Performance Analysis over Software Router vs. Hardware Router: A Practical Approach

Edward Guillen, Ana María Sossa and Edith Paola Estupiñán

Abstract— **For implementation of layer 3 connectivity, it is possible to use multiple vendor equipments with hardware and software based solutions. Performance results between *close source* and *open source* routing solutions are important parameters for network designers. Performance analysis in convergence time, throughput and delay between routing solution based on virtual software router (VSR) and routing solution based on proprietary hardware router (PHR) is presented. Results show that a VSR have a better convergence time in comparison with hardware router and the throughput performance is better on PHR.**

Index Terms—Convergence Time, Delay, Performance Measurement, Routing Solutions, Throughput.

I. INTRODUCTION

Benefits such as flexibility, scalability, affordability, security, administration and relationship between cost and profit are important considerations when choosing a routing solution. This is because the better routing solution performance, the more reliable will be the implementation and later use. The network administrator's decisions are supported by performance analyses. The analyses help to seek and evaluate different choices of hardware and software routing solutions to achieve and optimal network performance. These analyses have been made in order to determine how to evaluate specific routing solutions through performance metrics and the comparisons between routing solutions were made with multiple networks scenarios.

Evaluations made in this paper are independent and it cannot be seen as a positive or negative opinion against any vendor or provider, it is just a technical result of network tests.

Over the last few years, several research and development efforts have been dedicated to analyze performance over routing solutions. In 1999, IETF introduces RFC 2544 Benchmarking Methodology for Network Interconnect Devices. This document presented a methodology to measure the performance of data network devices [1]. In 2007, Tolly Group elaborated different test to compare the standard hardware between routing solutions Vyatta versus Cisco. Throughput and delay were measured on routing solutions [2], [3]. In march 2009, IXIA a testing performance's provider made a description to measure the convergence time on data network. Although IXIA described how to measure the performance of routing protocols [4].

In this paper a general overview of networking routing solutions and its features is presented. In addition a comparative analysis of routing performance measurements such as convergence time, throughput and delay between a closed source routing solution Cisco and open source Vyatta is shown.

This paper is organized as follows. In section II basics concepts of routing solutions are presented, section III shows the routing performance measurement, section IV presents the test scenarios. Section V explains the simulation results and its analysis and finally section VI presents conclusions.

II. NETWORK ROUTING SOLUTIONS: BASICS AND FOUNDATIONS

A routing solution finds a route for data packets from a source to a destination points. These solutions are designed to satisfy the needs the user´s data network. The users might be companies or service providers [5]. In data networks, routing solutions are classified in open source or closed source, the classification is shown in the Fig. 1.

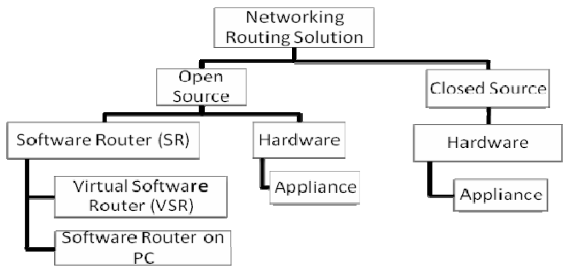


Fig 1. Routing solution classification. Closed source solutions running on hardware and open source solutions running on software and hardware.

A. Networking Routing Solution: A Open Source Overview

Open software solutions might be viable alternatives to expensive proprietary network devices [3]-[6]. Vendor's open system can scale better in enterprise or service provider edge deployments. The economic advantages of open solutions provide users a cost-effective way to increase performance that is unattainable with proprietary routing solutions. A benefit of open solutions is that it uncouple software from hardware. This advantage permit to achieve software features and service extensibility with a truly integration environment [7].

E. Guillen is with Telecommunications Engineering Department, Military University Nueva Granada. Bogotá, Colombia. (e-mail: edward.guillen@unimilitar.edu.co).
A. Sossa is with Telecommunications Engineering Department, Military University Nueva Granada. Bogotá, Colombia (e-mail: gissic@unimilitar.edu.co)
E. Estupiñán is with Telecommunications Engineering Department, Military University Nueva Granada. Bogotá, Colombia. (e-mail: edith.estupinan@unimilitar.edu.co).

ISBN: 978-988-19252-4-4
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

Software Router (SR) is low-cost option and moderate performance [8]. A SR with standard hardware x86 parameters permits to have routing equipments with high performance for the enterprises [9]. A SR running in a virtual environment is then called a Virtual Software Router (VSR).

A host workstation may be able to allocate a single or multiple VSR. The main difference between SR and a VSR is most of the VSR functions runs on software while SR interfaces runs on hardware.

Therefore, the performance of a VSR is expected to be lower than a SR. For this reason, significant research efforts are focused in optimizing the internal architecture of Open Software Router (OSR), its researches are concentrated on developing strategies to build more powerful routing devices [6]-[8]. Open source based hardware appliance is composed by routing software and standard hardware platforms. The open networking solution removes any reliance on proprietary hardware [10].

B. Networking Routing Solution: A Closed Source Overview

Hardware-Appliance closed source routing solutions are sold with proprietary software and hardware. Market offers several routing solutions such as, Cisco, Juniper, Alcatel, among others. The constraints of hardware and software and the applications control limit users to have scalable network [11].

Instead of buying a closed source hardware-appliance an Internet Services Provider (ISP) or a network administrator could use logical elements running on SR; this choice may depend of the needs of network [6].

The aim of this research is to perform a comparison between a closed routing solution in hardware i.e. Cisco and a routing solution open source i.e Vyatta running as VSR.

Table I shows the features comparatives of this routing equipment [12].

TABLE I
COMPARATIVE FEATURES CISCO VS. VYATTA

CHARACTERISTIC	VYATTA	CISCO
System Operating	Linux	Cisco IOS
Open Source	Yes	No
Static Routing	Yes	Yes
Routing Protocols (RIPv2-RIPNG, OSPFv2-OSPFv3,BGP)	Yes	Yes
NAT, VPN IPSec,	Yes	Yes
VPN SSL	Yes	No
FTP Client, TFTP Client, Telnet.	Yes	Yes
SSH Server	Yes	Yes/No
HTTP Server, DHCP Server, DHCP Client	Yes	Yes
SNMP	Yes	Yes

C. Network Routing: Protocols

Routing protocols are better known as dynamic routing protocols and these are classified in Interior Gateway Protocols (IGP) and Exterior Gateway Protocols (EGP) [13], [14]. The classification of routing protocol is shown in Fig. 2.

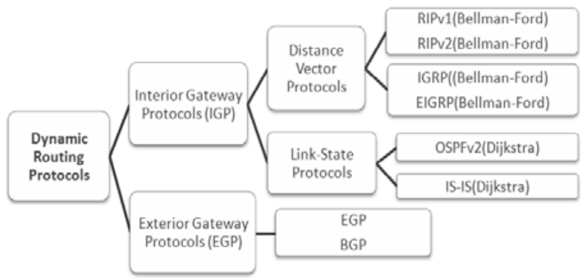


Fig. 2. Routing protocols classification according to routing domain. This Figure shows a classification according to algorithm used for each routing protocol.

III. ROUTING PERFORMANCE MEASUREMENT

In data networks performance measurements are necessary for understanding current data network behavior. The measurement analysis help to identify weaknesses on data network and it will allow evaluating how to fix it [15]. There are many performance metrics used to evaluate network performance, such as: throughput, delay, jitter, convergence time, bandwidth and packet loss [16], [17].

A. Convergence Time

According to Cisco "The network has converged when all routers have complete and accurate information about the network" [18]. In the route convergence process, all components of router are updated, as well as the Routing Information Base (RIB) and Forwarding Information Base (FIB) including the most recent route changes of network topology or information about available or unavailable of network´s links [19].

The measure of how fast the routers reach the state of convergence is called convergence time and it is given in seconds [20].

In the updating route each network´s router runs a routing algorithm to recalculate metrics and build a new routing table based on this information. Once all routing tables have been updated, convergence is completed. A time diagram is a useful tool to understand how to measure the convergence time. Time diagram is shown in Fig. 3.

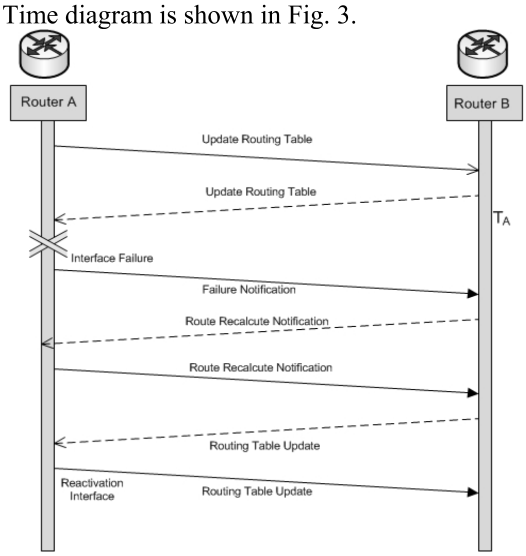


Fig. 3. Time Diagram for measuring convergence time between two routers. These figure shows the update process over routing table when occur a failure in a router´s network.

ISBN: 978-988-19252-4-4
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

Convergence time –C_T –is given by equation (1) and it is described by two parameters: Reactivation Time –*T* *(Reactivation)* –, Error Time –*T* *(Error)* – [19].

$$C_T = T_2 - T_1$$
$$C_T = T_{reactivation} - T_{error} \quad (1)$$

B. Delay

Delay ***–D–*** of a packet in data networks is time taken up by the packet to reach the destination after it leaves the source [21].

Delay is usually affected by network infrastructure due to the queuing at switches and routers [22]. Network delay is composed by transmission, queuing and propagation. Delay includes playback delay, delay for buffer-jitter and processing delay at destination terminal [23], [24].

Figure 4 shows a possible scenario to measure delay on client. The relation time is defined by two parameters: –T_A – is time when the ACK is received on server to indicate confirmation of the packet reception *n* and –T_B - is the time when a new packet is received in the client side. The time relationship is given by equation (2)

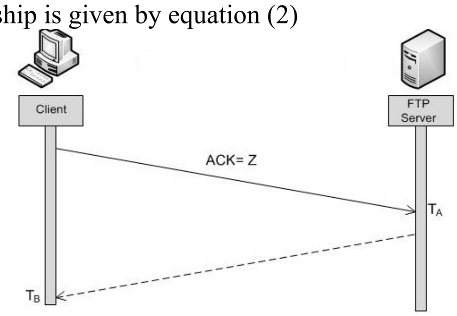


Fig.4. Time diagram to measure delay in client. This figure shows data transmission on data network, it process is useful for measurement delay on client.

$$T_{client} = T_B - T_A \quad (2)$$

A time diagram to measure the server delay is shown in fig 5. The time relationship on server is given by equation (3) and it is described by two parameters: –T_C– indicate the time when an ACK is received on server side, this ACK indicate the confirmation of reception packet *n*. –T_D- is the time when a packet is received in the client side [23].

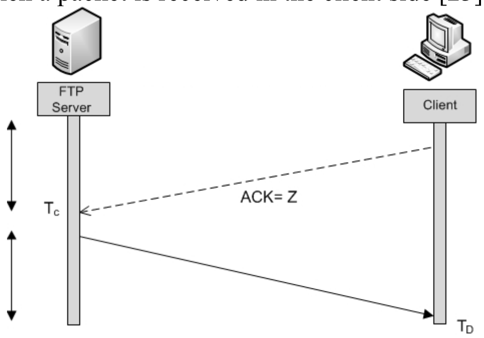


Fig.5. Time diagram in server side. This figure shows the time elapsed between the reception of an ACK in FTP server and the sending a new packet.

$$T_{Server} = T_D - T_C \quad (3)$$

Finally equation (4) shows total Delay of a sending file:

$$Delay = \sum_1^n \mathrm{T}_{\mathrm{Cliente}} - \sum_1^n \mathrm{T}_{\mathrm{Server}} \quad (4)$$

C. Throughput

Throughput is the maximum rate at which none of the offered frames are dropped by device and it's given by the relation between the user-data load ***–L–*** and the transmission time ***–t–*** [25]. Throughput is represented by equation (5) and it is obtained by dividing the file size given in bits between the time taken by the data in reaching its destination in seconds. The throughput is usually given in Mbps.

$$T = \frac{L}{t} \quad (5)$$

IV. Network Scenarios

Performance and quality of service (QoS) analysis was performed over two different scenarios. The scenarios are based on both routing architectures Cisco and Vyatta.

Routing protocols RIPV2 and OSPFV2 were configured. Throughput, convergence time and delay measurements were analyzed.

These routing performance measurements were made with a network analyzer in client and the network server. Finally, the aim is to evaluate the network performance between both routing solutions.

A. Base Scenario 1:

Base scenario 1 represents a traditional Local Area Network (LAN) and it is shown in Fig. 6. The network scenario is composed by three routers, a FTP server and a client.

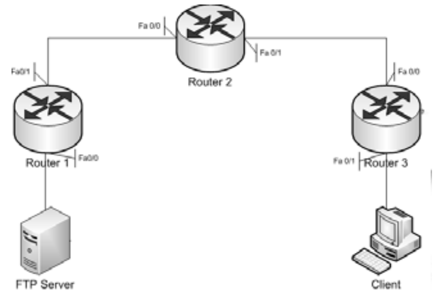


Fig. 6. Base Scenario 1

B. Base Scenario 2:

Base scenario 2 is shown in Fig 7. This network scenario has the same equipments that were used in base scenario 1.

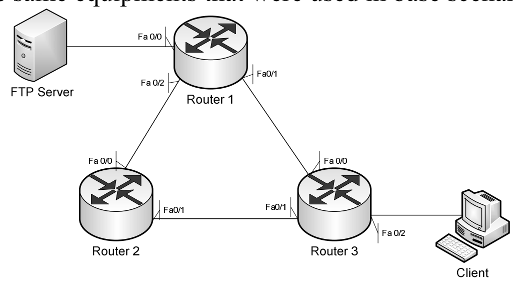


Fig.7. Base Scenario 2

Some specific tests were designed to perform a comparative performance analysis. The test descriptions are shown in table II.

TABLE II
Scenarios Description

Base Scenario	Test N°	Protocol	Routing Solution
1	Test 1	RIPV2	CISCO
	Test 2	RIPV2	VYATTA
1	Test 3	OSPFV2	CISCO
	Test 4	OSPFV2	VYATTA
2	Test 5	RIPV2	CISCO
	Test 6	RIPV2	VYATTA
2	Test 7	OSPFV2	CISCO
	Test 8	OSPFV2	VYATTA

ISBN: 978-988-19252-4-4
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

C. Equipment Characteristic

CISCO: Technical specification of selected router is shown table III.

TABLE III
CISCO ROUTER -TECHNICAL SPECIFICATIONS

Characteristics	*Router Cisco 2811*
RAM Memory	768MB Max.
Capacity	256 MB compact flash
Ethernet Port	3 Fast Ethernet (10/100Mbps)
Serials Port	2

VYATTA: Vyatta router was configured over virtual machine. Table IV presents the technical specification.

TABLE IV
VYATTA ROUTER -TECHNICAL SPECIFICATION

Characteristics	*Virtual Machine VYATTA*
RAM Memory	512 MB
Capacity	Hard Disk 8 GB
Ethernet Port	3 Fast Ethernet (10/100Mbps)
Serials Port	0
Operating Systems	Windows XP
Virtualization Software	Oracle VM Virtual Box 3.2.8

V. RESULTS

In order to study the performance of each routing solution, the tests defined in table II was performed. In these tests the performance metrics mentioned in section III was measured.

Also routing performance metrics were studied with statistical parameters such as: Arithmetic mean (μ) and Standard deviation (σ). The aim is to find average and dispersion about convergence time, throughput and delay.

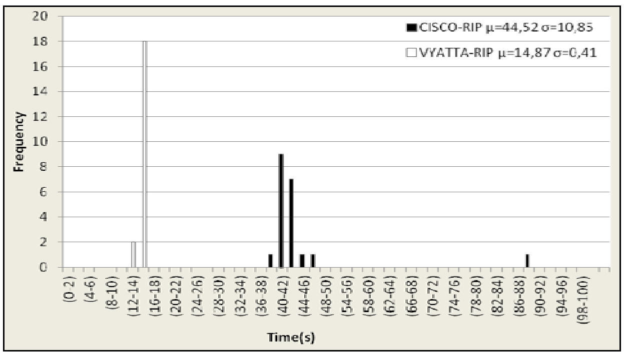
Arithmetic mean is given by equation (6), where β represents data measure in each metric. Standard deviation is given by equation (7) and was calculated in each case.

$$\mu = \frac{1}{n}\sum_{i=1}^{n}\beta_i \qquad (6)$$

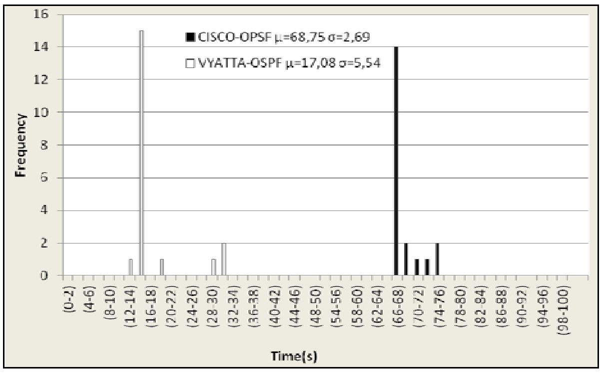
$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(\beta_i - \mu)^2}{n}} \qquad (7)$$

A. Base Scenario 1 and 2: Convergence Time

Measurements of convergence time are summarized in a histogram for base scenarios 1 and 2. The results are shown in Fig 8 and Fig 9. The histograms show convergence time intervals of the tests performed. In each test was calculated μ with the equation 6 and σ with the equation 7. This measurement results show that in the base-scenarios 1 and 2, convergence time is smallest on Vyatta. In Fig 8(a) the best time of convergence is into the interval 16-18 s for Vyatta and Fig 8(b) the interval time is between 14-16 s.



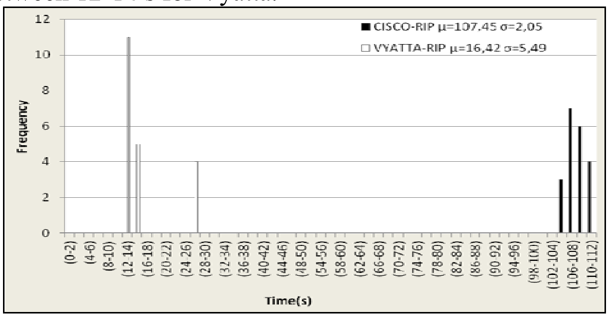
(a)



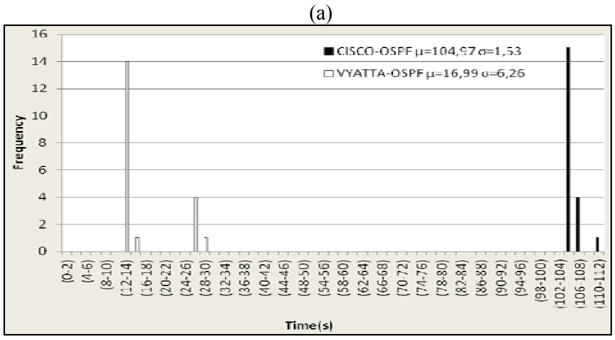
(b)

Fig.8. Histogram of convergence time measured on scenario 1 using IPV4. With (a) RIPV2 (b) OSPFV2.

In Fig. 9(a) the best time of convergence is between the interval 10-12 s for Vyatta, and Fig.9 (b) the interval time is between 12-14 s for Vyatta.



(a)

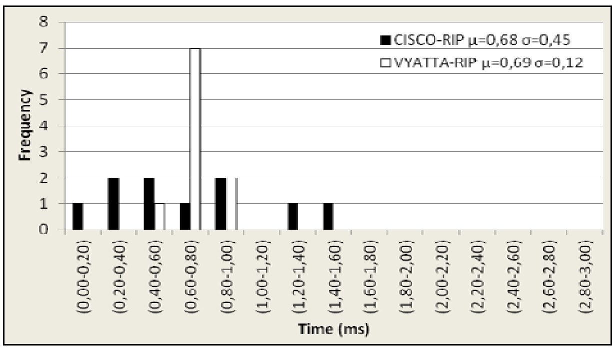


(b)

Fig.9. Histogram of convergence time measured on scenario 2 using IPV4 in Cisco and Vyatta with (a) RIPV2 (b) OSPFV2.

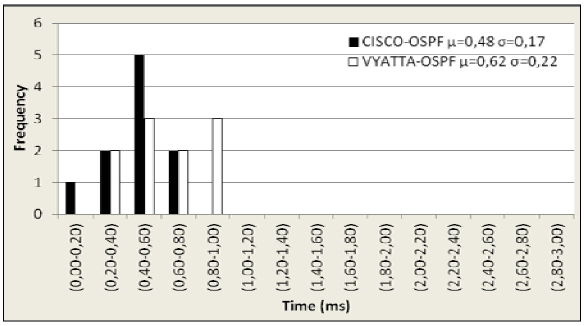
B. Base Scenario 1 and 2: Delay

Delay in base scenario 1 is shown in Fig. 10 and delay in base scenario 2 is shown in Fig 11. The tests show that the delay is affected by the interconnections routers and also there are not a relevant difference between Cisco and Vyatta Fig 10 (a) shows that most representative time of delay is between the interval 0.60-0.69 ms for Vyatta and Fig 10(b) the interval time is between 0.40-0.60 ms for Cisco.



(a)

ISBN: 978-988-19252-4-4
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

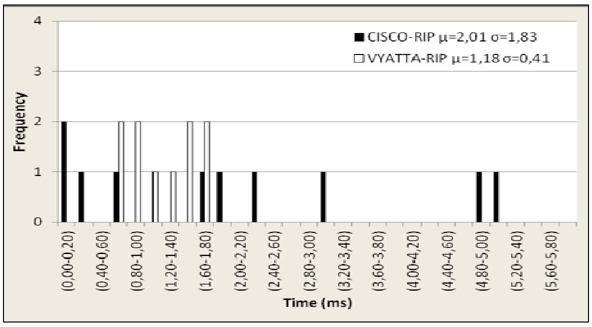


(b)

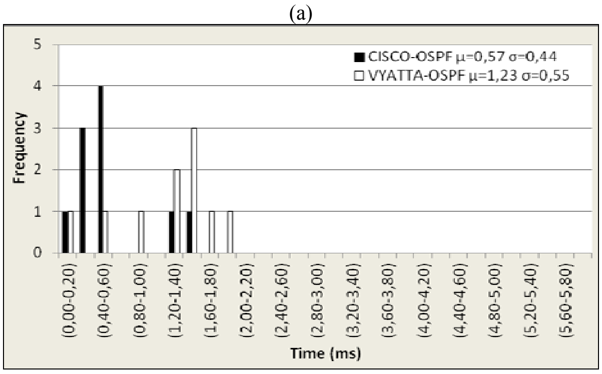
Fig.10. Histogram of delay measured on scenario 1 using IPV4. With (a) RIPV2 (b) OSPFV2

Fig 11 (a) shows that there is not a representative time interval and it behavior is the same for Vyatta and Cisco.

Although delay presents a bigger spread of data in all measurement in the Fig 11(b) is shown that the most representative interval time is between 0.40 -0.60 ms for Cisco.



(a)

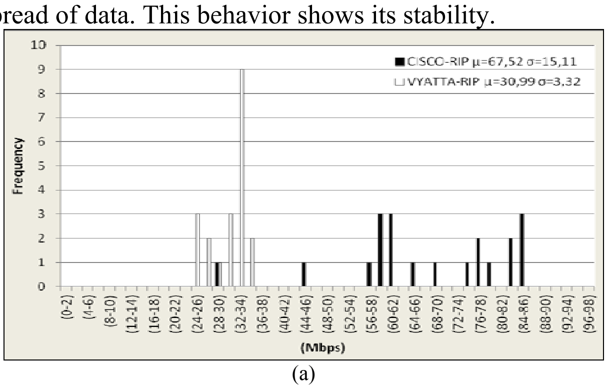


(b)

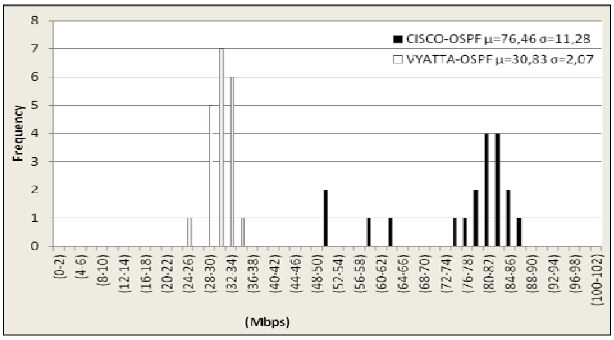
Fig.11. Histogram of delay measured on scenario 2 using IPV4. With (a) RIPV2 (b) OSPFV2

C. Base Scenarios: Throughput

Throughput in base scenario 1 is shown in Fig 12 and Fig. 13 shows throughput results on base scenario 2. In Fig 12 (a) the most representative value of throughput is in the interval 32-34 Mbps and Fig12 (b) is the 30-32 Mbps. Finally it is possible to conclude that Vyatta have a smaller spread of data. This behavior shows its stability.



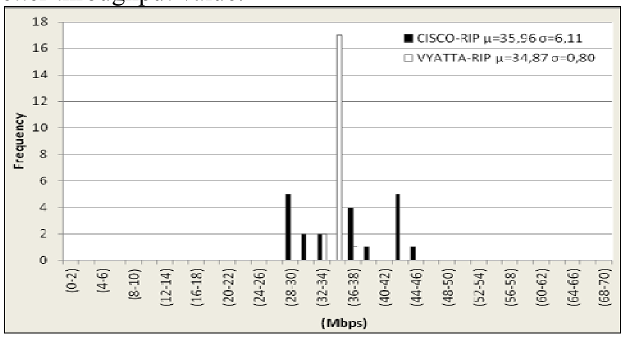
(a)



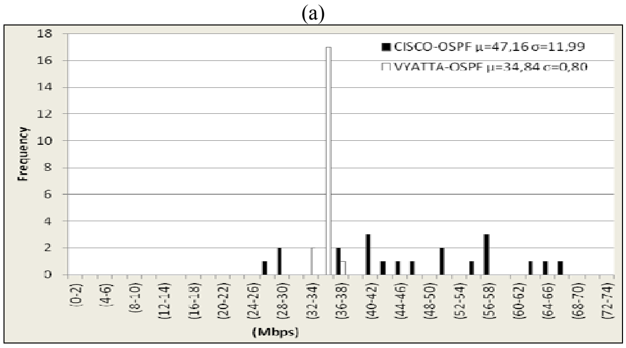
(b)

Fig. 12. Histogram of throughput measured on scenario 1 using IPV4. With (a) RIPV2 (b) OSPFV2

In Fig 13 (a) and Fig 13 (b), the most representative interval is the same and its value is 34-36 Mbps. Throughput stability is better on Vyatta but Cisco shows a better throughput value.



(a)



(b)

Fig.13. Histogram of throughput measured on scenario 2 using IPV4. With (a) RIPV2 (b) OSPFV2

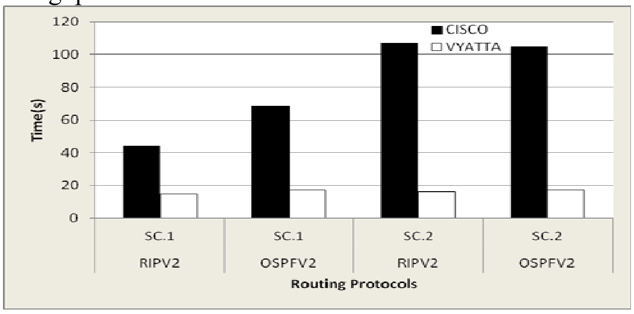
Table V shows the performance results and includes statistical parameters results such as: μ and σ.

TABLE V
ROUTING PERFORMANCE MEASUREMENTS

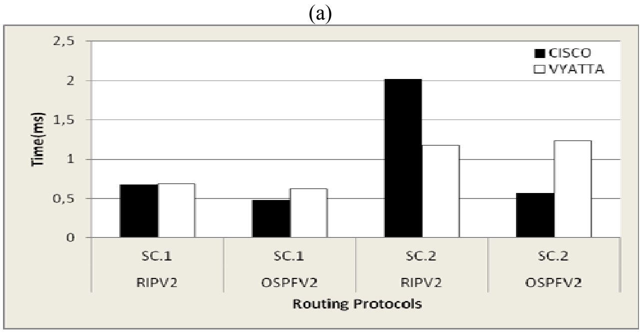
Routing Protocol	N°	Routing Solution	Convergence Time(s)		Delay(ms)		Throughput (Mbps)	
RIPV2	1	Cisco	μ	44,52	μ	0,68	μ	69,96
			σ	10,85	σ	0,45	σ	14,30
RIPV2	1	Vyatta	μ	14,87	μ	0,69	μ	31,01
			σ	0,41	σ	0,12	σ	2,93
OSPFV2	1	Cisco	μ	68,75	μ	0,48	μ	71,76
			σ	2,69	σ	0,17	σ	11,61
OSPFV2	1	Vyatta	μ	17,08	μ	0,62	μ	30,35
			σ	5,54	σ	0,22	σ	2,96
RIPV2	2	Cisco	μ	107,45	μ	2,01	μ	35,96
			σ	2,05	σ	1,83	σ	6,11
RIPV2	2	Vyatta	μ	16,42	μ	1,18	μ	34,87
			σ	5,49	σ	0,41	σ	0,80
OSPFV2	2	Cisco	μ	104,97	μ	0,57	μ	47,16
			σ	1,53	σ	0,44	σ	11,99
OSPFV2	2	Vyatta	μ	16,99	μ	1,23	μ	34,84
			σ	6,26	σ	0,55	σ	0,80

ISBN: 978-988-19252-4-4
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

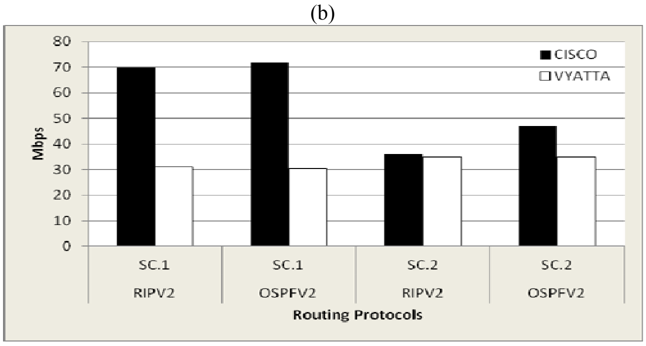
Finally, Fig. 14 shows the behavior of Arithmetic mean (μ) for each data measured, convergence time, delay and throughput.



(a)



(b)



(c)

Fig.14. Metrics measured on scenarios using IPV4. (a) convergence time measured in seconds (b) delay measured in ms. (c) throughput measured in Mbps. Finally, this Figure allows to summarize the data's analize. (a) Convergence time is shorter in Cisco than Vyatta. (b) Delay doesn't have changes in the measurements, except in scenario 2 and (c) throughput shows that Cisco has a better performance than Vyatta.

VI. CONCLUSION

General performance measurements showed high stability in standard deviation for Vyatta routing solutions, with a predictable behavior for convergence time, delay and throughput design parameters.

A convergence time in Vyatta is low. These results show the software speed to fix a faulty communication link. Convergence time over Vyatta in comparison with Cisco is 70% better while Cisco has a better throughput. The Delay results were similar in both routing solution (see Fig 11).

The possibility of modifying the physical features VSR, such as: RAM memory, hard disk or network interfaces is easier. The modification over physical features allows to have better performance on VSR in comparison with dedicated routing solutions.

ACKNOWLEDGMENT

We would like to thank to Security and Communication System Research Group GISSIC and to Military University Nueva Granada. Bogotá, Colombia.

REFERENCES

[1] S. Bradner, J. Mc Quaid. RFC 2544: Benchmarking Methodology for Network Interconnect Devices. March 1999. . [Online] Available : http://www.ietf.org/rfc/rfc2544.txt
[2] VYATTA Inc. White Paper: Why Vyatta is better than Cisco, March 2007. [Online] Available: http://www.vyatta.com/downloads/whitepapers/Vyatta_Better_than_Cisco.pdf
[3] Tolly Group. Tolly Report: Vyatta 1.1.2 Competitive Gigabit Ethernet LAN RoutingThroughput Evaluation versus Cisco 2821 Integrated Service Router. March 2007. [Online] Available: http://www.cs.ait.ac.th/~on/Vyatta/Tolly207190_Vyatta_March2007.pdf
[4] IXIACOM. Measuring Network Convergence Time. March 2009. [Online] Available: http://www.ixiacom.com/library/white_papers/download.php?mkt_paper=convergence
[5] Deepankar Medhi Karthikeyan Ramasamy. Network Routing Algorithms, Protocols, and Architectures. ISBN 13: 978-0-12-088588-6.
[6] Andrea Bianco, Robert Birke, Luca Giraudo and Nanfang Li, Multistage Software Routers in a Virtual Environment ISBN: 978-1-4244-5638-3
[7] Tolly Group. Tolly Report: Vyatta ,Inc. BGP Performance Evaluation versus Cisco 7204VXR Router. March 2008. Page 2[Online] Available: http://www.cs.ait.ac.th/~on/Vyatta/Tolly208289VyattaBGPPerfMar2008.pdf
[8] Roberto Rojas-Cessa, Khondaker M. Salehin, and Komlan Egoh "Experimental Performance Evaluation of a Virtual Software Router" New Jersey Institute of Technology, Newark, NJ 07102, USA.
[9] Vyatta Solutions. Vyatta in Box. [Online] Available: http://www.vyatta.com/solutions/enterprise/non-virtualized
[10] Vyatta Solutions. Vyatta Hardware Appliances[Online] Available: http://www.vyatta.com/solutions/physical/appliances
[11] "Cisco and Juniper, a company threatened by open source routing" CIO España. Cisco y Juniper, amenazados por una compañía de routing de código abierto. 2006 [Online] Available: http://www.idg.es/cio/estructura/imprimir.asp?id=46182&cat=not
[12] Héctor Egea Chueca and Daniel Morató Osés. "Adaptation of Cisco routers use of laboratory practices routers Open Source", Adaptación del uso de routers Cisco en prácticas del laboratorio a routers Open Source. Pamplona. 2011
[13] Cisco Net working Academy. CCNA Exploration 4.0 Routing Protocols and Concepts. Introduction to Dynamic Routing Protocols Chapter 3.1 Introduction and Advantages.
[14] Cisco Net working Academy. CCNA Exploration 4.0 Routing Protocols and Concepts. Introduction to Dynamic Routing Protocols Chapter 3.2 Classifying Dynamic Routing Protocols. 3.2.2 IGP and EGP.
[15] Shufen, L. Lu, H. Xinjia, Z. Study of Network Performance Measurement Based on SNMP. The 8th International Conference on Computer Supported Cooperative Work in Design Proceedings.2003.
[16] Y. T, Dong, Y. Zhang L. Network Performance Measurement And Analysis. Part 1: A server-Based Measurement Infrastructure.
[17] Mohammad, N. Md. Ahsan Simulation-Based Comparative Study of EIGRP and OSPF for Real-Time Applications. September 2010
[18] Cisco Networking Academy. CCNA Exploration 4.0 Routing Protocols and Concepts. Introduction to Dynamic Routing Protocols Chapter 3.2 Classifying Dynamic Routing Protocols. 3.2.5 Convergence.
[19] Internet Engineering Task Force (IETF). RFC 6412. Terminology for Benchmarking Link-State IGP Data-Plane Route Convergence pp.5. ISSN 2070-172.
[20] "CCNP1. Advanced Routing Companion Guide". Cisco Press. 2004. pp. 93f. ISBN 1-58713-135-8
[21] Ahhas El Gamal, James Mammen. Balaji Rahhakar, Devavrat Shah "Throughput-Delay Trade-off in Wireless Networks" Departments of EE and CS Stanlord University, 2004. ISSN: 0-7803-8355-9.
[22] I. Baronak, M. Halas, "Mathematical Representation of VoIP Connection Delay," Department of Telecommunications, Slovak University of Technology, Prague, Slovak Republic, April 2008.
[23] E. Guillen, D. Padilla, J. Alvarez, "Throughput Evaluation on Network Firewall Architectures". New Advanced Technologies, Aleksandar Lazinica (Ed.), ISBN: 978-953- 307-067-4, INTECH, March 2010.
[24] E. Guillen, D. Chacon, "VoIP Networks Performance Analysis with Encryption Systems," World Academy of Science, Engineering and Technology, Issue 58, October 2009, ISSN: 2070-3724, pp 688-695.
[25] S. Bradner, J. McQuaid. RFC 1242: Benchmarking Terminology for Network Interconnection Devices. Julio 1991. [Online] Available: http://www.ietf.org/rfc/rfc1242.txt