1.0 Introduction

In this report I have researched the common problem of slow convergence time within modern IP networks. Convergence time is the time taken for each router in a topology to learn paths to all available remote networks. I have conducted a review of literature relevant to this topic which has left me with several key findings: Firstly, it is clear that Open Shortest Path First (OSPF) converges much quicker when compared to older, legacy routing protocols such as the Routing Information Protocol (RIP). This is because the mechanism that OSPF uses to share routing information is much more efficient compared to RIP. Additionally, I have found that alterations to the OSPF configuration can affect the time taken for OSPF to converge within a given topology. Finally, I have discerned that when implementing a Software Defined Network (SDN) or hybrid network, convergence time is typically a lot slower compared to implementing a distributed, OSPF network. However, when the link delay (latency) for the network is high, the SDN convergence time can be faster since it doesn’t need to distribute routing information to its neighbours.

2.0 Problem Statement

In modern IP networks, a common issue is slow convergence time. This issue causes high latency and high packet loss during the time it takes for each router in the network to re-converge after a fault. The ramifications of the problem are more noticeable when using time-sensitive applications such as Voice over IP (VoIP), video streaming or video conferencing. Sometimes, the recovery time from a fault can be above the time acceptable for these types of applications. It is thought that 50ms is the “upper bound of failure recovery to guarantee the performance of real-time applications” (JIN 2015, p. 278).

This project intends to address this issue of slow convergence time by manipulating the Hello interval and Dead interval for all OSPF routers in a given topology. Convergence time and packet loss will be measured to gather results based upon the change of the Hello and Dead intervals.

3.0 Hypothesis

I am testing to see whether OSPF convergence time within an IP network can be improved by manipulating the OSPFv2 Hello and Dead intervals. The convergence time in a LAN environment is greatly improved by lowering OSPFv2 Hello and Dead interval timers.

4.0 Literature Review

In order to acquire relevant literature, I have used IEEE Xplore to search for sources. To achieve this, I used the following query string: ("convergence time" AND ospf). The results returned from this search comprised of 3 journal articles and 30 conference papers. This meant that unfortunately, I had to result in accepting conference papers as sources for my study. This is because the amount of relevant journal articles surrounding my topic is very low. However, although I have 33 studies to choose from, I have to narrow down my results to find the most pertinent sources. To do this, I have applied some inclusion and exclusion criteria.

INCLUSION CRITERIA

- Sources include OSPF and convergence time.
- Study took place within the last 15 years.
- Study is in English.
- Study is either a journal article or conference paper.
- Study contains research results.

EXCLUSION CRITERIA

- Sources do not include OSPF or convergence time.
- Study did not take place within the last 15 years.
- Study is not in English.
- Study is neither a journal article or conference paper.
- Study did not contain any research results.

In order to research my hypothesis, I am reviewing 5 pieces of relevant literature.

Jin's (2015) conceptual paper presents a method of configuring routing protocol parameters based upon a real-time evaluation of the network state. Within his study, Jin proposes that a numeric value is used to identify the importance of a given link, thus allowing failures to be treated differently depending on importance. Alongside importance, Jin states that the damage degree is the impact of a link fault on the overall network performance. The damage degree value is used to determine the Hello and Dead interval parameters used within OSPF to re-converge. Jin's results clearly show that the convergence time when using the parameters based upon the damage degree is considerably lower than when using the default OSPF values. However, Jin's study has several limitations when it comes to the network topology that was used. This is because the study only used one OSPF topology for the experiment. As a result of this, it could be said that the data gathered from this study is only pertinent to the topology used and is not representative of other network topologies. Additionally, it was stated that Jin assumes that "all routers are in the same area" (p. 280). This means that the results are only directly applicable to intra-area OSPF instead of inter-area OSPF.

Jayakumar, Ramya Shanthi Rekha and Bharathi (2015) conducted a comparative study on the RIP and OSPF routing protocols. They set out to compare the latency, throughput, convergence time and packet loss between the two protocols. Within this study, Jayakumar, Ramya Shanthi Rekha and Bharathi display results from testing these attributes of each protocol on a given topology. The gathered results show that convergence time is considerably lower for OSPF compared to RIP. This supports the argument that OSPF's mechanism for sharing routing information is better suited for fast convergence over RIP. Additionally, the results show that the latency, throughput and packet loss results for OSPF were better compared to the results for RIP. However, much like the research conducted by Jin (2015), the experiment was only carried out using a single network topology. This meant that the study was limited in terms of generalisation since the results could not be directly applied to topologies of other sizes and/or layouts. It could be said that since RIP is almost considered a legacy protocol, it is uncommon to find it operating on a modern network. Therefore, a better comparator to OSPF could have been Enhance Interior Gateway Routing Protocol (EIGRP).

Anu and Vimala (2016) produced a conceptual paper proposing a new method of optimising convergence time for OSPF. Anu and Vimala describe how convergence time can be optimised by clustering each OSPF area. Within each cluster, designated devices called 'Cluster Heads' are selected using a novel algorithm. This dramatically reduces the time for Link-State Advertisement (LSA) Flooding during convergence by only informing the cluster heads of the topology change, instead of every OSPF router. Anu and Vimala state that when implemented, OSPF is a protocol that provides "functionality as well as stabilization and is easy to maintain" (p. 5). However, it could be said that this new proposed algorithm may not be applicable to different network topologies since the experiment only tests one mesh and one tree topology. Additionally, despite the results showing quite an impressive convergence time for OSPF using the new algorithm, the only comparators available are results from other protocols and not an OSPF result without using the proposed changes. Because of this, it makes it hard to compare the new algorithm's results to how barebones OSPF would normally perform.

Khan et al. (2017) conducted a study on the performance of a hybrid network using both SDN and OSPF. Khan et al. propose that select devices within a topology could be replaced with OpenFlow capable nodes, thus making the topology hybrid instead of either fully centralised or distributed. Additionally, Khan et al. conducted multiple experiments testing the end-to-end node response time and the convergence time of both their proposed hybrid topology and a standardised OSPF topology. From the results, it is clear that the node response time is greatly improved by implementing the OpenFlow capable devices. However, when reviewing the results for convergence time, it is evident that the hybrid topology had a much higher convergence time compared to the OSPF network. Khan et al. described this as a "tradeoff between node response time and convergence time" (p. 4) when implementing their proposed hybrid topology. Because of this, the proposed hybrid network implementation may not be best applied to topologies in which stability and reliability are an issue. It could also be said that the trade-off between response time and convergence time may be more detrimental to the network's performance if a fault occurs since in some of the tests, the convergence time was approximately six times higher for the hybrid topology compared to the OSPF topology.

Zhang and Yan (2015) conducted a comparative study between SDN routing and distributed routing. Zhang and Yan produced two equations; one to calculate the convergence time for the OSPF network, and one for the SDN network. In order to carry out the experiment, Zhang and Yan developed two network topologies. One topology was comprised of 16 nodes whereas the second was comprised of 120 nodes. By having two topologies of different sizes, this allows the results of each test to be compared to those of the other topology. Zhang's and Yan's results show that the convergence time for OSPF in both the 16 node and 120 node topologies is considerably faster than the time for the SDN implementation. However, when increasing the latency on the links from 2ms up to either 16ms or 26ms, it is evident that the benefits of the SDN implementation start to show. This is because as the latency on the link increases, the overall time taken for OSPF to re-converge the network also increases. Zhang and Yan explained this by stating that the SDN implementation "does not need to transmit network information between switches" (p. 494). This means that the link delay has a very small impact on the convergence time in the SDN environment. These results are similar to those collected by Khan et al. (2017) in the sense that the convergence time for the OSPF network, was in most cases lower compared to the convergence time for the SDN implementation.

5.0 Proposed Methods

In order to gather results for my project, I will collect quantitative data comprising of the convergence time and the packet loss for each OSPF test. The convergence time will be measured by timing the number of seconds it takes for every OSPF router in the topology to re-converge after a fault. Every time I change the OSPF Hello and Dead interval parameters, I will conduct another test to measure the convergence time. Additionally, I will measure the packet loss during the time taken for the network to re-converge after a fault. By combining these two measurable values, I will be able to understand which OSPF parameters are best suited for a faster convergence time. However, in order to establish a baseline result, I will conduct a test using the default OSPF Hello and Dead interval timers. This will allow me to better compare my results to how OSPF would normally perform if left with a default configuration.

6.0 Legal, Ethical and Social Issues

In order to maintain legality when carrying out my research, I will ensure that I only carry out tests on equipment that I am authorised to use. Additionally, I will ensure that tests are not carried out on equipment that others are using so I do not negatively affect their session. From an ethical standpoint, I will make sure that I do not inadvertently capture any users' network traffic other than that from my experiment. By following these rules, I will ensure that my study conforms with any pertinent laws and ethics.

7.0 Conclusion

I am proposing that to combat the issue of slow convergence time within modern IP networks, the OSPFv2 Hello and Dead interval timers can be lowered. Additionally, by lowering the aforementioned timers, the overall time taken to re-converge after a fault will be significantly reduced. In order to research into this topic, I have reviewed pertinent literature and have found several important findings that relate to how OSPF performs and how it can be improved. First off, I have found that when compared to older routing protocols like RIP, OSPF performs better in terms of convergence time, throughput, latency and packet loss. This is typically down to how OSPF operates and shares routing information with its neighbours. Secondly, I have discovered that the time taken to re-converge the network can be manipulated and is some-what dependant on the parameters used by OSPF. However, it was hard to compare how much the convergence time had changed since there was no baseline result for OSPF and were only comparators such as RIP and EIGRP. Finally, I have found that when comparing an SDN or hybrid network versus a distributed routing implementation such as OSPF, it was evident that OSPF out-performs the SDN network in terms of convergence time. However, if network latency is high, this can have adverse effects on the convergence time for OSPF. When this occurs, the convergence time for the SDN or hybrid networks can be faster than the time for OSPF.

8.0 References

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Appendix A – Sources Summary

Author & Date	Aim of Study	Data Collection Methods	Main Findings
Anu and Vimala (2016)	Proposes a new method of optimising convergence time using a clustering technique.	Quantitative measurements of convergence time for OSPF.	The convergence time of the new proposed method for OSPF is considerably faster compared to the other routing protocols that were tested.
Jayakumar, Ramya Shanthi Rekha and Bharathi (2015)	Conducts a comparative study of OSPF and RIP. The aim is to discern which protocol is more suitable for the given topology.	Quantitative measurements of latency, throughput, convergence time and packet loss for OSPF and RIP.	The convergence time for OSPF was much faster than that for RIP. Additionally, OSPF was a better protocol all round since it had better measurements recorded in every category.
Jin (2015)	Proposes a new method of manipulating OSPF parameters in real-time based upon an evaluation of the network state.	Quantitative measurements of the damage degree and overall convergence time.	The OSPF convergence time was improved when using parameters calculated by the damage degree of the fault.
Khan et al. (2017)	Conducts a study on the performance of hybrid network comprising of SDN and OSPF. The aim is to decide whether a hybrid or barebones OSPF network performs better.	Quantitative measurements of node response time and convergence time for both the hybrid and OSPF implementations.	The node response time for the hybrid network is evidently better than the time for the OSPF network. However, the convergence time for the OSPF network is much faster than the time for the hybrid network. Khan et al. describes this as a “tradeoff between node response time and convergence time” (p. 4).
Zhang and Yan (2015)	Conducts a comparative study between centralised routing (SDN) and distributed routing (OSPF).	Quantitative measurements of convergence time based upon link delay.	The lower the link delay, the faster the convergence time for the OSPF network. When the link delay is higher, the SDN network has a faster convergence time.