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PIM-SM based Multicast Comparison for IPv4 verses IPv6 using GNS3 and JPERF

Saif S. Shihab*, Imad J. Mohammed
Department of Computer Science, College of Science, University of Baghdad, Baghdad, Iraq

Abstract

The multicast technology implements a very high-efficiency point-to-multipoint data transmission over IP networks (IPv4 and IPv6). Multicast reduces network load, eliminates traffic redundancy, and saves network bandwidth. Therefore, multicast used widely in LAN/WAN applications such as online games, video conferencing and IPTV. The multicast technology implements varied protocols such as DVMRP(Distance Vector Multicast Routing Protocol), MOSPF(Multicast Open Shortest Path First), or PIM-DM (Protocol Independent Multicast- Dense Mode) which considered source tree type, while PIM-SM (Protocol Independent Multicast-Sparse Mode) and CBT (Core Based Tree) uses shared tree. Current paper focuses on the performance evaluation of the two multicast protocols: PIM-SMv4 and PIM-SMv6 based on QoS metrics like throughput, jitter, datagram loss and Data received. PIM-SM over IPv6 showed good results compared with PIM-SM over IPv4 by 1.04%, 0.64%, 32.56% and 89.84% in terms of data received, throughput, jitter and datagram loss respectively .GNS3 simulator/emulator and JPERF used to evaluate this performance

Keywords: Multicast, PIM, RP, shared-tree, Qos.

مقارنة اداء بروتوكول PIM–SM عبر الجيل السادس والجيل الرابع من بروتوكول الانترنت باستخدام برنامجي GNS3 مع برنامج JPERF

سيف سعد شهاب*، عماد جاسم محمد
قسم الحاسبات، كلية العلوم، جامعة بغداد، بغداد العراق.

الخلاصة

تقنيه الارسال المتعدد تقوم بتفيذ ارسال البيانات من نقطة الى عده نقاط عبر بروتوكول الانترنت (IPv6/IPv4) بكفاءه عاليه. تقنيه الارسال المتعدد تقلل الحمل على الشبكه ، ويزيل حركه المرور المتكرره و تحافظ على عرض النطاق الترددي للشبكة. لذلك الارسال المتعدد يستخدم بشكل واسع في تطبيقات LAN/WAN مثل الالعاب عبر الانترنت، مؤتمرات الفديو و البث التلفزيوني عبر الانترنت. يتم تنفيذ الارسال المتعدد عبر عدد متنوع من البروتوكولات مثل DVMRP و MOSPF او PIM–DM التي تستخدم شجره المصدر، بينما PIM–SM و CBT التي تستخدم الشجره المشتركه . يركز هذا البحث على تقيم الاداء نوعين من انواع بروتوكولات الارسال المتعدد: PIM–SMv4 and PIM–SMv6 بالاعتماد على مقاييس جوده الخدمه مثل الانتاجيه ، jitter، فقدان حزمه البيانات والبيانات المستلمه . اضهر بروتوكول PIM–SM عبر الجيل السادس من بروتوكول الانترنت نتائج افضل منه عبر الجيل الرابع من بروتوكول الانترنت بنسبه

*Email: saif.alani9@gmail.com

%1.04، %0.64، %32.56 و %89.84 فيما يتعلق ب البيانات المستلمه ،الانتاجيه ، jitter، وفقدان حزمه البيانات على التوالي. استخدم برنامج محاكي الشبكه GNS3 لتقيم هذا الاداء.

Introduction

Multicast technology appeared approximately twenty years ago. Although right, from its conception it attracted big interest for a long time but did not become the accredited technology. However, the recent huge growth in network traffic and the creation of new applications like YouTube, IPTV [1]. Internet Protocol version 4 (IPv4) is one of the key fundamentals of the Internet, which is currently serving up to four billion hosts over various networks. In spite of this, IPv4 protocol has still been successfully functioned well since 1981. Over the last couple of years, the vast growth of the Internet has been evident requiring an evolution of the whole architecture of the Internet Protocol. Therefore, the new version of IP is critical in maintaining the pace of the Internet's development. IPv6 considered more efficient than IPv4 with respect to reliability, scalability, speed and security. Furthermore, the size is larger than IPv4, as it uses 128 bits that will be able to include all of the nodes and services that might require the IP. Both now and in the future, also IPv6 offers a significant improvement of IPv4 when it comes to the unlimited address space, the security support, built-in mobility, easy configuration of end systems, as well as enhanced multicast features [2]. Multicasting itself is one of the basic technologies that supported in the next generation of the internet [3]. In IPv4, however, multicasting was presented as an extension of the basic specification, thus IPv4 nodes do not necessarily support multicasting [4]. On the other side, specifications of IPv6 require that all IPv6 nodes support multicasting (built in multicast support).

IP Multicast means computer sends one stream of packets destined to the multicast group address, and the interested recipients who want to receive a multicast data programming their computers to listen for data that has these addresses. Multicasting also provides enhanced efficiency by controlling the traffic on your network and reducing the load on network devices. The clients on your network are able to decide whether to listen to a multicast address, so packets only sent to where they are required. In addition, multicasting is scalable across different sized networks but is particularly suited to WAN environments [5]. It enables people at different locations access to streaming data files, like a video, film or lives presentation without taking up excessive bandwidth or broadcasting the data to all users on the network. Multicast communication uses multicast distribution tree for data routing. The multicast distribution tree divided into two types, source and share based tree. The source-based tree creates separate multicast routing tree for each source, while shared multicast tree creates one tree for the whole group and shared among all sources. In addition, shared tree has an advantage over source tree because of only one routing table needed for the group. Shared multicast trees require the selection of a central router called "Core Point" in the case of CBT multicast protocol [6] and "Rendezvous point or RP" in the case of PIM-SM [7].

The current paper focuses on the comparison between multicast protocols PIM-SM [7] in IPv4 and PIM-SM in IPv6. PIM-SM protocol support many-to-many transmission model (Any Source Multicast) [8] and also very popular and implemented widely. Various network performance metrics such as bandwidth, jitter, and throughput for both the IPv4 Sparse mode Multicast and IPv6 Sparse mode Multicast collected and then analyzed in order to understand the performance of these protocols using GNS3 emulator supported by JPERF traffic generator.

Literature Review

In 2008, Bartczak, Tomasz, and Piotr Zwierzykowsk described the comparison between different multicast routing protocols for different approaches. It focuses on similarities and differences between PIM-SM protocol that uses source tree and PIM-DM protocol that practice shared tree [8]. The research covered IPv4 multicast only.

In 2009, Shaukat.U et.al, determine the number of metrics to evaluate the performance of the multicast protocols. These metrics are divided into two perspectives in mind. The first include efficiency of multicast protocol to deal with resource network utilization like (Link Traversed, Overhead traffic, and Storage Overhead) and second the quality of service that provides to the end user like (End-To-End Delay, Packet loss, and jitter). The multicast routing protocols that evaluated was sparse mode protocols such as (PIM-SM and CBT) and dance mode protocol such as (DVMRP and PIM-DM). The results showed that the performance of PIM-SM protocol remains steady whereas the performance of PIM-DM and DVMRP protocols are getting better at network expansion (the number of join receivers increased). The CBT protocol works well in a very sparse scenario, but the efficiency is reduced when the number of users increased. This means the performance of multicast sparse mode protocols decreases when users join the multicast group is increased whereas dance mode protocols are enhanced. However, the dance mode protocols performed badly when a network is scattered [9]. The research covered IPv4 multicast only, also, not been verified from the throughput.

In 2010, Hua Wang, Xiangxu Meng, Min Zhang, Yanlong Li, suggested tabu search algorithm in PIM-SM multicast routing to select multicast RP, because PIM-SM uses shared tree and the main problem is how to determine the position of the RP. The algorithm selects multicast RP by considering both cost and delay. The outcome of Wang's proposed algorithm indicates good performance in multicast cost, ETE delay and having good expansion and practical feasibility [10]. However, the paper does not consider IP network (IPv4/IPv6). In addition, does not measure the jitter and datagram loss.

In 2010, Ko, J., Park, S., &Lee, E, proposed a method to reduce the processes of traditional PIM-SM multicast protocol that uses (RPT) to deliver the content of IPTV services. This method assumes use SPT distribution tree immediately to deliver multicast data packets rather than RPT distribution tree. In addition, presumed the Edge router to be an RP that receives the data packet from a source. Also, the LHR that receives a request from a receiver for IPTV services, sends PIM (S, G) join message to RP rather than sends (*, G) join message. The RP that receives the PIM (S, G) join message from LHR, in turn, sends the data packet to the receiver through LHR via the SPT. The results of proposed method showed reduce utilization of RP; in addition, reduce the bandwidth usage of the RP. However, the experiment in this paper still requires more validation for further QoS investigation such as throughput, jitter, and datagram loss [11].

In 2013, Youssef Baddi, Mohamed Dafer, presented 2DV GRASP-RP algorithm based on Parallel GRASP Procedure using PIM-SM multicast routing protocol to select the right RP by considering cost, delay and delay variation functions. As a result, the algorithm shows good performance in terms of multicast cost, end-to-end delay and other aspects compared to other three algorithms; AKC , DDVCA, and Tabu RP Selection algorithm (or TRPS) [12]. It focused on IPv4 multicast only

In 2014, Lencse, G., & Derka, I. introduces a method to limited service outage time caused by the complete failure of a router by an appropriate choice of the Dead Interval parameter of OSPF. Because the PIM-SM protocol does not have a routing table, it depends on unicast routing protocols such as OSPF (Open Shortest Path First) and RIP (Routing Information Protocol) in order to build a multicast distribution tree. In addition, RP failure is a very important issue in multicast shared tree. The result shows the length of the service outage depends on the parameters of the underlying OSPF and can be bounded by the appropriate choice of the Dead Interval parameter of OSPF. also, the complete failure of a PIM-SM router does not interrupt the ongoing media streaming but the stream will be restored when the underlying unicast routing (OSPF) finds a new route from the DR (designated router) of the server to the DR of the client [13]. It focuses on limiting service outage time, did not take into consideration any QOS parameters.

In 2016, Ko, J., Park, S., and Lee, E., described the performance of IPv6 multicast routing over a dual stack virtual local area network based on Parameters such as throughput, jitter, datagram loss. The experiment has shown that IPv6 multicast routing did not perform well running it alongside with IPv4. The throughput was 100% in the experiment IPV4 and IPv6 multicast routing over a dual virtual network since no significant data lost was noticed in all the experimented duration and scenarios. While the jitters (variations in latency), running IPv4 multicast routing only in dual network performed better than running IPv6 multicast routing in a dual stack. However, the jitter when multicasting to IPv4 group and IPv6 group simultaneously in a dual virtual network has no clear difference as it fluctuates from hosts across the two protocols [14]. It focuses on doing all multicast experiments in dual stack, did not tested individually on each of IPv4 and IPv6 only network.

Compared to related works, the current paper focuses on further investigation to the performance of IPv6 multicast versus IPv4 multicast using QoS metrics such as throughput, available bandwidth, jitter and datagram loss.

PIM PROTOCOLS

In general, the number of sources involved in multicast transmission is not limited. Transmission with an arbitrary number of sources is referred to as Any Source Multicast (ASM).The important difference between unicast and multicast communication model is in the case of unicast transmission, the receiver knows the source address and as a result is able to request the desired data stream. However, the situation is quite different in the case of multicast transmission because receivers know only the group address. What makes the problem even more difficult is the fact that nodes sending the data to a multicast group can start and terminate the transmission at any point, without sending any notification.

PIM-SM protocol works in two phases as follow:

In order to handle transmission with any sources, the PIM-SM protocol utilizes the Rendezvous Point (RP), PIM-SM has two phases as followed:

1. Establishing shared tree:

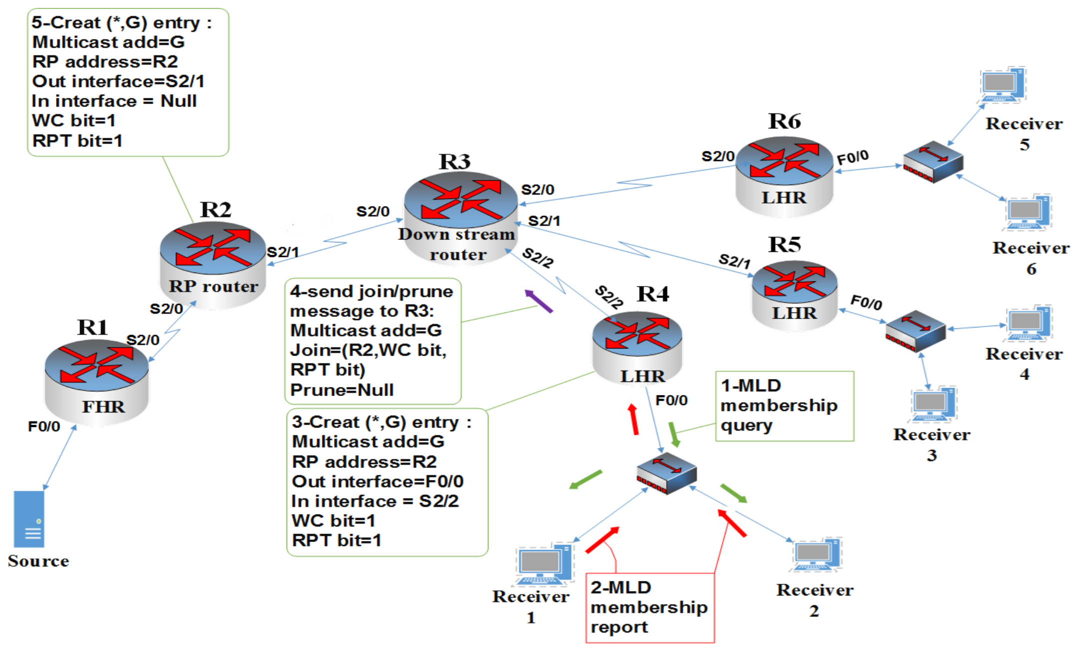


Figure1- Establishing of shared tree

The Rendezvous Point Tree (RP-tree) is being built in the following way. The receivers send their IGMP (or MLD) membership report with the required group address as destination IP address after receiving MLD/IGMP membership query, described in (1,2 respectively rectangle labels),as shown in (fig 1). When the Last Hop Router (LHR) is router directed connected to receivers. For example, Router 4 (R4) in Figure-1 gets membership report indication from IGMP/MLD for group G. The LHR looks up the associated RP. The LHR creates a wildcard multicast route entry for the group, referred to (*, G) entry, as described in (3). The LHR (R4 in Figure-1) creates join/prune message with RP address in the join list and both RP-tree bit (RPT-bit) and the wild card (WC bit) is set to 1 as described in (3). The RPT-bit indicates that this join is being sent up the RP-tree while, the WC bit refers that any source may match and be forwarded according to this entry, the prune list in this situation is left empty. When the RPT-bit is set to 1 it refers that the join is associated with shared RP-tree, so the join/prune message spread along the RP-tree, when WC-bit is set to 1 it refers that the address is an RP and downstream receivers expect to receive packets from all sources via this (shared tree) path. Each upstream router creates or updates its multicast route entry for (*, G) when it receives a join/prune with the RPT-bit and WC-bit set. The interface on which the join/prune message arrived is added to the list of outgoing interface for (*, G). Based on this entry each upstream router between the receiver and RP sends a join/prune message in which the join list includes the RP. Finally, the join message will reach to the RP router, the RP router sets the interface that joins message came from to outgoing interface and set null to the incoming interface because the source does not specify yet, as described in (5 rectangle labels).

2. Phase Two: Host sending to a group: the following Figure -2 described how host sending data to the group.

When a source start sending multicast data packet destined for a multicast group, as described in (1 rectangle labels) (as shown in Figure-2). The First Hop Router (FHR) which is router directly connected to sender creates (S, G) entry, as described in (2 rectangle labels), and encapsulates each data packet in a register message and unicast it directly to the RP, as described in (3 rectangle labels). The RP receives the encapsulated data packets and initiate (S, G) entry, as described in (4 rectangle labels), in addition, de-encapsulates them and forwards the enclosed data packet natively into the shared tree (5 rectangle labels).

After the RP router receives the encapsulated data packets by register messages, the RP can either continuing to receive these messages or joining the shortest path that leading to the source. By default, the RP will join the shortest path, because delivery of native multicast traffic provides the highest throughput. The routers between the source and the RP build, and maintain (S, G) state in response to join/prune messages and send (S, G) messages upstream toward the source. The FHR Update (S,G) entry and Add interface S0/0 to outgoing interface list as described in (6 rectangle label). Therefore, the FHR sends data natively to RP. Upon receipt of the first packet that arrives natively through the shortest path, the RP will send a register-stop message back to the FHR, as described in (7-rectangle label). When the FHR receives this register-stop message, it will stop sending register messages to the RP as described in (8-rectangle label).

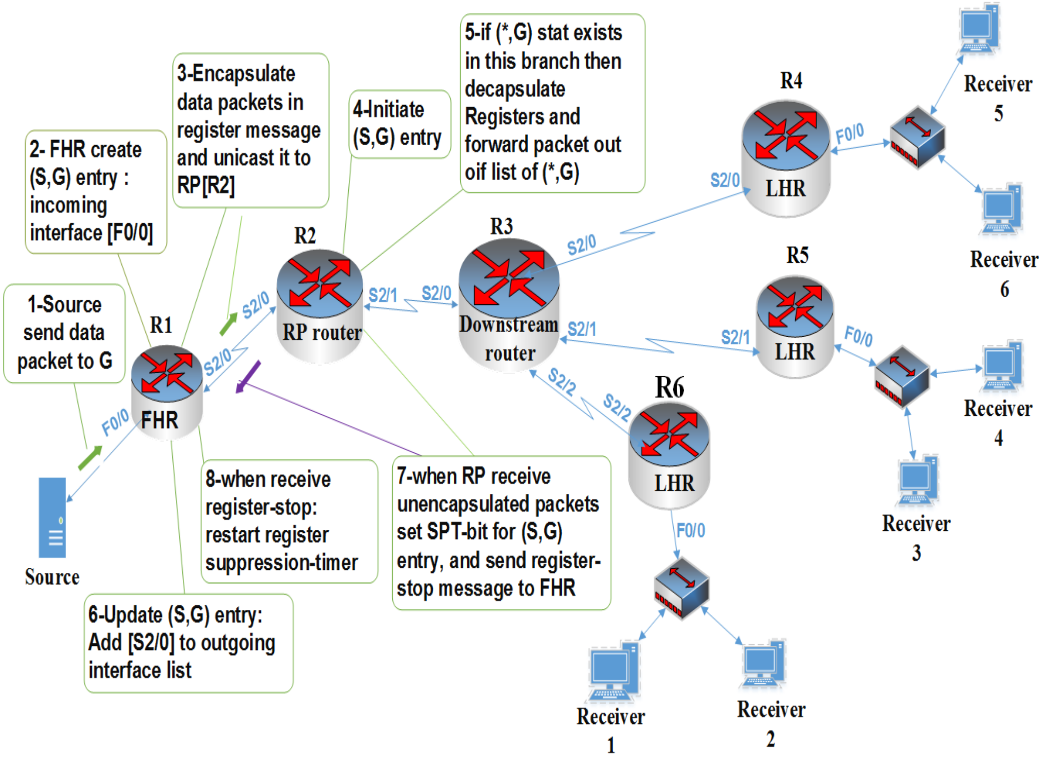


Figure 2- Host sending to group

Performance evaluation using GNS3 and Jperf (QoS validation)

This section introduces the performance evaluation using GNS3 (simulator/emulator) and JPERF. JPERF is an Internet Performance working group (IPERF) front-end application for generating multicast traffics. JPERF is a java GUI based on Iperf network measurement tool. As shown in Figure- 3 the network topology comprises 7 virtual computers define as VMWARE virtual machine with 10GB HDD and 1GB RAM per virtual machine and connected to virtual hub via 100MB Fast Ethernet. Four virtual hubs connected with virtual router via 100MB Fast Ethernet. Six virtual cisco 7200 routers connected between them via serial links. End-to-end connection realized using the server as a source for UDP media streaming, then received by clients over IPv6 and IPv4 multicast network using GNS3.

PIM-Multicast protocol relies on existed unicast routing table to understand the neighbors list and to implement reverse path forwarding (RPF) check, which distinguishes the nearest interface of the multicast router to the source. Thus, OSPF unicast protocol is utilized in the tested topology. The GNS3 setting and configuration steps for the tested IPv6/IPv4 multicast network topology are listed as follows:

- **Enable IPv6/IPv4 and Multicast routing:**

1. Enable IPv6 Unicast routing:

```
Router (config) # IPv6 unicast-routing
```

2. Enable multicast:

```
Router (config) #IPv6/IPv4 multicast routing
```

- **Configure IPv6 OSPF unicast protocol:**

The following two configuration commands represent OSPF unicast routing protocol activated in Router 1 as a requirement of PIM-SMv6 protocol.

```
Router1 (config) # IPv6 routing ospf <1-65535> process id
Router1 (config-router) # router-id 1.1.1.1
```

Additionally, the configuration commands of IPv6 addressing, OSPF and clock rate for Router 1 interfaces (serial and Ethernet) looks like:

```
Router1 (config) # interface fast Ethernet 0/0
Router1 (config-if) # IPv6 add 2001:1111:: 1/64
Router1 (config-if) # no shut
Router1 (config-if) # IPv6 ospf 1 area 0
Router1 (config) # interface serial 2/0
Router1 (config-if) # IPv6 add 2001:2222::1/64
Router1 (config-if) # no shut
Router1 (config-if) # clock rate 1612800
Router1 (config-if) # IPv6 ospf 1 area 0
Router1 (config) # interface loopback 0
Router1 (config-if) # IPv6 add 2001:DB8:1::1/64
Router1 (config-if) # IPv6 ospf 1 area 0
Router1 (config) # interface serial 2/1
Router1 (config-if) # IPv6 add 2001:5555::1/64
Router1 (config-if) # no shut
Router1 (config-if) # clock rate 1612800
Router1 (config-if) # IPv6 ospf 1 area 0
```

- **Configure IPV6/IPv4 PIM-SM:**

RP in PIM-SM acts as shared root between source and receiver of multicast data streaming. Typically, RP can configure in multicast IPv6/IPv4 using four ways; static-RP, Embedded-RP, BSR-RP or Auto-RP. The focus of this paper is based on static-RP. Static-RP means configure RP address on every router that will participate in the PIM domain including RP router. Where, one router selected randomly to be native-RP and configure the rest routers manually indoors of the multicast network. The Configuration steps for static-RP in IPv6/IPv4 are defined bellow respectively:

- Configuration command for Static-RP in IPv6 :

```
Router (config) # ipv6 pim rp-address <IPv6 address>
```

- Firstly, must enable PIM-SM multicast protocol on every interface pass multicast traffic before selects one router to configure Native-RP. The Configuration command in IPv4:

```
Router1(config)# interface serial 1/0
Router1(config-if)# ip pim sparse-mode
Router1 (config) # ip  pim rp-address <IPv4 address>
```

- **Configure IPv6 MLD/IGMP-Join Multicast Group:**

Since IPv6/IPv4 is activated in the tested multicast topology. Each router interface connected to the multicast receiver must configure with MLD/IGMP (multicast listener discovery)/ (Internet Group Management Protocol) protocols to understand the join or leave commands within the multicast group. The configuration command for MLD/IGMP is:

- Configuration command for MLD in IPv6:

```
Router (config-if) # IPv6 MLD join-group  FF08:8::1
```

- Configuration command for IGMP in IPv4:

```
Router (config-if) # IP IGMP join-group  239.9.9.9
```

TEST scenario

The tested network comprises Source denoted in Figure-3 as a multicast source (server) connected to the multicast router via hub by using 100 Mbps fast Ethernet cable, multicast routers connected to each other using 1.544 Mbps serial cable. In the tested scenario, Jperf server generates CBT/UDP multicast traffic that passes through GNS3 core network and then received by six Jperf receivers at the other end of the network. Jperf setting parameters conclude UDP bandwidth, which set to 1 Mbps, TTL set to 128, the datagram size (packet size) is 1470 byte, the experiment time is 300 sec, the IPv6-multicast group set to FF05::1, and the IPv4-multicast group set to 239.9.9.9.

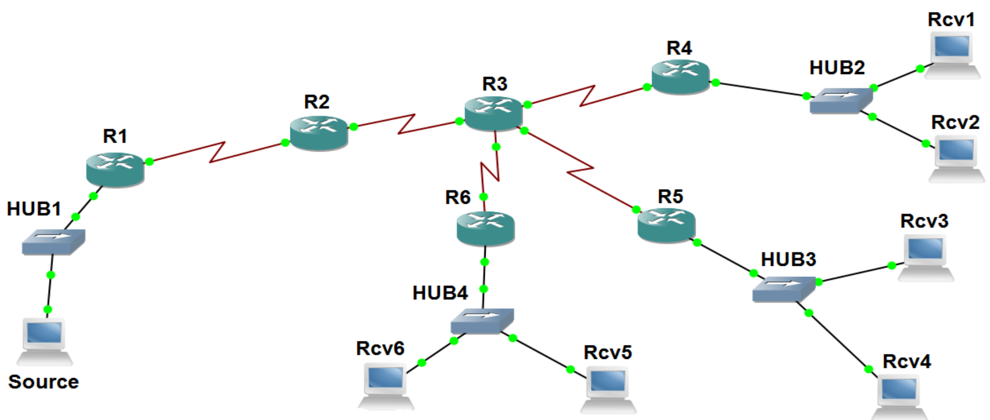


Figure 3- IPv6/IPv4 Multicast Network Topology

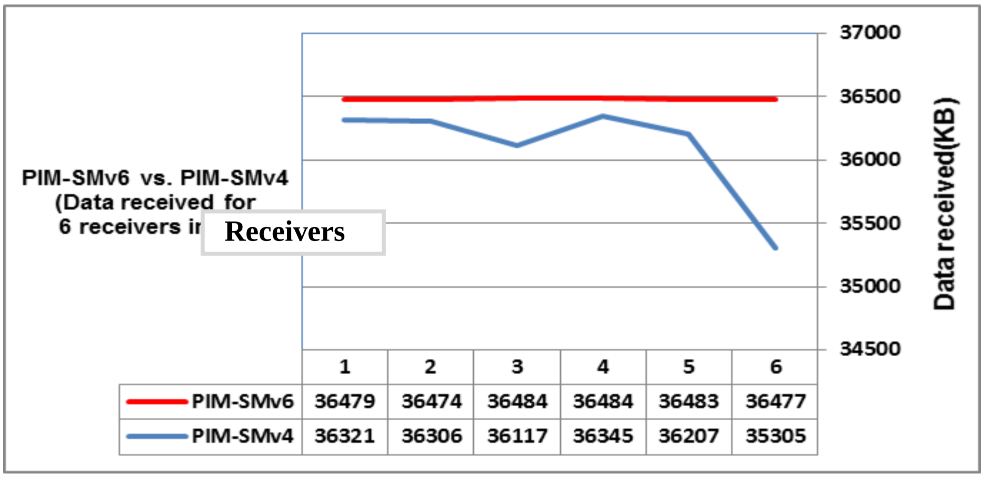
Performance analyses

This section discusses the analysis of PIM-SM for both IPv6 and IPv4 in terms of behavior using six receivers from one source based on QoS parameters: bandwidth utilization; data received, jitter, throughput, and datagram loss. Data received is the amount of data that received from the source (Total). Jitter is the variation in packet arrival time. Throughput is the measure of how fast the data can received over a link [15]. Datagram loss is the failure of one or more transmitted datagrams to arrive at their destinations. The results evaluation for each parameter discussed next. In addition, latter compared in terms of averages.

a. Data received

Figure- 4 shows the Data received for UDP packets at six receivers from the source. As shown, the obtained Data received over PIM-SMv6 range from (36474 to 36484) KB compared to (36117 to

36345) KB using PIM-SMv4. In terms of graph, IPv6 streaming (the red line) shows more stability or straight line behavior compared to IPv4 streaming (the blue line with up and down behavior).

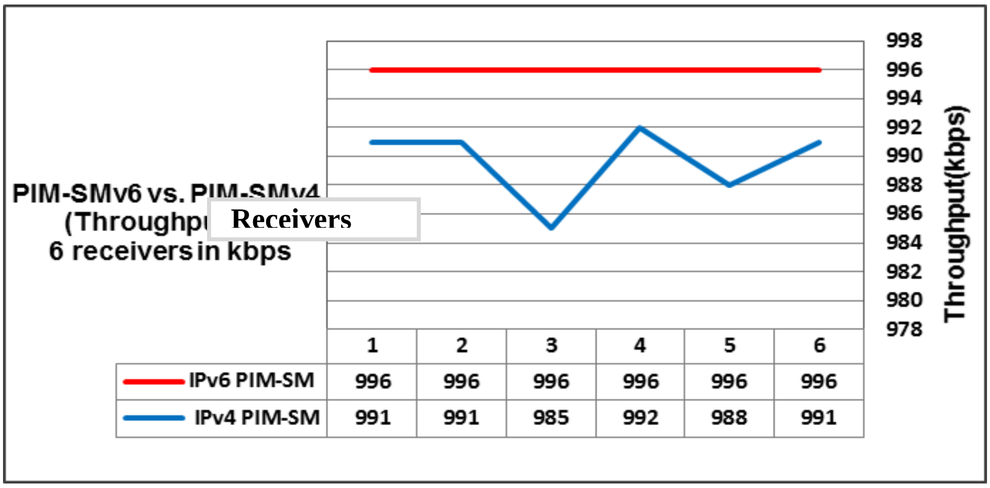


	1	2	3	4	5	6
PIM-SMv6	36479	36474	36484	36484	36483	36477
PIM-SMv4	36321	36306	36117	36345	36207	35305

Figure 4- PIM-SMv6 vs. PIM-SMv4 (Data received)

b. Throughput

The results of Throughput Figure- 5 obtained over network using PIM-SMv6 shows better with fixed value at 996 kbps whearas the throughput over PIM-SMv4 range from 985 kbps to 992 kbps (i.e. indirectly reflects the data received behaviour explaind above).

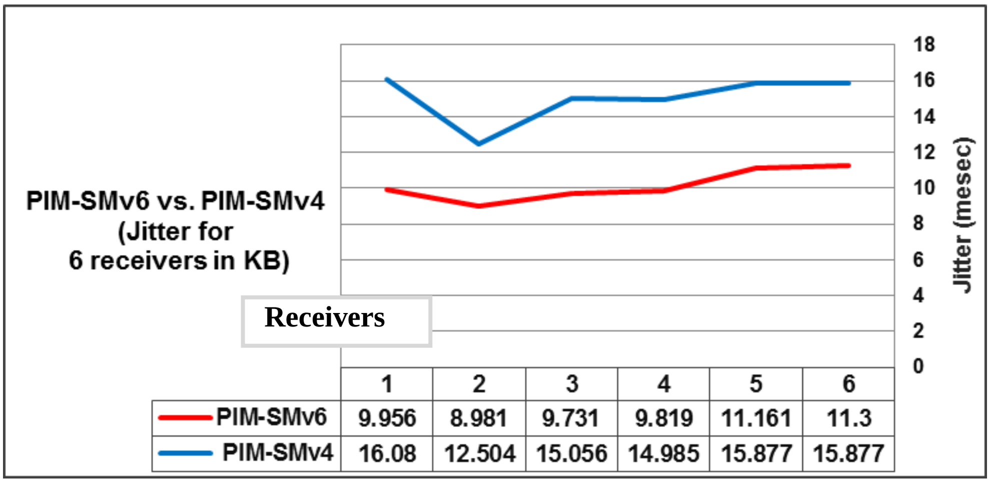


	1	2	3	4	5	6
IPv6 PIM-SM	996	996	996	996	996	996
IPv4 PIM-SM	991	991	985	992	988	991

Figure 5- PIM-SMv6 vs. PIM-SMv4 (Throughput)

c. Jitter

As shown in Figure- 6, PIM-SMv6 jitter falls in the range from 8.98 ms to 11.16 ms, whereas PIM-SMv4 falls in range from 12.50 ms to 16.08 ms. Since jitter plays an important factor in audio/video streaming, PIM-SMv6 showed better stability in terms of packet delay variation (jitter) compared to PIM-SMv4.

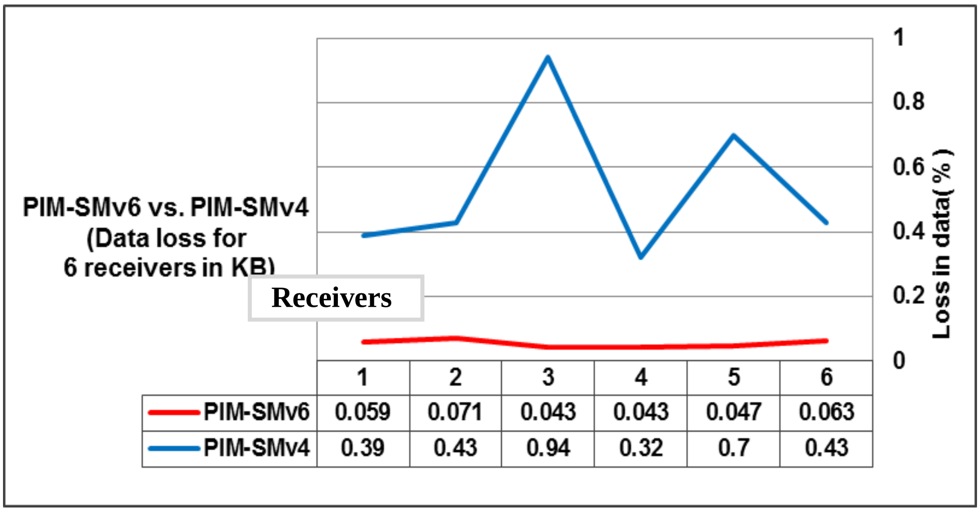


	1	2	3	4	5	6
PIM-SMv6	9.956	8.981	9.731	9.819	11.161	11.3
PIM-SMv4	16.08	12.504	15.056	14.985	15.877	15.877

Figure 6- PIM-SMv6 vs. PIM-SMv4 (Jitter)

d. Datagram lose

Datagram loss is the failure of one or more transmitted datagrams to arrive at their destinations. Each UDP datagram has own ID number, the jperf server uses this ID to detect the datagram loss. Typically, each UDP datagram segmented into several IP packets with a same ID number. Therefore losing one of this IP packet will lose the whole UDP datagram. The results of datagram loss over PIM-SMv4 range from 0.32% up to 0.94%, compared to 0.043% up to 0.071%. These results appear in Figure-7 in which PIM-SMv6 gives low datagram loss and small variation compared with high variation when PIM-SMv4 used.



	1	2	3	4	5	6
PIM-SMv6	0.059	0.071	0.043	0.043	0.047	0.063
PIM-SMv4	0.39	0.43	0.94	0.32	0.7	0.43

Figure 7- PIM-SMv6 vs. PIM-SMv4 (Datagram loss)

Considering of QoS averages Figure-8, it is notices that the jitter gain of PIM-SMv6 decreased up to 32.56% with fewer data loss (decreased up to 89.84%). Both contributed to the increase of throughput and data received at the six receivers with average (0.64% and 1.04% respectively). In summary, the effective gain appears in Jitter and datagram loss compared to a little difference in throughput and data received.

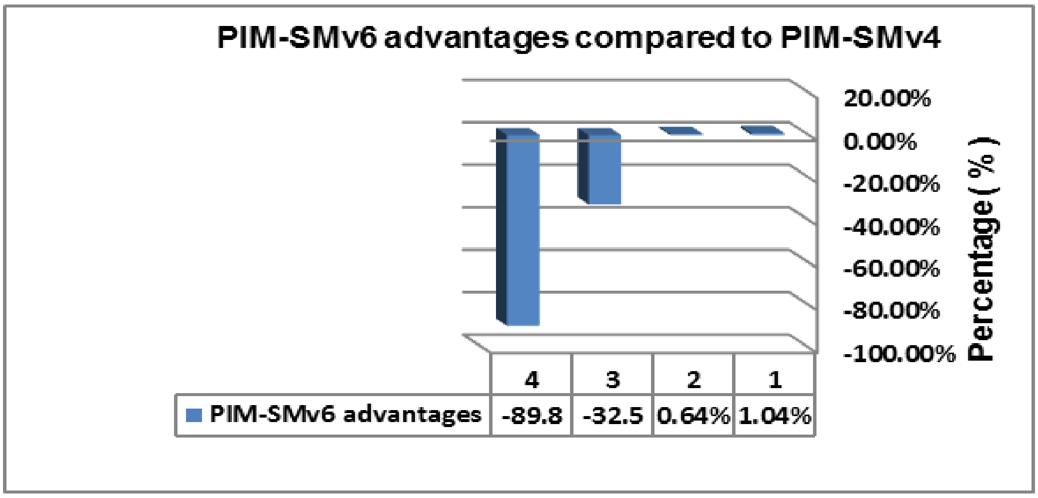


Figure 8- Average result of PIM-SMv6 vs. PIM-SMv4 with four Qos metrics

Results discussion and justification

The reason behind the superiority of IPv6-multicast (over IPv4-multicast) is due to the features of IPv6 protocol, such as larger address space, simpler header format which makes packet handling process more efficient. Furthermore, IPv6 simplifies packet-processing inside routers by assigning the packet fragmentation task to the source node whereas in IPv4 this task assigned to each router and considered as hop-by-hop packet processing. These features contributes in in the reduction of packet processing by performing either (1) Path Maximum Transfer Unit discovery (PMTUD), (2) end-to-end fragmentation, or (3) sending packets smaller than the default Maximum transmission unit (MTU) which is 1280 octets (compared to default MTU of IPv4 which is 576 octets) . Relatively, routers need extra processing to achieve IPv4 fragmentation in order to break down a datagram into smaller pieces to pass across a link with a smaller MTU.

Table-1 shows the similarities and differences between IPv4 and IPv6 multicast protocol based on two parts of the multicast domain called host-to-router and router-to-router.

Table 1- multicast protocol

Comparisons based on multicast protocol				
	Host-to-Router		**Router -to-Router**	
	(similarity)	**(differences)**	**(similarity)**	**(differences)**
IPv4	**Three type of messages with different names (Query, Report, Done)**	**IGMPv2 IGMPv3**	**PIMv2**	**Dynamic RP announcement uses auto-RP**
IPv6		**MLDv1 MLDv2**	**PIMv2**	**Dynamic RP announcement uses embedded RP**

For example, in terms of similarity; the host-router messages of IPv4 (IGMP Query, IGMP Report, IGMP Done) are defined equivalent to (MLD Query, MLD Report, MLD Done) in IPv6.

Whereas Table -2 show the Comparisons based on multicast features.

Table 2- multicast features

Comparisons based on multicast features			
	Differences		
IPv4	**Checksum calculation based on layer 3**	**Limit multicast address scope using TTL field in IPv4 address**	**small size of the IPv4 multicast addresses space**
IPv6	**Checksum calculation based on layer 4**	**Limit multicast address scope using scope field in IPv6 address**	**wider address space of IPv6 multicast addresses space**

SUMMARY OF RESULTS

To summarize all of these QoS parameters numerically, the following tables (Table- 3 and Table- 4) shows the network performance from server side and receiver's side for both versions PIM-SMv6 and PIM-SMv4.

Table 3-Client side

Source	Protocols	Transfer (KB)	BW (kbps)	Datagrams sent
Source	PIM-SMv6	36500	997	25426
	PIM-SMv4	36461	995	25399

Table 4- Server side

Receiver	Protocols	Data Received(KB)	Throughput(kb)	Jitter (ms)	(Lost/Datagram)
Receiver 1	PIM-SMv6	36479	996	9.956	0.059 %
	PIM-SMv4	36321	991	16.080	0.39 %
Receiver 2	PIM-SMv6	36474	996	8.981	0.071 %
	PIM-SMv4	36306	991	12.504	0.43 %
Receiver 3	PIM-SMv6	36484	996	9.731	0.043 %
	PIM-SMv4	36117	985	15.056	0.94 %
Receiver 4	PIM-SMv6	36484	996	9.819	0.043 %
	PIM-SMv4	36345	992	14.985	0.32 %
Receiver 5	PIM-SMv6	36483	996	11.161	0.047 %
	PIM-SMv4	36207	988	15.877	0.70 %
Receiver 6	PIM-SMv6	36477	996	11.300	0.063 %
	PIM-SMv4	35305	991	15.877	0.43 %

Conclusion

The results that obtained from various performance analysis of PIM-SM over IPv4 and over IPv6 showed that PIM-SMv6 achieves good performance in terms of throughput than PIM-SMv4. Data received in PIM-SMv6 is a little bit more than PIM-SMv4. Jitter in IPv4 is more than IPv6. Datagram loss in IPv6 is lower than IPv4. The measurement of both protocols carried out based on the UDP traffic. The Future work is measuring the delay of the multicast network, also send a real movie and measure the related QOS parameters.

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