Performance Evaluation of OSPF, EIGRP and RIP Protocols in Multiprotocol Label Switching

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ABSTRACT
Multiprotocol Label Switching (MPLS) is an emerging technology which ensures the reliable delivery of the Internet services with high transmission speed and lower delays. The key feature of MPLS is the Layer 3 VPN service that can provide a secure connection to any enterprise between its sites around the world. GNS3 has been used to build a network topology of internet service provider (ISP) MPLS core network. Moreover, OPNET 17.5 modeler which is network simulation tool software has been used to compare the performance of three different routing protocols; Routing Information Protocol (RIP), Open Shortest Path First (OSPF) and Enhanced Interior Gateway Protocol (EIGRP) in order to show the most suitable routing protocol needed in the small ISP MPLS core network. The results shows that the RIP has the highest time average end-to-end delay which is 0.19μs and the OSPF has the highest network convergence time which is 18.5 Seconds during the first minute of the all simulation period.

Keywords: MPLS, RIP, OSPF, EIGRP, ISP, VPN and Routing Protocols.

1. Introduction
Now a days Internet is playing a vital role in most of the people’s life due to wide variety of applications and services provided on Internet. The increased number of...
Internet users made the popular services like TVs and telephone use the Internet as a medium to reach their customers. These services are provided by convergence of voice and data communications over single network infrastructure known as Next generations networks (NGN). [1] Providing the real-time applications on Internet is a challenging task for the conventional IP networks as it uses best-effort services which doesn't provide guarantee of services and Traffic Engineering (TE). Moreover IP networks offer minimum predictability of services which is unacceptable for the applications like telephony and multimedia services. [2] The success of MPLS is undoubtedly a result of the fact that it enables the network to carry all kinds of traffic, ranging from IP traffic to Voice over IP (VoIP) traffic to Layer 2 traffic. MPLS is the means for an IP network to consolidate many networks into one. [3] MPLS can consolidate the ATM, Frame Relay, Voice, and IP networks into one unified network infrastructure, thereby generating a huge cost advantage.

In only a few years, Multi-Protocol Label Switching (MPLS) has evolved from an exotic technology to a mainstream tool used by service providers to create revenue-generating services. [4] There is rapid deployment of MPLS-enabled services and active development of new mechanisms and applications for MPLS in the standards bodies. The aims to describe the fundamental Mechanisms used by MPLS and the main service types that MPLS enables, such as Virtual Private Network (MPLS VPN). [5] MPLS has matured a lot and is a stable technology, seeing many new deployments and new features. Given the fact that MPLS is based on IP, and the Internet is based on IP technology, it seems that the future of MPLS is ensured for quite a while to come. [6] The main aim of this paper is to investigate the general study of MPLS and then the implementation of MPLS layer 3 VPN which is the main aim of this paper by connecting one company that has two sites interconnected across the common service provider MPLS infrastructure.

- Designing a small (ISP) internet service provider core network topology.
- Implementing (MPLS) multi protocol label switching to the core network.
- Configuring MPLS L3 VPN between two sites using GNS3 simulator.
- Then implementing three different scenarios with three different routing protocols in the MPLS network using OPNET IT GURU simulator.
Comparing the performance of each routing protocols in the MPLS network using OPNET IT GURU as results.

A simulation study is performed by using GNS3 to demonstrate the topology of the network and the MPLS L3 VPN connectivity between the sites and OPNET IT GURU for routing protocols comparison to get statistical results or data. [7]

In this paper is mainly focused on performance of the real-time MPLS L3 VPN. Simulation is done with a networking simulator called GNS3. The operation of the MPLS L3 VPN network was ensured with customer sites fully connected. Also using OPNET modeler to show the behavior of the packet through the core network like throughput, delay and network convergence as performance parameters. Simulation results are analyzed and shown in table and in graphical manner. It is to be realized that MPLS is not a replacement of IP but it is designed to add a set of rules to IP so that the traffic can be classified and policed.

2. Network Topology Diagram

An ISP simulated MPLS Core network was implemented to enable Layer 3 VPN service for large number of customers.

In this paper two customers where offered for VPN service. Each customer has two sites, which has to be connected between them using MPLS core network.

Customer CA has two sites one site is the Headquarter (HQ) located in Dubai, other site is the branch which is located in Khartoum, Sudan. Also Customer CB has two sites, the HQ located in Dubai and the branch site located in Khartoum, Sudan. Look at figure 1 for the network topology diagram.

Figure 1 MPLS core network
3. MPLS Core Network Results

Forwarding of packets in MPLS core is based on labels instead of IP address which is a great benefit reducing the processor overhead of the routers. The first label is imposed on the ingress LSR R1 and the label belongs to one LSP. The path of the packet through the MPLS network is bound to that one LSP. All that changes is that the top label in the label stack is swapped at each hop. The ingress LSR imposes one or more labels on the packet. The intermediate LSRs swap the top label (the incoming label) of the received labeled packet with another label (the outgoing label) and transmit the packet on the outgoing link. The egress LSR of the LSP strips off the labels of this LSP and forwards the packet.

Using core Router R6 as example to show MPLS enabled interfaces is shown in Table 1. Output is given by using Cisco ISO command.

<table>
<thead>
<tr>
<th>Interface</th>
<th>IP</th>
<th>Tunnel</th>
<th>BGP Static Operational</th>
</tr>
</thead>
<tbody>
<tr>
<td>GigabitEthernet1/0</td>
<td>Yes (ldp) Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>GigabitEthernet2/0</td>
<td>Yes (ldp) Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>GigabitEthernet3/0</td>
<td>Yes (ldp) Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Using core Router R6 as an example to illustrate MPLS labels used to forward traffic for all MPLS Core network destination IP addresses is shown in Table 2.

<table>
<thead>
<tr>
<th>Local Label</th>
<th>Outgoing Prefix</th>
<th>Label or Tunnel Id</th>
<th>Switched</th>
<th>Bytes Label</th>
<th>Outgoing Interface</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>302</td>
<td>5.5.5.3/22</td>
<td>0</td>
<td>Gig2/0</td>
<td>10.36.0.3</td>
<td></td>
</tr>
<tr>
<td>601</td>
<td>Pop Label 3.3.3.3/32</td>
<td>0</td>
<td>Gig2/0</td>
<td>10.36.0.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>602</td>
<td>303</td>
<td>10.57.0.0/24</td>
<td>0</td>
<td>Gig2/0</td>
<td>10.36.0.3</td>
<td></td>
</tr>
<tr>
<td>603</td>
<td>Pop Label 10.37.0.0/24</td>
<td>0</td>
<td>Gig2/0</td>
<td>10.36.0.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>604</td>
<td>Pop Label 10.43.0.0/24</td>
<td>0</td>
<td>Gig2/0</td>
<td>10.36.0.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>605</td>
<td>Pop Label 10.35.0.0/24</td>
<td>0</td>
<td>Gig2/0</td>
<td>10.36.0.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>606</td>
<td>307</td>
<td>7.7.7.7/32</td>
<td>0</td>
<td>Gig2/0</td>
<td>10.36.0.3</td>
<td></td>
</tr>
<tr>
<td>607</td>
<td>Pop Label 10.76.0.0/24</td>
<td>0</td>
<td>Gig2/0</td>
<td>10.36.0.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>608</td>
<td>Pop Label 1.1.1.1/32</td>
<td>0</td>
<td>Gig2/0</td>
<td>10.36.0.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>609</td>
<td>Pop Label 68.88.88.88/32</td>
<td>0</td>
<td>Gig2/0</td>
<td>10.36.0.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>610</td>
<td>Pop Label 5.5.5.1 [78]</td>
<td>25658</td>
<td>Gig1/0</td>
<td>10.16.8.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>611</td>
<td>811</td>
<td>1.1.1.1 [17]</td>
<td>26019</td>
<td>Gig3/0</td>
<td>10.68.0.8</td>
<td></td>
</tr>
</tbody>
</table>
Using Router R6 as example to illustrate MPLS label bindings for all MPLS Core destinations is shown in Table 3.

Table 3 MPLS label bindings

To show end-to-end VPN connectivity between customer CA sites look at table 4.

Table 4 End-to-End Connectivity between CA sites

4. Comparison between routing protocols

Now that the connectivity is done between the sites are going to do some comparison between routing protocols by using OPNET IT GURU v17.5 software this will generate some result. In order to understand further behaviour of the network, the network will be three different Scenarios:

- OSPF scenario
- RIP scenario
- EIGRP scenario
Using OPNET build three networks with the same specification only the routing protocol will be change during the simulation and then by comparing the three scenarios in order to find the major difference between these protocols.

As show in the figure 2 the same network of the simulator GNS3 is been built again using OPNET modeller to compare the routing protocols that is running in the network. Routers used in this scenario is Cisco 7000 core routers represented as node in OPNET simulator and the links is Ethernet 10Gbit links which is practicality used in the core network. In this network, the first scenario will be RIP scenario then OSPF and then EIGRP it’s easy to navigate between scenarios in OPNET modeller. In order to show the comparison in each network the link between R1 and PE (Provider edge) will be going under eight states of fail and recovery as shown in table 5.

<table>
<thead>
<tr>
<th>LINK</th>
<th>FAIL (Second)</th>
<th>RECOVERY (Second)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R_1 \rightarrow PE_2$</td>
<td>240</td>
<td>420</td>
</tr>
<tr>
<td>$R_1 \rightarrow PE_2$</td>
<td>520</td>
<td>580</td>
</tr>
<tr>
<td>$R_1 \rightarrow PE_2$</td>
<td>610</td>
<td>620</td>
</tr>
<tr>
<td>$R_1 \rightarrow PE_2$</td>
<td>625</td>
<td>626</td>
</tr>
</tbody>
</table>

The link between R1 and PE2 will fail at 240 seconds and will recover at 650 seconds; the duration time of simulation will be 10 minutes.
After implementing the routing protocol in each network the simulation will be running in order to get results of the comparison but first let’s show each network. There are no differences between the GNS3 topology and the OPNET topology only the protocol has been changed during each scenario in order to record result, and also the fail and recovery apply each scenario.

RIP has been configured in the network the ‘R’ between each pair of routers represent actual running protocol in the network which also clearly shows in figure 4.
Figure 5 and figure 6, shows EIGRP and OSPF network scenarios respectively. Finally by running the simulation results has been found illustrated as a graphs which is easy to understand the difference between protocols as simulation goes on in this project the major differences will be show in this project.

5. The performance result

The first result is the network convergence duration of all three protocols (RIP, OSPF, and EIGRP) shown as overlaid. Convergence is important when dealing with routing protocols, the convergence of a routing protocol is the state of a set of routers that have the same topological information about the internetwork in which they operate, for a set
of router to have converged they must have collected all available topology information from each other via the implemented routing protocol.

Figure 7 network convergence duration

Figure 8 network convergence activities
As shown in figure 7, this graph shows the average network convergence duration between RIP, OSPF, and EIGRP. The fastest network convergence duration goes to the EIGRP (blue line) which approaches zero seconds. RIP (green line) in our scenario converges faster than OSPF (red line) because the link failure is just one hop far so RIP has less convergence duration time than OSPF, in addition to that OSPF is a link-state protocol which depends on topology database flooded throughout the network area.

Figure 8 shows the second comparison which is the network convergence activity—it’s a bit different from the network convergence duration.

Figure 8 shows the three scenarios convergence activity is illustrated and the OSPF it has the slowest activity convergence. The red line pulse has a bigger width that shows OSPF is slow compared to RIP and EIGRP, the blue line represents EIGRP which has only two peaks which means it has the fastest convergence activity. After convergence, the next performance is the point-to-point throughput which is a very important parameter in order to compare our three scenarios. A network throughput is the average number of bits successfully received or transmitted in bits per second. The data these messages belong to may be delivered over a physical or logical link or it can pass a certain network node. Throughput is usually measured in bit per second (bit/s) and sometimes in data packets per second or data packets per time slot.

Figure 9 Average Point-to-Point Throughputs
As shown in figure 9, the average point-to-point throughput of the EIGRP (blue line) has high throughput in the first minute and stabilize with time goes on, just because the protocol learns the network topology in the beginning it sends high data rates. The RIP (green line) has the less point-to-point throughput.

The last performance is the Ethernet delay, which represents the end-to-end delay of all packets received by all stations. It is very important when designing a network to know the end-to-end delay in our case the core network delay overlaid in three different cases.

![Figure 10 Time average end-to-end delay](image)

The graph shown in figure 10 is the end-to-end delay of each scenario. The higher delay goes to RIP (green line), which clearly shows the lack of intelligence in the RIP protocol; the OSPF (red line) starts less delay than the EIGRP (blue line) and then increases where EIGRP starts higher and then decreases with time goes on. So, in the network when EIGRP is implemented, less delay is given.

6. Conclusion

The connectivity between sites of the customers has been ensured and the MPLS core network ran successfully. Next, the scope of the work of the paper was extended to include study of the performance of three IP routing protocols; RIP,
OSPF and EIGRP. In fact, IP routing protocols is a key condition to implement every network whether it’s pure IP network or MPLS network.

In order to be able to compare the performance of the protocols, results of network convergence, throughput and end-to-end delay was found as graphs. Simulation results were confirmed that EIGRP has the fastest convergence for all network topologies. It has been observed that EIGRP and OSPF both efficiently utilize the bandwidth because both protocols do not periodically send updates as the case of RIP protocol. The RIP sends full routing information through periodic updates, which floods the network and unnecessarily wastes of bandwidth.

References


