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Performance Evaluation of First Hop Redundancy Protocols

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Abstract

High level of availability can be expensive to maintain, but lack of availability may also increase cost as it may damage the reputation of the business. Which led to the development of techniques that reduce downtime until it became transparent to the user. The first hop redundancy protocols are protocols used to manage and maintain network default gateway router by using one or more redundant routers that will take over in case of default router failure.
The First Hop Redundancy Protocols (HSRP, VRRP, and GLBP) will be implemented, tested, optimized, and compared to one another in terms of convergence time, packet loss and CPU utilization, by using GNS3 simulator and Wireshark the results of comparison will be provided and analyzed. The comparison indicates that which protocol is best in which scenario and which is best among the three protocols.

Keywords: FHRP, availability, redundancy, HSRP, GLBP, VRRP

1. Introduction

In today's network, availability became a major issue for corporations and businesses. Each minute of outage could cause a company hundred, if not thousands of dollars. In order to minimize outages, we try to increase the uptime of the network by using redundant links and nodes. Although redundancy is good it is costly too, and there is no single way of achieving optimal availability for network it depends on the customer business needs and how much it can tolerate the downtime of the network. The availability can be expressed as a percent uptime per year,

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month, week, day, or hour, compared to the total time in that period. For example, in a network that offers 24-hour, 7-days-a-week service, if the network is up 165 hours in the 168-hour week, availability is 98.21 percent [1].

In general, availability means how much time the network is operational. Availability is linked to reliability but has a more specific meaning (percent uptime) than reliability. Reliability refers to a variety of issues, including accuracy, error rates, stability, and the amount of time between failures [3].

2. First Hop Redundancy Protocols

First, Hop Redundancy Protocol (FHRP) is a group of protocols that allow a router on a network to automatically take over if a primary default gateway router fails. The devices on a shared network segment are configured with a single default gateway address that points to the router that connects to the rest of the network. The problem comes when this primary router fails, and there is a second router on the segment that is also capable of being the default gateway but end devices don't know about it. Hence, if the first default gateway router fails, the network will terminate [2]. One of the solutions to this problem is First Hop Redundancy Protocols. The three main First Hop Redundancy Protocols are HSRP - VRRP -GLBP[14].

First hop redundancy protocols such as HSRP and VRRP provide default gateway redundancy with one router acting as the active gateway router with one or more other routers held in standby mode. While others like GLBP enables all available gateway routers to load share and be active at the same time [4].

2.1. Hot Standby Routing Protocol

Hot Standby Routing Protocol (HSRP) is a Cisco proprietary redundancy protocol for establishing a fault-tolerant default gateway. The Hot Standby Redundancy Protocol (HSRP) supports two versions.

2.1.1 Hot Standby Routing Protocol operation

HSRP provides a set of routers work in concert to present the illusion of a single virtual router to the hosts on the LAN. This set is known as an HSRP group or a standby group. A single router elected from the group is responsible for forwarding the packets that hosts send to the virtual router. This router is known as the active router another router is elected as the standby router. In the event that the active router fails, the standby assumes the packet forwarding duties of the active router. This process is transparent to users. Although an arbitrary number of routers may run HSRP, only the active router forwards the packets sent to the virtual router. Devices in an HSRP group select the active router based on device priorities [7].
To minimize network traffic, only the active and the standby routers send periodic HSRP messages once the protocol has completed the election process [9].

Multiple hot standby groups may coexist and overlap. Each standby group emulates a single virtual router. For each standby group, a single well-known virtual MAC and IP address are allocated to the group. The IP address should belong to the primary subnet in use on the LAN, but must differ from the addresses allocated as interface addresses on all routers and hosts on the LAN, including virtual IP addresses assigned to other HSRP groups. If multiple groups are used on a single LAN, load splitting can be achieved by distributing hosts among different standby groups. In the case of multiple groups, each group operates independently of other groups and individual routers that participate in multiple groups maintains separate state and timers for each group [8] [16].

2.2. Virtual Router Redundancy Protocol

Virtual Router Redundancy Protocol (VRRP) is an open standard redundancy protocol for establishing a fault-tolerant default gateway. VRRP is a protocol that provides redundancy to routers within a LAN. It provides an alternate route path for hosts without changing the IP address or MAC that the host knows. VRRP follows the same concept of cisco's HSRP with some differences [11].

2.2.1 VRRP Operation

VRRP provides a set of routers work in concert to present the illusion of a single virtual router to the hosts on the LAN. This set is known as a VRRP group. A single router elected from the group is responsible for forwarding the packets that hosts send to the virtual router. This router is known as the Master router another router is elected as the Backup router. In the event that the Master router fails, the Back assumes the packet forwarding duties of the Master router. This process is transparent to users. Although an arbitrary number of routers may run VRRP, only the Master router forwards the packets sent to the virtual router. Devices in a VRRP group select the master based on device priorities [6].
The master periodically sends VRRP Advertisement packets to all backups in the VRRP group to advertise its configuration and running status [5].

2.3. Gateway Load Balancing Protocol

Gateway Load Balancing Protocol (GLBP) is a Cisco proprietary protocol that attempts to overcome the limitations of existing redundant router protocols by adding basic load balancing functionality.
GLBP provides load balancing over multiple routers (gateways) using a single virtual IP address and multiple virtual MAC addresses. Each host is configured with the same virtual IP address, and all routers in the virtual router group participate in forwarding packets [9].

2.3.1 GLBP Operation

GLBP works by making use of a single virtual IP address, which is configured as the default gateway on the hosts. When the routers are configured to a GLBP group, they first elect one gateway to be the Active Virtual Gateway (**AVG**) for that group. The election is based on the priority of each gateway (highest priority wins). If all of them have the same priority then the gateway with the highest real IP address becomes the AVG [10]. A GLBP group only has a maximum of four AVFs. If there are more than 4 gateways in a GLBP group then the rest will become Standby Virtual Forwarder (SVF) which will take the place of an AVF in the case of failure [12].

3. Simulation and Results

This paper will focus on implementing first hop redundancy protocols in a network to increase the availability and reduce network downtime.
The main object is to implement different First hop redundancy protocols on three sites and compare the performance of each one of them, each site connects to two different ISP to provide high availability, and if one of the links fails the other will take over, this will provide a way to minimize network downtime with is one of the most important goals of corporations in today’s network.

3.1 Simulation Tool

GNS3 is a cross-platform graphical network simulator that runs on Windows, OS X, and Linux, it allows the combination of virtual and real devices, used to simulate complex networks without having dedicated network hardware such as routers and switches [13].

3.2 Network Design

The design used is a hierarchical design each enterprise has two core layer routers and two access layer switches with partial mesh network topology in order to eliminate single points of failure in the enterprise network.

The design consists of three enterprises (Tripoli, Sabha, and Benghazi) each of them is connected to two ISP to disrepute internet access to the enterprises, each enterprise consists of two routers inside that connect internal network to the internet and two switches that provide layer 2 connectivity as shown in Fig. 1. In order for the network to work and provide connectivity between the network nodes with fast convergence time EIGRP routing protocol is used to forward packets between the ISPs and the enterprises [15].

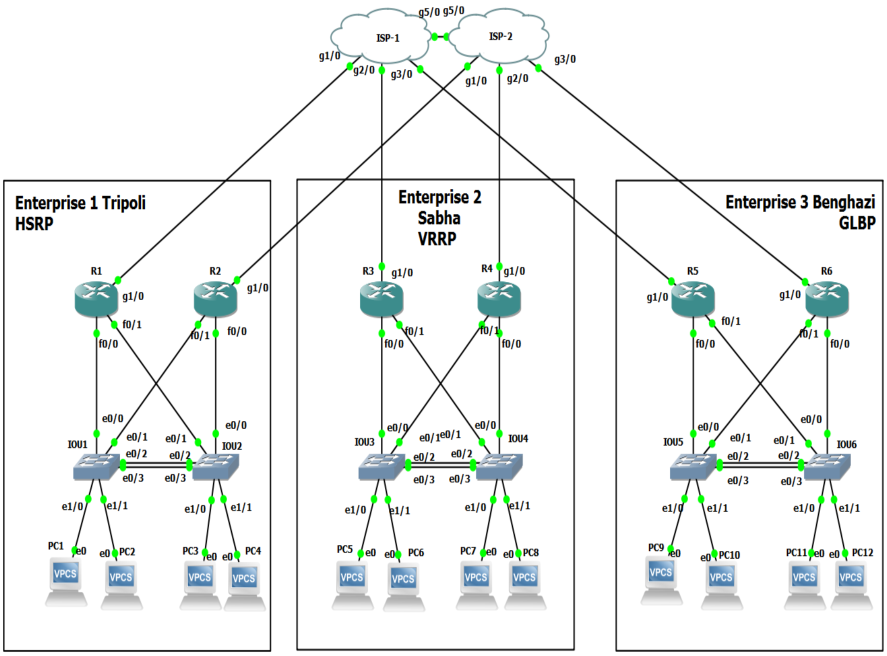


Fig. 1. Network Topology Used

3.3 Configuration

HSRP Hot standby router protocol is configured on the first enterprise that contains R1 and R2, the following is a sample of the configuration used to enable HSRP on the routers, the configuration needs to be the same on both routers in order to connect and exchange hello packets.

VRRP Virtual Router Redundancy Protocol is configured on the second enterprise that contains R2 and R3, the following is a sample of the configuration used to enable VRRP on routers. The configuration needs to be the same on both routers in order to connect and exchange hello packets.

GLBP Gateway Load Balancing Protocol is configured for the third enterprise that contains R5 and R6 the following is a sample of the configuration used to enable GLBP on routers. The configuration needs to be the same on both routers in order to connect and exchange hello packets.

IP SLA is Configured on enterprise routers to check the reachability of the ISP if the reachability goes down it will report it back to the FHRP on the router, by using track object and binding it to the IP SLA when the ISP goes down the track object will decrement a value of the priority of the router making it do to standby/backup while the other router becomes the active/master.

Note that we optimized the hello and dead timers for the HSRP and GLBP to 1 second for hello we will later show the results before and after the optimization in the comparison.

4. Results

A- HSRP Result

1- CPU Utilization

Before optimization HSRP consumed an average of 0.15% of CPU usages for R1 and R2 while both routers CPU utilization at average 6%. After Optimization HSRP took an average of 0.32% of CPU usages for R1 and R2 due to the change of timers while both routers CPU utilization still at average 7%.

2- Hello Packet Bandwidth Consumption

Fig. 2.a shows bandwidth consumption of HSRP hello packets in bytes/sec. HSRP hello packet size is 62 Byte. Fig. 2.b. shows bandwidth consumption of HSRP hello packets in bytes/sec.

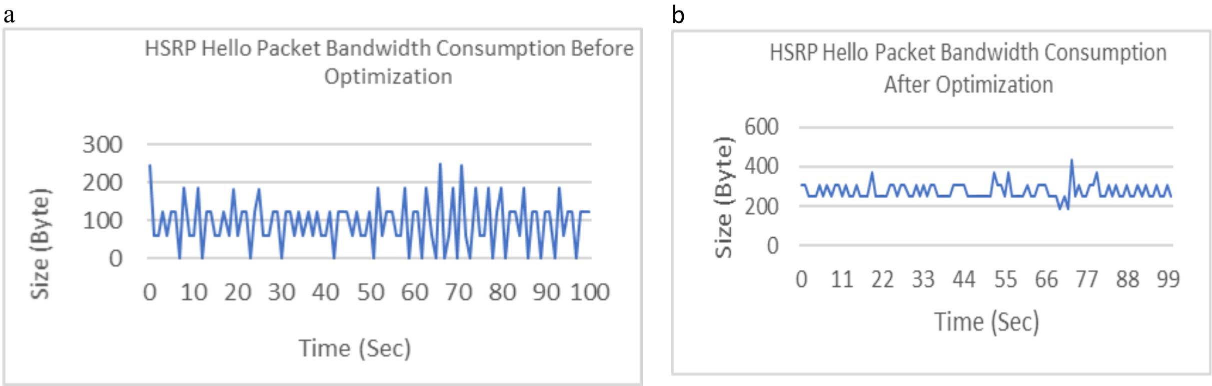


Fig. 2. HSRP Hello Packet Consumption (a) Before Optimization; (b) After Optimization.

3- Traffic Flow

Fig. 3.a shows data traffic flow in HSRP network throw R1. This shows major drops in bandwidth after reaching 5000 byte/sec. Fig. 3.b shows data traffic flow in HSRP network through R1, this shows major drops in bandwidth after reaching 5000 byte/sec.

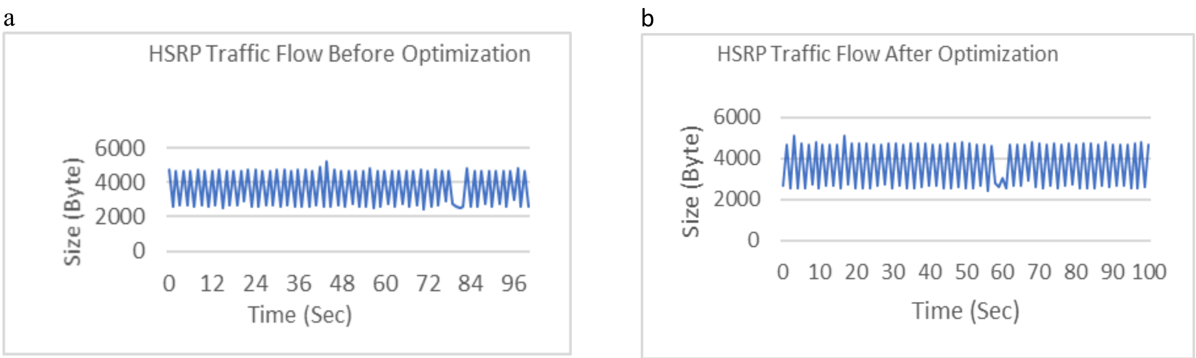


Fig.3 HSRP Traffic a) Before Optimization; (b) After Optimization.

B- VRRP Result

1- CPU Utilization

VRRP took an average of 0.10% of CPU usage for R3 and R4 while both routers CP utilization at average 6%.

2- Packet Bandwidth Consumption

Fig. 4.a shows bandwidth consumption of VRRP hello packets in bytes/sec. HSRP hello packet size is 60 Byte. Fig. 4.b shows data traffic flow in VRRP network throw R3. This provides similar results to that of HSRP.

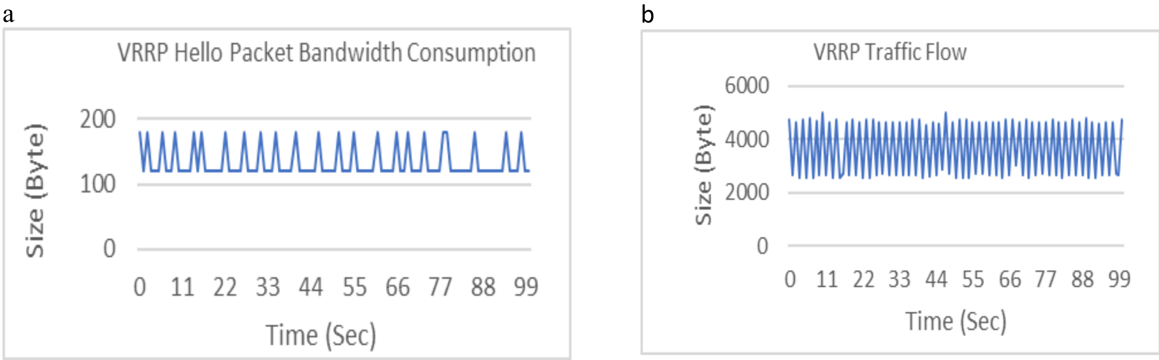


Fig. 4. VRRP Hello Packet Bandwidth Consumption a) Before Optimization; (b) After Optimization.

3- Traffic Flow

Fig. 5. shows data traffic flow in VRRP network throw R3. This provides similar results to that of HSRP.

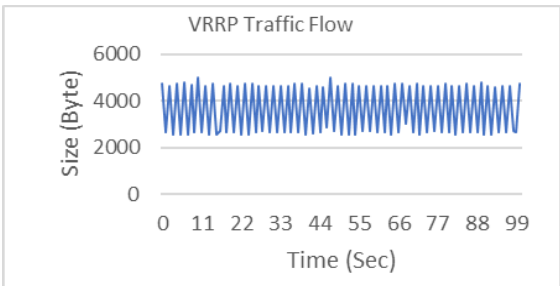


Fig 5. VRRP Traffic Flow

C- GLBP Result

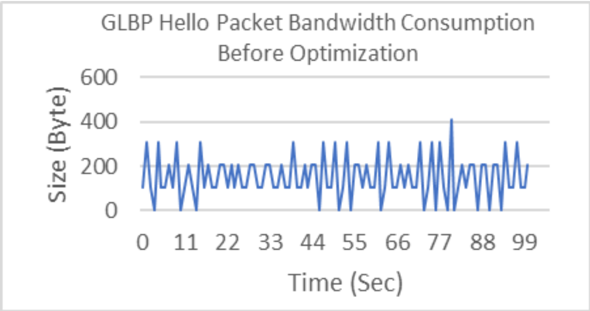
1- CPU Utilization

Before Optimization GLBP took an average of 0.13% of CPU usages for R5 and R6 while both routers CPU utilization at 6%, After Optimization GLBP took an average of 0.13% of CPU usages for R5 and R6 while both routers CPU utilization at an average 6 %.

2- Hello Packet Bandwidth Consumption

Before Optimization Fig. 6.a shows bandwidth consumption of GLBP hello packets in bytes/sec. GLBP hello packet size is 102 Byte. After ooptimization Fig. 6.b. shows bandwidth consumption of GLBP hello packets in bytes/sec.

a



b

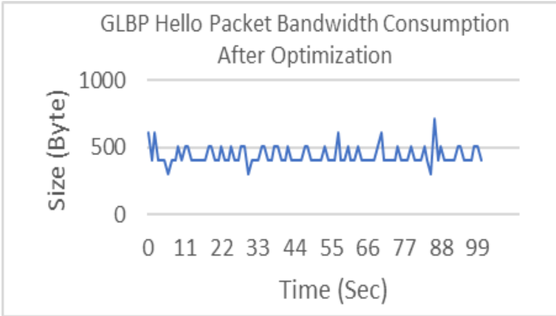


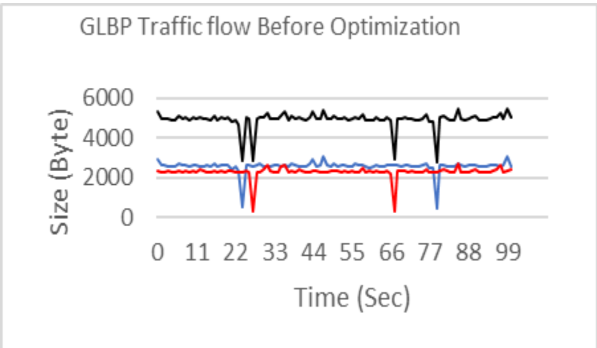
Fig 6. GLBP Hello Packet Consumption a) Before Optimization; (b) After Optimization.

3- Traffic Flow

Before Optimization Fig. 7.a data traffic flow in GLBP network throw R5 and R6, because of the default load balancing of GLBP each router became a forwarder. This makes the flow load balance between those two routers and this also provide more reliable flow without much drops like the HSRP and VRRP.

After Optimization Fig. 7.b. shows average data traffic flow in GLBP network throw R5 and R6. It provides a similar result to GLBP without the optimization.

a



b

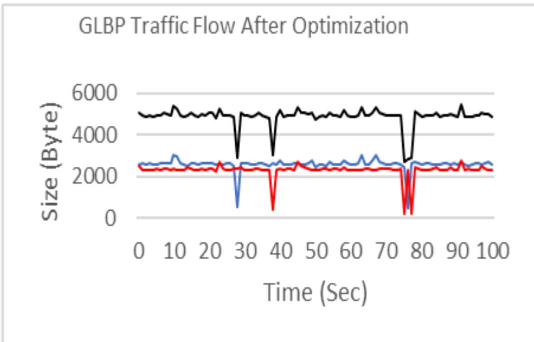


Fig 7. GLBP Traffic Flow Before Optimization a) Before Optimization; (b) After Optimization

5. Comparison

A- CPU Utilization

Fig. 8.a show CPU Utilization comparison between FHRP. VRRP has the best utilization of CPU then the GLBP.

B- Packets Loss

Fig. 8.b show Packet loss comparison between FHRP during convergence time. GLBP has the lowest packet loss after optimization.

C- Convergence Time

GLBP has the best convergence time at 2.372 seconds when optimized compared to HSRP at time 3.271 second, and VRRP at 4.861second.

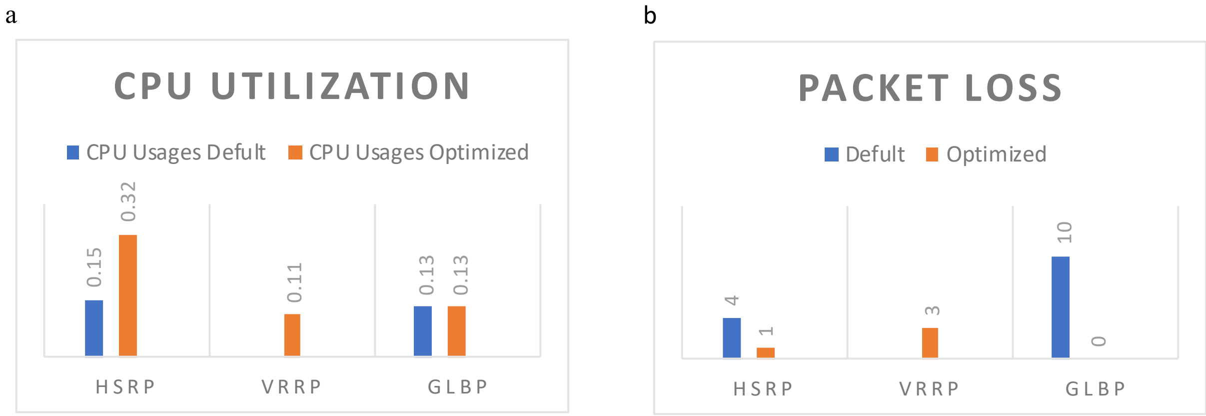


Fig 8. CPU Utilization and Packet Loss Comparison

6. Conclusion

After implementing, optimizing and testing of different FHRP and studying and analyzing their output of the conversion time, CPU utilization, and traffic flow it is clear to see that GLBP has higher performance than HSRP and VRRP. Also, the load balancing futures all make GLBP an efficient and reliable protocol used for redundancy and providing more availability to the network, but the only downside is GLBP is cisco proprietary.

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