Routing Protocol Convergence Comparison using Simulation and Real Equipment

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Abstract

Routing protocol is one of the significant factor in determining the quality of IP communication. RIP, EIGRP and OSPF are the dominant interior gateway routing protocols. Factors that discriminate different routing protocols are convergence duration, ability to select the best path among the different routes and the amount of routing traffic generated. The convergence time is one of the key factors which determines performance of the dynamic routing protocol. The primary objective of this paper was to deliver an in depth understanding of Interior Gateway Routing Protocols (RIP, EIGRP and OSPF) and compare the convergence duration of different routing protocol. We also analyse how convergence duration affect the quality of realtime application using OPNET simulation tool and real equipment.

Keywords

Routing Protocols, Convergence Duration, RIP, EIGRP, OSPF, OPNET.

1 Introduction

Routing is selecting the best path from a source to a given destination. It can be done by means of routing protocols that are based on various routing algorithms (Kurose and Ross 2010). Routing protocols are broadly classifieds as “Interior Gateway Routing Protocols and Exterior Gateway Routing Protocols”(Ivener and Lorenz 2004). Most popular interior gateway routing protocols are RIP, EIGRP and OSPF. They are used for routing within an autonomous system (Ayub, Jan et al. 2011). Factors that discriminate different routing protocols are their swiftness to adapt to the changes in the network called the convergence, capability to select the optimal path among the different routes and the amount of routing traffic generated (Thorenoor 2010).

This research is a comparative study of convergence duration of different routing protocol and how it affects the quality in realtime application. We make this study by designing similar scenarios and implement it both in simulation and real equipment with realtime application.

Our Research questions are follows:

I. Analyse how quickly RIP, EIGRP and OSPF adapt to network changes.

II. How network convergence affects realtime application performance. Convergence Duration is the time it takes by a group of routers in a network to come to an agreement on which links are up/down, on which links are faster and which are the best path to every destination. Performance of the realtime application can bemeasured using the performance metrics like end to end delay, jitter and the amount of traffic lost during re-convergence.

In the first phase of our research we design a network model in OPNET and create three same scenarios with RIP, EIGRP and OSPF respectively. In all three scenarios we observe the network convergence behaviour and analyse how it will affect the packet loss and quality of realtime application. Second Phase of our project includes the design of a network model using real equipment and configure with RIP, EIGRP and OSPF. In all three scenarios we observe the network convergence behaviour and analyse how it will affect the packet loss and round trip time.

"Optimised Network Engineering Tool (OPNET)" will be used to measure and analyse the performance of routing protocol in simulation. In the real equipment experiment we used Cisco routers to configure the network topology.

2 Routing Protocol Overview

Routing protocol are classified into following groups based on their characteristics: Static routes are administratively defined routes and will not change until the administrator override it (Ivener and Lorenz 2004). A routing protocol is said to be dynamic routing protocol, when it follows predefined rules defined by the routing algorithm, exchange routing information, and selects the optimal path based on the routing algorithm it uses. Classful routing protocols does not incorporate the subnet mask details along with the routing updates so the subnet mask should be same throughout the entire network. In Classless routing, routing updates includes the subnet mask details and it support VLSM. Distance vector routing protocols are centred with the distance and vector/direction of the destination. Link-State routing protocols offer a greater scalability and quick convergence compared to distance vector routing protocol.

2.1 Routing Information Protocol (RIP)

RIP is one among the first distance vector routing protocols designed and is still popular because of its simplicity and extensive support. Important characteristic of RIP is that it uses hope count as the metric for the best path selection. The route with hope count greater than 15 is considered as unreachable. RIP sends its routing table to all of its neighbours as a broadcast every 30 seconds. The Data part of the RIP routing protocol is encapsulated into a UDP segment and the source and destination port is set to 520. RIP uses broadcast address 255.255.255.255 as the destination address (Graziani and Johnson 2008).

2.2 Enhanced Interior Routing Protocol (EIGRP)

“Enhanced Interior Gateway Routing Protocol (EIGRP)” is a Cisco proprietary routing protocol and operate only on cisco routers. Cisco design EIGRP in 1994 and it is a fast converging and extremely scalable routing protocol for medium and large scale computer networks. EIGRP supports classless inter domain routing (CIDR), variable length subnet masking (VLSM) and also legacy protocols like Novell NetWare, Internetwork Packet Exchange (IPX) and AppleTalk. The key feature of the EIGRP is DUAL. All route calculation in EIGRP is managed by DUAL.Topology table is created by the DUAL finite state machine using the information collected from neighbour routers. From the information available from the topology table DUAL calculates the best route to the destination and makes that path as the successor. DUAL also calculates the feasible successor (second loop free best path) if available. The EIGRP composite metrics consists of Bandwidth, load, reliability and delay. EIGRP keeps information about routes and network topology details in three different tables called neighbour table, topology table and routing table.

2.3 Open Shortest Path First (OSPF)

“Open Shortest Path First (OSPF)” is a link-state routing protocol. It uses SPF (Shortest Path First) algorithm to calculate the best path to a destination in a network. OSPF is a widely preferred non-proprietary routing protocol because of its significant scalability. OSPF keeps information about all the networks in its topology table. OSPF has a hierarchal structure. To run OSPF, the router needs to have a more powerful processor and more memory. OSPF packet header is included in every frame and it contains the source and the destination address. OSPF uses multicast address 224.0.0.5 or 224.0.0.6 as the destination address. To indicate it is an OSPF packet the protocol field is set to 89 (Graziani and Johnson 2008). OSPF rely on 5 distinct types of OSPF LSP’s to distinguish their neighbours and to update the link-state routing informations. It has a hierarchical design. Every router depends on their position in the network have a specific role. Different types of OSPF routers are Internal router, Backbone router, Area border router and AS Boundary routers (Zottmann 2000). OSPF uses cumulative bandwidth from the source interface to the destination interface to calculate the cost. It does support VLSM.

3 Simulation Experiment Setup

In this research, to design the network model we used OPNET Modeler V 17.1.A. To obtain the desired statistics and analyse the RIP, EIGRP and OSPF routing protocol we designed three different scenarios using cisco 3600 router, Ethernet server, Client PC, 100 Base T Ethernet link, 10 Base T Ethernet link.

Experiment testbed is configured on the geographical outline of Europe. We placed each router in London, Amsterdam, Frankfurt, Berlin and Stockholm. An ethernet server is placed in London and the client PC is configured in Stockholm.

An Application Definition is used to generate the application traffics. In this paper we used both video and voice traffic. The video traffic we used is a multimedia video stream of 128x120 pixel video frames and we used video with different frames per second to study the effect of packet loss with different transmission rate. The Audio traffic used is built in PCM quality speech.

The first network scenario is configured with RIP routing protocol. The same model is then duplicated and configured with EIGRP and OSPF. We configured the network topology in such a way that all the routing protocol will select the path London->Amsterdam->Stockholm in the beginning. A link failure is configured between the link London and Amsterdam at 300 sec of the simulation. This will force the router to re-converge to the new path London->Frankfurt->Berlin->Stockholm. The Server is connected to the London router and the client Pc to the stockholm router. Different scenarios are used for Video and Audio traffic.

4 Simulation Result and Discussion

In order to compare three different routing protocols, we measure the following: performance metrics, convergence duration, routing protocols traffic, End-to-End delay in video/voice traffic, and number of packet loss during the re convergence.

Routing Protocol	Initial Convergence (sec)	Re-Convergence (sec)
RIP	11.010	8.66
EIGRP	5.018	0.025
OSPF	10.75	5.01

Table 1 Convergence Duration using simulation

Initial convergence duration of EIGRP is better compared to OSPF and RIP and RIP takes a long time to converge. When a network change occurs EIGRP re-converge in milli seconds where RIP and OSPF takes more time, as shown in table 1.

In order to measure how the convergence duration affect the quality of the real time application we now measure the packet loss, end to end delay and the jitter with different routing protocols.

Figure 1: Video and Voice Traffic Sent and received (bytes/sec)

The above figure shows that when the link failure happens the packet loss percentage of RIP becomes high compared to the other two routing protocol. This is because RIP will take more time to re-converge and it may cause the buffer overflow which eventually leads to packet loss. Since the EIGRP re-converge in sub seconds the packet loss percentage is very less compared to OSPF and RIP as we expected.

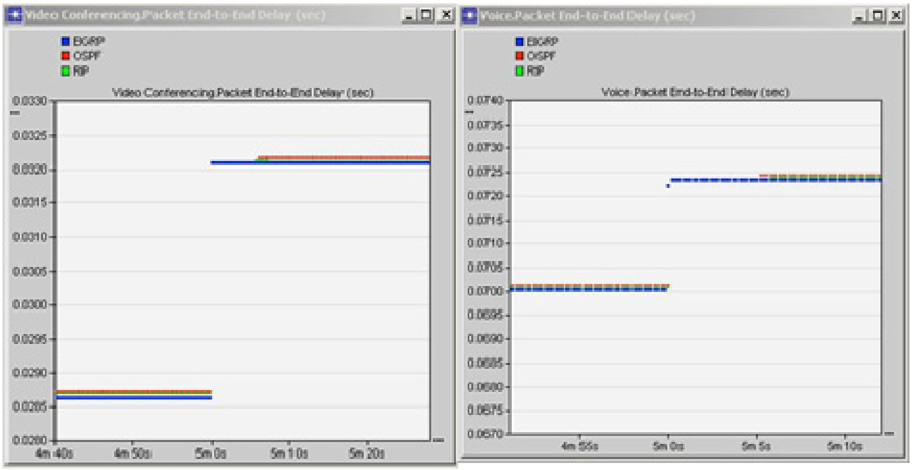

Figure 2: Video and Voice End to End Delay with link fail

End-to-end delay in the EIGRP network is slightly less than the RIP and the OSPF network before and after the link failure.

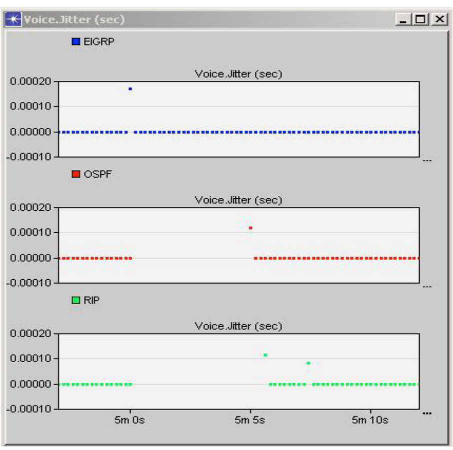

Figure 3: Voice Jitter with Link Failure

The above figure shows the voice jitter when the link failure occurs. When there is no link failure jitter in all the three routing protocol is null. In case of link failure the jitter value of the EIGRP goes to higher than OSPF and RIP.

5 Real Equipment Experimental Setup

In order to investigate the performance of different routing protocols, we set up a experimental topology as shown in the figure 5. In this experiment we used five cisco 2811 routers connected using the serial link and the two clients are connected to the router R1 and R3 using 100 Base T Ethernet link respectively.

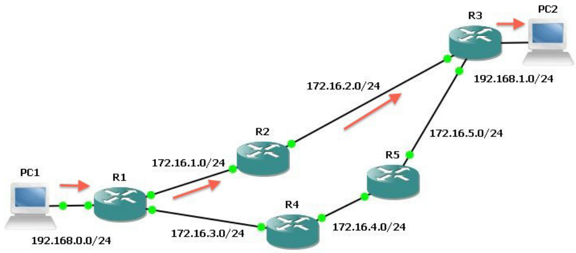

Figure 4: Experiment Testbed

To analyse how the routing protocol behave to a sudden network change, we fail the link between router 1 and 2 using the shutdown command in the respective interface. It is not easy to measure the convergence duration in the real equipment so we generate UDP packets using a network packet generator and send from client 1 to client 2 at different transmission rate and at client 2 we capture all the packets received using Wireshark. Using the amount of packet lost and transmission speed we measure the convergence duration.

6 Result and Discussion

Initially we measure the convergence duration using the ICMP packets and the result shows that RIP, EIGRP and OSPF took 14, 3 and 6 second respectively to converge. In order to calculate more accurate convergence duration we conduct the following experiment. Using the packet generating software (Ostinato packet generator) we created dummy UDP packets with the source address as PC1 address and destination as PC2 address. The packets are sent from the PC1 to PC2 with different transfer speed (05 pkt/sec, 10 pkt/sec, 15 pkt/sec, 20 pkt/sec, 25 pkt/sec and 30 pkt/sec) and calculate the number of packet lost every time. In every experiment ten seconds after transmission is started, we fail the link between routers R1 and R2. All the packets received by PC2 are captured using the Wireshark. The captured packets are analysed and the number of packet lost during the re-convergence of the routing protocol is measured and calculated the convergence duration.

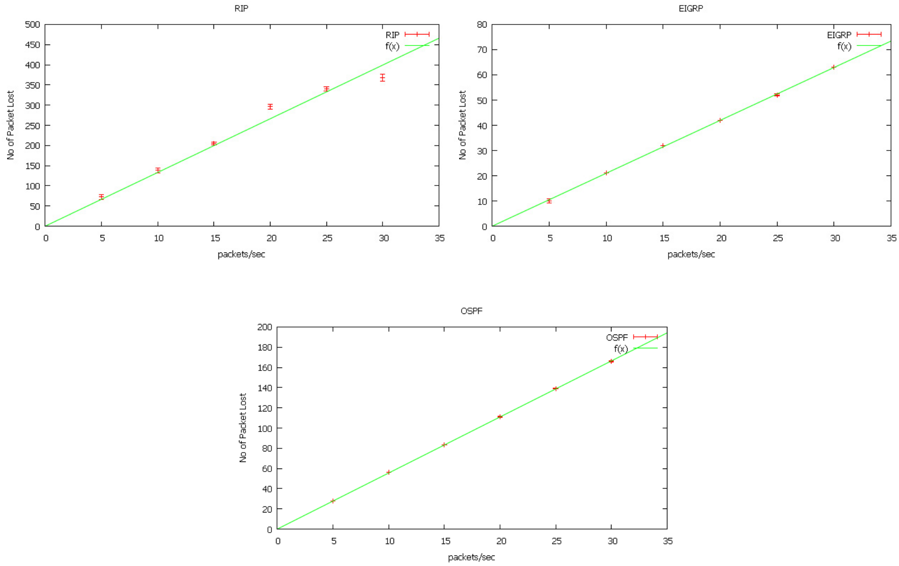

Figure 5: RIP, EIGRP and OSPF Packet Loss

The measured results show that the number of packets lost will increase linearly as we increase the number of packets transmitted. For every transmission rate we repeated the experiment for six times, and calculated the standard deviation and plotted in the graph (shown in figure 5). The time it takes to re-converge this topology is the aggregate of the time taken to detect the link failure of a valid forwarding path and the time it takes to update routing tables and related CEF tables with the new routing details. The measured convergence duration in the real equipment is shown in table below.

Routing Protocol	Re-Convergence (sec)
RIP	13.66
EIGRP	2.12
OSPF	6

Table 2: Convergence Duration using real equipment

The average RTT of an IP packet for different routing protocols is measured using the ICMP packets. The time difference between the request and the reply will give us the RTT.

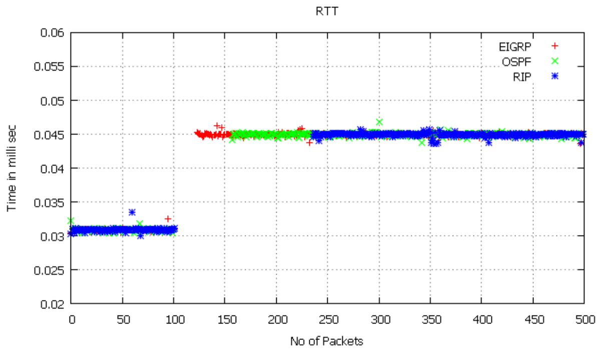

Figure 7: Round-trip Time

The experimental result shows that the average round trip time of the packets in the network using OSPF protocol is slightly less than the network with EIGRP and RIP routing protocol. The scale of difference in RTT is in micro seconds, which in-fact does not have significant impact on application performance. This small variation is possibly because the hello packets that are sent by the OSPF are smaller than EIGRP and RIP and this will reduce the overhead in the router and in turn reduce the delay.

7 Conclusion

In this research, first we compare the routing protocols in terms of convergence both using simulation and realtime and we found that the re-convergence time for EIGRP is much quicker than all other routing protocols. Convergence duration of all routing protocol shown in the simulation is lesser than the convergence duration we measured using real equipment. Analysis using the network simulator shows that EIGRP re-converge within milli seconds but in real equipment it took around 2 seconds. This is possibly because simulator will not count the time it takes to identify and detect the link failure of a valid forwarding path. RIP takes long time to converge both in network simulator and in real equipment compared to other protocols. Convergence time of RIP in the real equipment is suffered from a small variation. This may be because RIP routers send triggered update only to the failure interface and depends on the moment the link failure happen router will converge at different time. Also the convergence time will vary depending on the size and design of the network.

Since the time to re-converge the EIGRP network is lesser, both in simulation and real equipment, packet loss in the EIGRP network is very low compared to the other routing protocol. Packet loss is a significant factor in determining the performance of realtime applications. In order to analyse how packet loss vary with different transmission rates, we transfer different traffic with different transmission rate both in simulation and realtime. The result shows that packet loss linearly increases as the transmission speed is increased.

In this thesis, among the different findings the most significant one is the superior convergence of EIGRP compared to RIP and OSPF both using simulation and real equipment.

8 References

Ayub, N., F. Jan, et al. (2011). "Performance Analysis of OSPF and EIGRP Routing Protocols with Respect to the Convergence." European Journal of Scientific Research 61(3):434-447.

Graziani, R. and A. Johnson (2008). Routing Protocols and Concepts, CCNA Exploration Companion Guide, Cisco Press.

Ivener, R. and J. Lorenz (2004). CCNP 1 : advanced routing, companion guide. Indianapolis, Ind., Cisco Press.

Kurose, J. F. and K. W. Ross (2010). Computer networking : a top-down approach. Boston, Addison-Wesley.

Thorenoor, S. G. (2010). Communication Service Provider's Choice between OSPF and IS-IS Dynamic Routing Protocols and Implementation Criteria Using OPNET. 2010

Second International Conference on Computer and Network Technology (ICCNT). Zottmann, H. (2000). "OSPF -- Scalable Autonomous System Routing." from http://www.cellsoft.de/telecom/autonomoussystemrouting.htm.