

Performance Analysis of Protocol Independent Multicast (PIM)

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Abstract
This research was conducted for the purpose of analyzing the performance of a network through the use of a combination of Protocol Independent Multicast (PIM) and a unicast routing protocol which is the Open Shortest Path First (OSPF).A physical and logical topology was built using the Graphical Network Simulator (GNS3). A Class B address was subnetted into eight (8) subnets, each of which are accorded with the appropriate addresses. The Wireshark Network Protocol Analyzer was used for the analysis part to interpret the behavior and performance of the network with the protocol used. The performance of the network was analyzed on the basis of the following parameters: length of packet, total packets captured. packets captured between first and last packet, average packet per second, average packet size in bytes, number of bytes , and average bytes per second.
Based on the results, given the same number of packets captured, the links differ in the duration between the 1st and last packet captured. It shows that the link R3 to R1 shows a considerable delay of 245.19 secs while R4 to R3 shows the fastest duration. The average packets/sec and the average size in terms of bytes are almost close to each others on all the links except R3 to R1. This is so because the duration is directly proportional to the packet size and bytes.
Keywords: packet; protocol; Protocol Independent Multicast; network; unicast

Introduction

Protocol Independent Multicast (PIM) is a multicast routing protocol for Internet Protocol (IP) which provides one-to-many and many-to-many mode of distribution over a LAN, WAN or the Internet. PIM uses a source distribution tree or shortest path tree (SPT) for each group address present in the network. [1].

The reason for the choice of protocol is that: it is the only multicast routing protocol that is fully-supported by Cisco devices and as in a Multicast routing, there is one source and a group of destination [2]. Hence, it is the aim of this study to analyze the performance of the chosen protocol through scenario-based implementation and simulation.

While there are three different modes supported by PIM, this study will focus only on the implementation of PIM Dense Mode alongside Open Shortest Path First (OSPF).

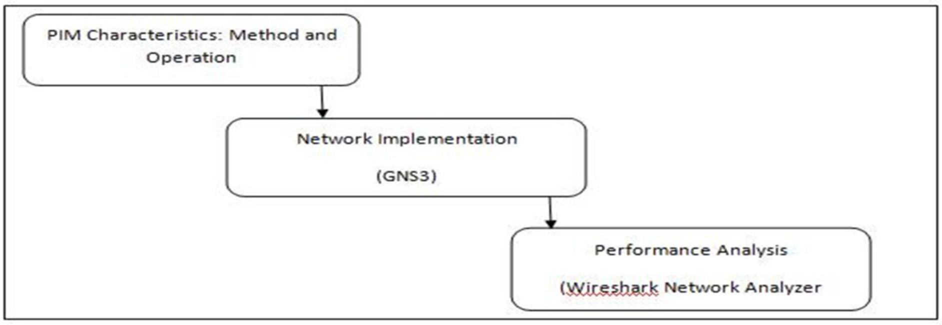

Fig. 1. Framework of the Study

As shown in Figure 1, the study was based on this framework. The characteristics of PIM were thoroughly discussed in terms of the methods and operation. These parameters were the basis for the underlying concepts. A network topology was designed and PIM-DM was used as the routing protocol. The network design was built using the Graphical Network Simulator 3 (GNS3). Simulation was done to test the network using the Wireshark Network Analyzer. The performance of the network was analyzed and recorded.

Related Literature

Types of Messages

Unicast. In a unicast mechanism, a message is sent from one source to exactly one destination. When a message is sent to multiple destinations, multiple unicast messages are sent, each addressed to that specific destination. In other words, the sender will have to send separate messages to each of the destination; hence, it has to know the exact IP of the destination device. Each packet is destined for only one device.

Broadcast Message. In a broadcasting method, the packet is sent to all devices in a specific network. A packet with a broadcast address, the receiving devices that receives the message will process it. This means, all the devices on the same network block will receive the message. Routers in a broadcast mechanism don't forward messages, instead the rather receives the broadcast traffic.

Multicast Message. In multicasting, logical groups of hosts are identified. This means, a single message can then be sent to the group. [3]

Information about PIM

PIM is used between multicast-capable routers and advertises group membership across a routing domain by constructing multicast distribution trees. PIM builds shared distribution trees on which packets from multiple sources are forwarded, as well as source distribution trees on which packets from a single source are forwarded [4].

In multicasting, there is one source and a group of destinations. The relationship that exists is one-to-many. In this type, the source address is a unicast address, however, the destination address is a group address(a group of one or more destination networks) in which there is at least one member of the group that is interested in receiving the multicast datagram. The group address defines the members of the group [5].

Routing protocols like Routing Information Protocol (RIP) (distance-vector) or OSPF (link-state) are unicast while PIM is a multicast which was designed to allow multicast routing without needing to rely on other specific unicast routing protocols. PIM operates in two main modes: Dense mode and Sparse mode [6].

Related Studies

The study conducted by Girija (2011) discusses IP multicast in production networks. The objective of the study was to discuss IP multicasting. The author provided an introduction that bridges the gap between the existing unicast networks and the developing multicast network. The study included multicast addressing scheme; different protocols used for multicast transmission; various distribution trees that are formed by these protocols and various aspects of multicast forwarding. PIM Dense mode was thoroughly discussed in terms of Neighbor Discovery, Hello Messages, Designated Router, Distribution Trees, Asserts, and Scalability.

The study revealed that the biggest obstacle for network designers to adapt PIM-DM as protocol for a multicast network is the "periodic flooding of the network with the flood-prune traffic" that could be periodic in the network-based on the expiry of the hold timer expiry. However, this impediment could be considered insignificant in high-speed networks where the bandwidth consumed by periodic flooding can be neglected [7].

Another study evaluated the performance of Protocol Independent Multicast-Dense Mode (PIM-DM) Multicasting Network through a scenario-based network with two sources and four receivers attacked by five attackers. In the study, attackers attacked the source 1 in network by Internet Control message Protocol (ICMP) Ping Flood and the researchers executed the simulation and drew network throughput between source 1 and source 2 and then queuing transmission delay; dropping-out data packets at source 1 for ping packet of size 16, 64 and 96 Bytes for 500, 1500 and 2500 ping packets per second. The simulation results indicated that the "throughput decreases with the increase in attack packet size and intensity" and the "delay increases with increase in attack packet size and decrease with increase in attacking intensity" . It was also noted that with the increase in attack packet size the number of dropped packets remain nearly same for different intensities [8].

Findings

Network Implementation

To measure the performance of PIM, the network topology below was designed for this purpose:

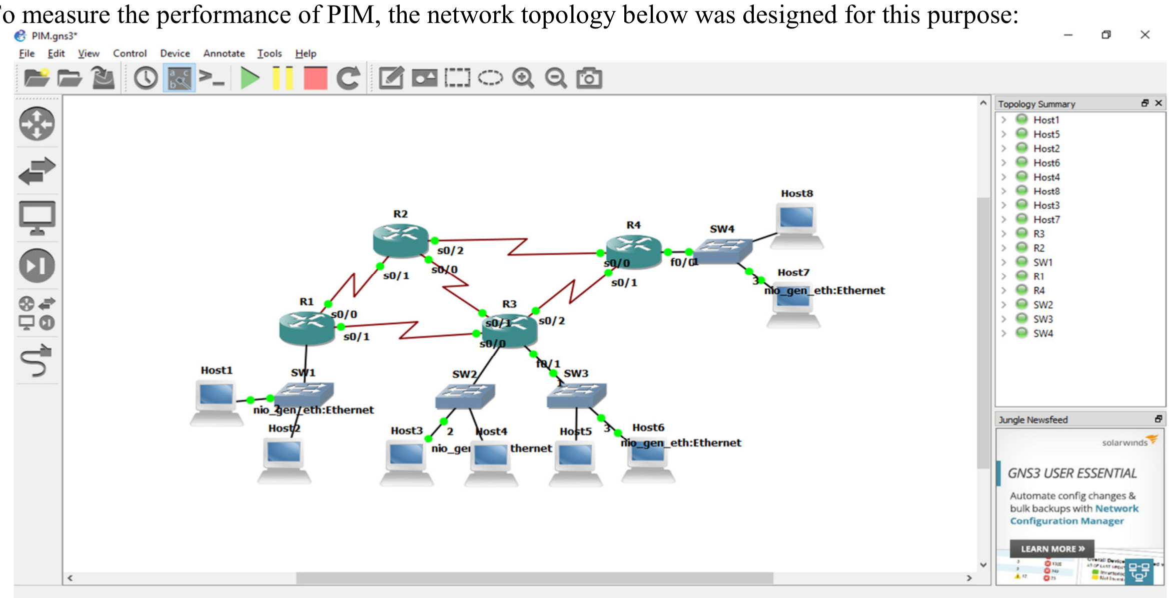

Fig. 2. Network Topology

Figure 2 shows the network topology that was used for the performance analysis. All intermediary devices made use of Cisco devices. For the assignment of IP addresses, Class B subnetted network was used. The number of hosts/end devices were randomly determined by the researcher for the purpose of discussion and to show the IP addresses assigned in each network.

Major Network: **172.16.0.0/16**
Available IP addresses in major network: **65534**
Number of IP addresses needed: **1640**
Available IP addresses in allocated subnets: **1698**
About **3%** of available major network address space is used
About **97%** of subnetted network address space is used

Table 1. IP Addresses

Subnet Name	Needed Size	Address	Mask	Subnet Mask	Assignable Range	Broadcast
LAN 1	1000	172.16.0.0	/22	255.255.252.0	172.16.0.1- 172.16.3.254	172.16.3.255
LAN 2	500	172.16.4.0	/23	255.255.254.0	172.16.4.1- 172.16.5.254	172.16.5.255
LAN 3	100	172.16.6.0	/25	255.255.255.128	172.16.6.1- 172.16.6.126	172.16.6.127
LAN 4	30	172.16.6.128	/27	255.255.255.224	172.16.6.129- 172.16.6.158	172.16.6.159
WAN1	2	172.16.6.160	/30	255.255.255.252	172.16.6.161 - 172.16.6.162	172.16.6.163
WAN2	2	172.16.6.164	/30	255.255.255.252	172.16.6.165 - 172.16.6.166	172.16.6.167
WAN3	2	172.16.6.168	/30	255.255.255.252	172.16.6.169 - 172.16.6.170	172.16.6.171
WAN4	2	172.16.6.172	/30	255.255.255.252	172.16.6.173 - 172.16.6.174	172.16.6.175
WAN5	2	172.16.6.176	/30	255.255.255.252	172.16.6.177 - 172.16.6.178	172.16.6.179

Table 1 shows the IP addresses of the different subnets. The address of each interface and end devices were taken from table corresponding the appropriate subnet.

Performance Analysis

Below are the details of the performance analysis. The Wireshark Network Protocol Analyzer was used as the tool to generate important information regarding the links.

IPv4 Conversations

Table 2. Conversations: Link from R1 to R2

IPv4:1 Conversations	*Details*	*Details*	*Details*	*Details*
Address A (Source)	172.16.6.161	172.16.6.162	172.16.6.162	172.16.6.161
Address B (Destination)	224.0.0.5	224.0.0.5	224.0.0.13	224.0.0.13
Packets	21	21	21	21
Bytes	1764	1764	1764	1764
Packets A to B	21	21	21	21
Bytes A to B	1764	1764	1764	1764
Packets B to A	0	0	0	0
Bytes B to A	0	0	0	0
Rel Start	0.00	2.64	11.71	14.79
Duration	190.50	191.63	177.75	175.90
bps (A to B)	74.08	73.64	18.27	18.47
bps (B to A)	N/A	N/A	N/A	N/A

Table 2 shows the details of the captured packets in real time. The source address as 172.16.6.161 and the destination address as 172.16.6.162. As shown from the table, the packets and bytes from source to destination are equal while the packets and bytes from destination to source are zero (0). This is so because the captured packets are only from the source to destination and not vice versa. The relative start from source to destination is 2.64secs on the first instance versus 3.08secs on the second instance. This implies that the relative start on the first instance is faster than the second. The duration from source to destination is 1.13secs and 1.85secs respectively, which shows a difference of 0.72 secs. As for the bits-per-second, difference is 0.44 on the first instance while there is no difference in the second instance. This means that the bps for the second instance is faster than the first.

Table 3. Conversations: Link from R2 to R3

IPv4:1 Conversations	*Details*	*Details*	*Details*	*Details*
Address A (Source)	172.16.6.169	172.16.6.170	172.16.6.169	172.16.6.170
Address B (Destination)	224.0.0.5	224.0.0.5	224.0.0.13	224.0.0.13
Packets	20	20	6	6
Bytes	1680	1680	348	348
Packets A to B	20	20	6	6
Bytes A to B	1680	1680	348	348
Packets B to A	0	0	0	0
Bytes B to A	0	0	0	0
Rel Start	4.79	7.13	15.43	16.54
Duration	181.84	181.76	148.95	148.73
bps (A to B)	73.91	73.94	18.69	18.72
bps (B to A)	N/A	N/A	N/A	N/A

Table 3 shows the details of the captured packets in real time. The source address as 172.16.6.169 and the destination address as 172.16.6.170. As shown from the table, the packets and bytes from source to destination are equal while the packets and bytes from destination to source are zero (0). This is so because the captured packets are only from the source to destination and not vice versa. The relative start from source to destination is 2.34secs on the first instance versus 1.11 secs on the second instance. This implies that the relative start on the second instance is faster than the first. The duration from source to destination is 0.08secs and 0.22 secs respectively, which shows that the packet duration on the first instance is faster. As for the bits-per-second, difference is 0.03 on both the first instance. This means that the bps for both instances are of the same rate.

Table 4. Conversations: Link from R3 to R1

IPv4:1 Conversations	*Details*	*Details*	*Details*
Address A (Source)	172.16.6.173	172.16.6.174	172.16.6.173
Address B (Destination)	224.0.0.5	224.0.0.13	224.0.0.13
Packets	26	9	8
Bytes	2080	522	464
Packets A to B	26	9	8
Bytes A to B	2080	522	464
Packets B to A	0	0	0
Bytes B to A	0	0	0
Rel Start	0.00	0.95	24.23
Duration	237.18	236.46	206.14
bps (A to B)	70.16	17.66	18.01
bps (B to A)	N/A	N/A	N/A

Table 4 shows the details of the captured packets in real time. The source address as 172.16.6.173 and the destination address as 172.16.6.174. As shown from the table, the packets and bytes from source to destination are equal while the packets and bytes from destination to source are zero (0). This is so because the captured packets are only from the source to destination and not vice versa. The relative start from source to destination is 0.95secs on the first instance while the duration is 0.72secs. This means that the duration it takes from R1 to R2 and R3 to R1 are equal. As for the bits-per-second, difference is 0.44 on the first instance while there is no difference in the second instance. This means that the bps for the second instance is faster than the first.

Table 5. Conversations: Link from R2 to R4

IPv4:1 Conversations	*Details*	*Details*	*Details*	*Details*
Address A (Source)	172.16.6.165	172.16.6.166	172.16.6.166	172.16.6.165
Address B (Destination)	224.0.0.5	224.0.0.5	224.0.0.13	224.0.0.13
Packets	21	20	7	6
Bytes	1764	1680	406	348
Packets A to B	21	20	7	6
Bytes A to B	1764	1680	406	348
Packets B to A	0	0	0	0
Bytes B to A	0	0	0	0
Rel Start	4.06	4.38	13.28	16.85
Duration	189.44	180.15	176.72	147.62
bps (A to B)	74.49	74.61	18.38	18.86
bps (B to A)	N/A	N/A	N/A	N/A

Table 5 shows the details of the captured packets in real time. The source address as 172.16.6.165 and the destination address as 172.16.6.166. As shown from the table, the packets and bytes from source to destination are equal while the packets and bytes from destination to source are zero (0). This is so because the captured packets are only from the source to destination and not vice versa. The relative start from source to destination is 0.32secs on the first instance versus is 3.57secs in the second instance. This shows a considerable delay in the second instance. As per the duration, it takes 9.29secs and 29.1 secs for both instances. This shows a very big delay for the packet to reach the destination. As for the bits-per-second, difference is 0.12 on the first instance and 0.48 in the second instance. This means that the bps for the first instance is faster than the second.

Table 6. Conversations: Link from R4 to R3

IPv4:1 Conversations	*Details*	*Details*	*Details*	*Details*
Address A (Source)	172.16.6.178	172.16.6.177	172.16.6.178	172.16.6.177
Address B (Destination)	224.0.0.5	224.0.0.13	224.0.0.5	224.0.0.13
Packets	22	7	22	6
Bytes	1940	406	1860	348
Packets A to B	22	7	22	6
Bytes A to B	1940	406	1860	348
Packets B to A	0	0	0	0
Bytes B to A	0	0	0	0
Rel Start	0.00	1.98	3.07	10.07
Duration	177.00	176.08	177.85	146.68
bps (A to B)	87.68	83.66	18.37	18.98
bps (B to A)	N/A	N/A	N/A	N/A

Table 6 shows the details of the captured packets in real time. The source address as 172.16.6.165 and the destination address as 172.16.6.178. As shown from the table, the packets and bytes from source to destination are equal while the packets and bytes from destination to source are zero (0). This is so because the captured packets are only from the source to destination and not vice versa. The relative start from source to destination is 1.98secs on the first instance versus is 7.00secs in the second instance. This shows a considerable delay in the second instance. As per the duration, it takes 0.92secs and 31.17 secs for both instances. This shows a very big delay for the packet to reach the destination in the second instance. As for the bits-per-second, difference is 4.02 on the first instance and 0.61 in the second instance. This means that the bps for the second instance is faster than the first.

Table 7. Summary of Captured Packets

Parameters	R1- R2	R2-R3	R3-R1	R2-R4	R4-R3
Length	0 bytes	0 bytes	0 bytes	0 bytes	0 bytes
Packets captured	100	100	100	100	100
Between 1st and last packet (sec)	194.097	190.05	245.19	193.51	185.59
Avg. packets/sec	0.515	0.526	0.414	0.525	0.544
Avg. packet size (bytes)	72	76	68	71	73
Bytes	7190	7600	6930	7238	7404
Avg. bytes/sec	37.043	39.389	28.09	37.23	39.85

Table 7 shows the summary of the captured packets. Given the same number of packets captured, the links differ in the duration between the 1st and last packet captured. It shows that the link R3 to R1 shows a considerable delay of 245.19 secs while R4 to R3 shows the fastest duration. The average packets/sec and the average size in terms of bytes are almost close to each others on all the links except R3 to R1. This is so because the duration is directly proportional to the packet size and bytes.

Conclusion

Based on the parameters used, namely: length of packet, total packets captured, packets captured between first and last packet, average packet per second, average packet size in bytes, number of bytes , and average bytes per second, it can be seen from the performance analysis that the results show variation on the links that were under study. On this study, it can be noted that almost all the links have values that are close to each other in terms of relative start, duration and bytes except from R3 to R1.

The study can be further examined through the use of other unicast routing protocols and to consider other parameters in the analysis part. A comparative study can also be undertaken to compare the performance of networks under different networking protocols, conditions and requirements.

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