.67
500	498	352		522	373.33						
	504	192									
517.19	516	4314				350	348	352		504	6176
	522...534	0					354	192	515	510	816
	540	544				369.36	366	3930.67		516	821
	546	4080					372 & 384	0		528	944
							390	437.33			
							396	3706.67			
						500	498	298.67			
							504	837.33			
						517.19	516	4314			
							522 & 534	0			
							540	544			
							546	4080			

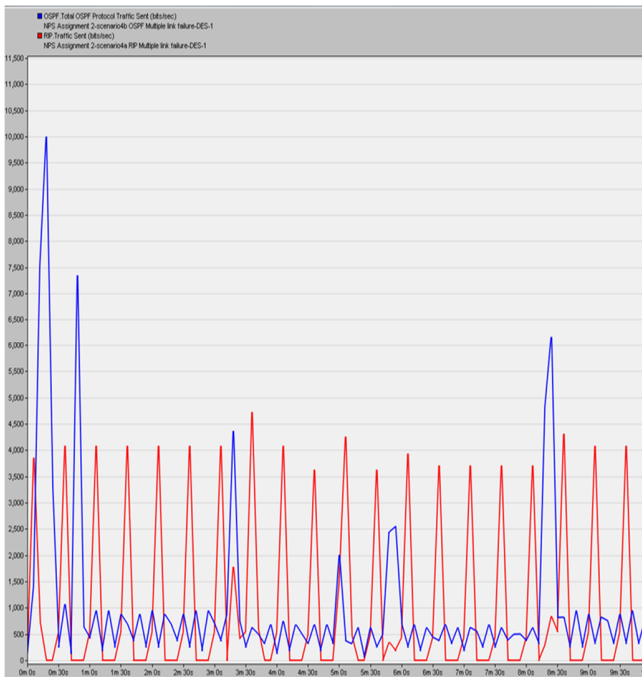


Figure 14. Traffic sent for multiple link failure/recovery scenario

TABLE VI COMPARISON OF ROUTING TRAFFIC SENT FOR MULTIPLE LINK FAILURE/RECOVERY SCENARIOS

RIP			OSPF		
Event Time (s)	Simulation Time (s)	Traffic sent (bps)	Event Time (s)	Simulation Time (s)	Traffic sent (bps)
200 & 201.2	198	1786.67	200	198	4362.67
	204	416		204	752
222.43	216	4720	205	210	256
	222	597.33		216	624
	228 & 234	0	300	294	314.67
	240	544		300	2005.33
300 & 302.08	246	4080	305	306	373.33
	300	1493		312	314.67
314.17	306	4261	350	348	2442.67
	312	469.33		354	2544
	318 & 324	0	365	360	688
	330	490.67		366	256

V. CRITICAL EVALUATION OF THE DESIGN

OSPF learns the complete topology of the network at the beginning calculating the metric cost of the paths in the network. RIP only learn about the neighbouring routers to get to its destination. This was responsible for the OSPF converging slower than RIP at the beginning of the simulation.

On failure of the link, OSPF after learning after the failure will make the route unavailable and use next best route (as it already has the complete topology of the network). RIP, however, will react slower because of the waiting period to get an update from the neighbour. RIP will have to learn about how to get to other destinations in the network through the available neighbouring routers. This is responsible for the slow convergence of RIP.

On recovery of the link, OSPF and RIP reacts immediately because the recovered link will advertise its presence. OSPF will learn the entire possible path based on metrics to the different destination of the network. This was responsible for much higher convergence time after recovery (15s) with respect to after link failure (5s). RIP will also react immediately but will learn about the recovered link.

RIP uses much more bandwidth by sending routing traffic every 30 seconds. OSPF sent much more routing traffic at the beginning of the simulation, during link failure and recovery. OSPF routing traffic reduces after convergence as it has learned the complete topology.

VI. CONCLUSION

It was observed that RIP converges faster (11.21s) than OSPF (53.06s) at the initial stage of the network in all cases. However, OSPF converges faster (Average of 5s – link failure, Average of 15s – Link recovery) than RIP (Average

of 18.57s- link failure, Average of 18.28s – link recovery) in both single and multiple link(s) failure/recovery scenarios. Therefore, based on the performance comparison, OSPF should be used in a network prone to frequent link failure as it performs better in this situation. However, RIP would be preferred if the network is not prone to frequent network failure. This conclusion correlates with existing facts in [8], [11]–[15]. However, unlike [8], [11], [13] which were based on LAN and [12], [14], [15] which were based on WAN, this research was based on MAN with mesh topology.

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