Implementing multicast communication system making use of an existing data network to offer free TV channels

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Abstract: *This paper discusses how a company can implement multicast communication system making use of its existing data network to offer free TV channels. The advantages and challenges involved in multicast communications system and the design, configurations and deployment of a prototype multicast communications network while implementing an appropriate multicast routing protocol are discussed.*
Keyword: *Multicast, High availability, PIM, IGMP*

I. Introduction

Taking a look at the early IP networks, it can be observed that packets could only be sent to a single device or to all the devices within a network and this can be identified as unicast or multicast respectively [10]. Back then, the transmission of packets to certain group of devices was impossible. However the development of new applications has brought about the emergence of multicast transmission that enables efficient transmission of packets between groups of network devices. The devices in a group share a single multicast IP address through which data is transmitted and received by any member of the group that needs such data. The multicast protocols are designed such that they supports efficient streaming of data, voice and video [5]. Based on this, many organization now implement multicast communications within their network to offer IP Television and this has enabled them to save the money invested on the proprietary TV transmission.

Take for instance, Hotels now have more customers coming around from far and near and they deserve to get value for their money during their stay while having access to different TV channels in their different locations within the Hotel premises. A high subscription cost is generally attached to the proprietary TV system which is mostly being utilised by many of these Hotels. Therefore, offering the same service freely while making use of the existing data network in the hotel by making use of IP Multicast communications system will help them save cost. Customers willing to watch TV programs on television or through mobile devices such as laptops and smart phones will be offered such services conveniently [2]. This makes it necessary for these Hotels and other business organisations to implement IP multicast routing communications system within their existing network.

II. Multicast Video Communication System

This is a communication system in which video packets are sent from a source to a group of devices. This is always more than one device but not all the devices in the network [7]. All multicast addresses fall between the range of **224.0.0.0** to **239.255.255.255** and uses no subnet. Looking at unicast routing, it has its packets sent from a source to a single destination while broadcasting has its packets sent from source to every possible destination [10].

2.1 Advantages Of Multicast Video Communication System
* It reduces the tasks at the source devices compared to unicast network where it is essential for the video source to have the exert IP address of each and every receiving client.
* In a unicast network, video contents are delivered to each requesting client directly from the source each time there is a request from the receiver. This causes more bandwidth consumption in a situation where a video content has to be delivered to many clients across the network. Multicasting solves this problem by sending just a copy of the video stream to a multicast address and not concerned about the numbers of receivers in the multicast group identified by the multicast address and this greatly reduces the amount of bandwidth required [5].
* Servers in a unicast network get overloaded as more video streams are requested by clients and may at a point be unable to service more request. This is not the case in multicast streaming cause only a single video stream is sent by the server to the entire group.
* Routing calculations and updates are reduced in multicast system and this reduces load on the router CPU because fewer network traffics will be handled.

2.2 Challenges Of Multicast Vidoe Communication System
* All receiving clients in a multicast network receives the same stream same time and cannot be rewinded, forwarded or pursed.
* All equipments in a multicast network must be multicast enabled and this may involve replacement or an upgrade of equipments.
* User Datagram Protocol (UDP) is used in transporting multicast packets and this is an unreliable protocol because it works based on best effort and does not retransmit lost packets and may even deliver packets out of sequence which may require buffering to restore.
* Controlling access to multicast stream may be very difficult and this may lead to serious security challenges.

III. Overview Of PIM And IGMP
There are different multicast routing protocols used in IP multicasting. They include Distance Vector Multicast Routing Protocol (DVMRP), MOSP and the Protocol Independent Multicast (PIM) which will be our focus for this report. The Internet Group Management Protocol (IGMP) is however common to all these multicast routing protocols.

3.1 Functions And Characteristics Of IGMP
The IGMP is used to report the membership of host and routers in a multicast group to other neighbouring multicast routers in order to receive multicast streams destined for the group and to let the group know when they want to terminate their membership[1]. There are three IGMP versions. They include version 1, 2 and 3 which is the latest.
A router can function as a multicast group member or as a multicast router. As a group member, IGMP requests for multicast streams by sending message to the upstream router in order to receive streams destined for the multicast group. These messages are also sent when there is an interruption in streaming and when leaving the group [1].
On a multicast router, IGMP is used to monitor multicast operations within the network so as to get the host membership details required by the multicast routing protocol.

3.2 Functions Of Unicast Within A Multicast Network
For communication in a multicast network, multicast packets are sent to multicast groups making use of the multicast address identified in the multicast packet. Since every configured interface of a multicast router is multicast enabled, streams are forwarded out of these interfaces to make sure all down streams routers get requested stream packets. These may result into a multicast loop or sending the stream to a wrong interface causing the circulation of unwanted packets within the network and thereby consuming bandwidth. Reserve Path Forwarding solves this problem by checking the source address in unicast routing table of the router to be sure of the source of the packet. If the receiving router interface is the closet to the source of the stream, it will be forwarded and if not, it will be dropped.
Also, since multicast operates on the existing IP infrastructure to build a multicast distribution Tree, the time taken to rebuild the tree in the case of a network failure depends on how fast unicast routing protocol re-converges. Therefore, PIM rebuilds a multicast tree only after unicast protocols have converged.

3.3 Functions Of Sap In Multicast Video Communication
For a multicast video session to be advertised and to communicate relevant video session setup information to routers participating in the session, Session Announcement Protocol (SAP) is used. SAP make use of Session Description Protocol (SDP), so that a multicast packet will always have a description of the session being announced by SAP and when the announcement is received by participating routers, the session description will be used to setup requirements to be part of the multicast video session [6].

IV. Protocol Independent Multicast (PIM)
This is a multicast protocol that is independent on a certain unicast routing protocol and enhance any unicast routing protocol such as EIGRP,OSPF,BGP and Static routes used in building a unicast routing table. PIM make use of the information provided in the routing table to carry out multicast functions while making use of the Reserve Path Forwarding (RPF) check function and does not have to build a totally independent multicast routing table. PIM does not send or receive routing updates between routers [7]. PIM can operate in Dense mode, Sparse mode and as Sparse-Dense mode.

4.1 Functions And Characteristics Of PIM Dense Mode (PIM-DM)
This is a multicast routing protocol that can only be used when there is enough bandwidth. PIM-DM sends multicast transmission that may not be needed to routers in a network segment. It is mostly used and efficient in networks where there are receivers in all subnets requesting for the multicast stream [7].

It makes use of Flood and Prune mechanism. That is, an upstream router will assume that every downstream router is interested in the multicast stream and sends it to them without any request for it. Any router not interested in the stream will therefore send an upstream prune telling the upstream router to stop forwarding the stream to it [12]. PIM-DM stops the stream on the upstream router when it receives the message but assumes the downstream router may need the stream, so it resends it after 3minutes. Therefore the downstream router resends the upstream message to stop it.

In a case whereby a client request for the stream after the router as sent an upstream message to stop the stream, the router will have to send a join message to the upstream router to request for the stream. This makes it efficient than having to wait for 3minutes for the stream to come again.

4.2 Functions And Characteristics Of PIM Sparse Mode (PIM-SM)
This multicast routing protocol operates on a PULL model in which a network segment with active receivers can only receive a multicast stream when they request for it. This help conserve bandwidth and makes it usable even in a slower WAN connectivity. It uses both Source and Shared tree to connect receivers [8]. PIM-SM must contain a minimum of one Rendezvous Point (RP). An absent of RP makes the multicast network operate as PIM-DM. Traffics from a multicast source are all directed to the RP and all multicast routers request streams from the RP.

When a client sends a stream to its edge router, the router send a unicast PIM register message to the RP which acknowledges it with a unicast reply. The video stream is not sent to the RP until there is a request for it. But the RP will build a route to the shared tree (*,G) and the source tree (S,G) which matches the new multicast tree so that the source of the stream can be recorded and tracked for any multicast group. The edge router also connected to the source of the stream will also build a (*,G) and (S,G) route but no other router will know anything about this route until any of its clients request for the stream through the RP [7]. Therefore every router must have the identity of the RP which can be defined statically by using the IP address of the routers through an election.

When a host joins a multicast group, the directly connected router then send a PIM join message to the RP which has all information of the multicast groups. The RP then send a join message back to the source and after which data is forwarded through the shared tree. When a router receives the first stream and calculates that the source of the stream is nearer than going through the RP, it sends a join message to the source and packets will be forwarded on a source tree [4].

4.3 Functions And Characteristics Of PIM SPARSE-DENSE-Mode
This combines the features of both Sparse and Dense mode. It allows multicast routers to operate in sparse mode or in dense mode depending on the RP and the group information. Here a RP identity maybe learnt through PIM-DM and the multicast stream forwarded to receivers through PIM-SM. This protocol is flexible in the sense that one group in the multicast network may be making use of Dense mode and the other making use of Sparse mode for their multicast streams [3]. Therefore, the PIM operation is based on per group and not per router. A group that has a RP information will operate in Sparse mode while a group without RP information will operate in Dense mode.

4.4 High Availability Features With PIM SPARSE-DENSE-Mode
The PIM sparse-dense-mode ensures that there is redundancy in a multicast network by utilising features such as load balancing and failover between multiple elected RPs. However, this involves some steps to set these features up.

4.4.1 Load Balancing Between Multiple RPs
If the RP fails in a multicast network, a statically configured PIM cannot initiate a failover to another RP Therefore it is better to configure PIM dynamically. This can be BOOTSTRAP (this is an open standard) and AUTO-RP (this is a Cisco proprietary solution and this will be used in this prototype network). The two protocols carry out an election of one or more RP so that when one RP fails, the backup RP will automatically take its position.

AUTO-RP uses two PIM routers, Candidate RP and Mapping Agent. The candidate RP is a router configured to offer itself as a RP for one or more multicast streams. While the Mapping Agent is a router configured to accept RP offers and decide which router should be elected as the RP for the multicast group based on the largest IP address and also advertises the result of the election to other multicast routers in the

network [5]. A candidate RP advertises itself every 60seconds by default through the reserved multicast address 224.0.1.39 while the Mapping Agent announces the result of the election through the reserved address 224.0.1.40.

For load balancing, multiple RPs will have to be elected for different groups. Therefore different routers will advertise their self as candidate RPs for different multicast groups. This can be achieved by configuring access-control list on one RP to permit certain multicast traffics for some multicast groups while another access list must be configured on another RP to permit multicast traffics for the remaining groups. This depends on the number of routers we are willing to load balance with. This allows the mapping Agent to elect the routers as RPs for only the multicast streams specified by the access list configured on them.

4.4.2 Failover Between Multiple RPs Using AUTO-RP

This is the process by which a Mapping Agent automatically elects a candidate RPs to take the position of a RP whenever the RP fails within a multicast network. The RP is always the router with the largest IP address while the backup RP is the router with the second largest IP address among the candidate RPs. Therefore both the RP and backup RP must continue to send multicast messages to the Mapping Agent (MA) using the address 224.0.1.39 [5]. This makes the MA discover if the RP is still up or down. IT is advisable to set the announcement time interval to a lesser time like 10seconds compared to the default 60seconds. This helps MA discover a RP failure faster and elects the backup candidate RP as RP for the multicast stream.

V. Configuring PIM SPARSE-DENSE-Mode

For the PIM sparse-dense-mode configuration, we shall be making use of the prototype multicast network topology in the figure below to describe the configuration steps. Basically before enabling multicast routing on a router, we must make sure the basic necessary configurations are implemented such as the IP addressing of interfaces and configuration of the unicast routing protocol. EIGRP used in this case. Loopback interfaces must also be configured because it is always reachable unless all router interfaces are not reachable. When we have achieved an end to end connectivity in the network, PIM can then be implemented.

Prototype Multicast Network Topology
Source: University of Sunderland
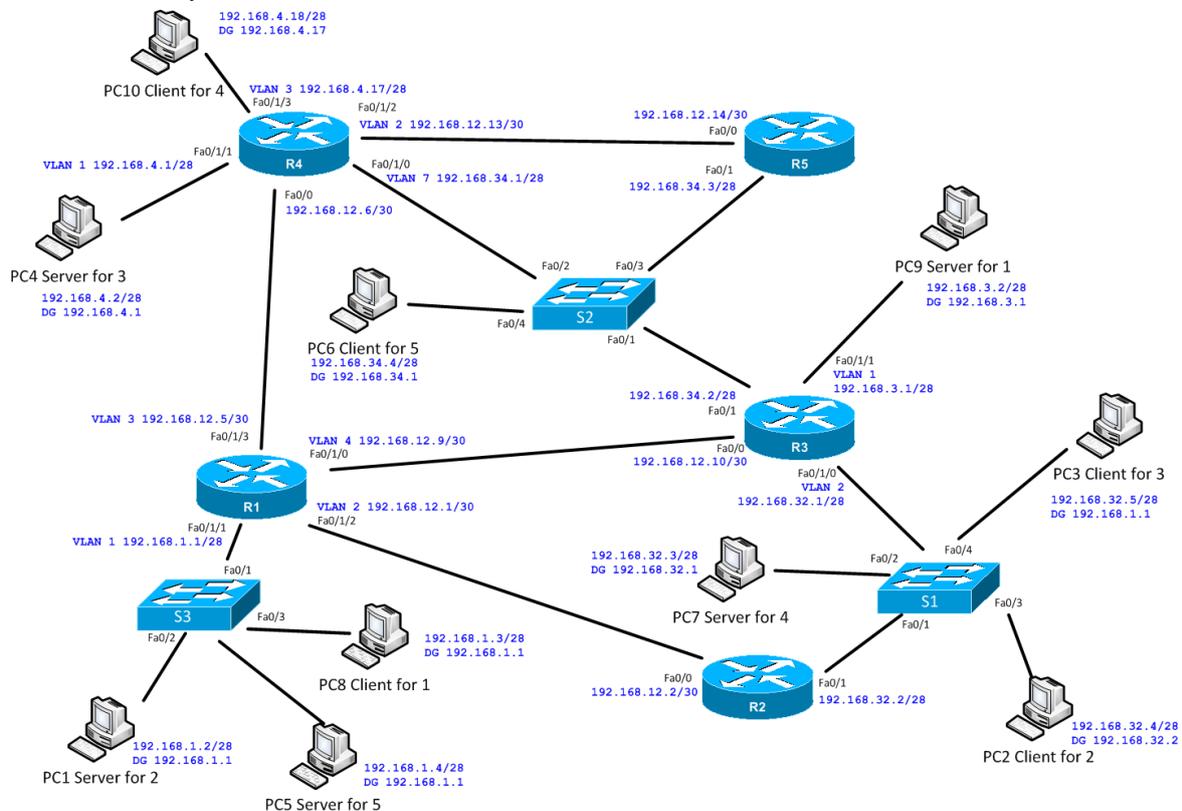
5.1 Enabling PIM SPARSE-DENSE Mode

When all configurations identified above has been done, then we must enable multicast routing on the routers. Using router Two from the prototype network topology as an example.

R2(config)#ip multicast-routing

This command enables multicast routing on R2 and same must be done on every other router in the network. We shall now proceed to making the routers participate in PIM Sparse-Dense-Mode. To achieve this, all configured router interfaces including loopbacks must be enabled for PIM sparse-dense-mode routing. This can be seen below.

```
R2(config)#interface fa0/0

R2(config-if)#ip pim sparse-dense-mode

R2(config)#interface fa0/1

R2(config-if)#ip pim sparse-dense-mode
```

These commands must also be configured on the interfaces of every other router in the network.

5.2 Load Balancing With Failover USING AUTO-RP

To configure load balancing with failover, two or more routers will serve as RPs and another two or more routers will serve as MA. In this paper, we shall be making use of two routers each for both RP and MA. Each candidate RP must be configure with 2 loopback interfaces such that the first RP will have a larger IP address on **lo0** which will be used to identify the router as RP for some multicast group while the other RP will have a larger IP address on **lo1** which will identify it as RP for the remaining multicast groups. At the same time, both RPs will also be serving as backup for each other.

In order to identify which multicast address each RP will handle, TWO access list must be configured and must be the same on both RPs. The configuration is shown below using **R4** and **R3** as the RPs and using **227.1.4.1, 227.1.4.2, 227.1.4.3, 227.1.4.4 and 227.1.4.5** as multicast group address.

```
R3(config)#access-list 1 permit 227.1.4.5

R3(config)#access-list 1 permit 227.1.4.4

R3(config)#access-list 2 permit 227.1.4.3

R3(config)#access-list 2 permit 227.1.4.2

R3(config)#access-list 2 permit 227.1.4.1
```

The loopback interfaces must be configured as stated above on both RPs

```
ROUTER 3 CONFIGURATIONS

R3(config)#interface Loopback 0

R3(config-if)#ip address 10.0.1.5 255.255.255.255

R3(config-if)#ip pim sparse-dense-mode

R3(config-if)#exit

R3(config)#interface Loopback 1

R3(config-if)#ip address 10.0.0.4 255.255.255.255

R3(config-if)#ip pim sparse-dense-mode

R3(config-if)#exit

R3(config)#ip pim send-rp-announce lo0 scope 5 group-list 2 interval 10

R3(config)#ip pim send-rp-announce lo1 scope 5 group-list 1 interval 10
```

ROUTER 4 CONFIGURATIONS

R4(config)#interface Loopback 0

R4(config-if)#ip address 10.0.1.3 255.255.255.255

R4(config-if)#ip pim sparse-dense-mode

R4(config-if)#exit

R4(config)#interface Loopback 1

R4(config-if)#ip address 10.0.0.6 255.255.255.255

R4(config-if)#ip pim sparse-dense-mode

R4(config-if)#exit

R4(config)#ip pim send-rp-announce lo0 scope 5 group-list 2 interval 10

R4(config)#ip pim send-rp-announce lo1 scope 5 group-list 1 interval 10

The last two configuration line on both R3 and R4 shows that lo0 is used to identify the router that will be used as RP for the multicast groups identified by group-list 2 while loopback1 will be used to identify the router that will be used as RP for the multicast groups identified in group-list 1. The scope 5 means the packets cannot go through more than 5 routers and the interval 10 tells the router to advertise itself as RP and candidate RP every 10seconds.

Configuring Router 1 And 5 As Mapping Agents

R1(config)#interface Loopback 0

R1(config-if)#ip address 10.0.1.1 255.255.255.255

R1(config-if)#ip pim sparse-dense-mode

R1(config-if)#exit

R1(config)#ip pim send-rp-discovery lo0 scope 5 interval 10

Only the configurations of Router 1 as a Mapping Agent is shown above because Router Five has the same configuration as Router 1 but only has a different Loopback 0 address. The discovery in the last line identifi.es the router as a mapping agent to announce the candidate RP with the largest IP address on Loopback 0 to serve as RP for traffics specified in group-list 2 and the candidate RP with the largest IP address on Loopback 1 to serve as RP for traffics specified in group-list 1. They also serve as backup for each other in case anyone fails.

The screenshot above displays the output of the **"show ip rp mapping"** on **R2** and this shows the multicast group-to-RP details for the network. The arrow points to the unique multicast address **227.1.4.2** and shows that R3 is elected as the RP because it has a larger ip address of **10.0.1.5** on lo0 compared to R4 that has a lower ip address of 10.0.1.3 on lo0 (this can be seen in the second screenshot below). It also shows the ip address of lo0 of R1 which is a mapping agent as the source of the multicast stream for client 2. The screenshot shows that R3 is the RP for **227.1.4.1, 227.1.4.2** and **227.1.4.3** while R4 is the RP for **227.1.4.4** and **227.1.4.5.**

Screenshot displaying the result of SHOW IP PIM RP MAPPING on R3 which is the mapping agent.

This shows that where R3 is the RP, R4 is the backup RP and where R4 is the RP, R3 is the backup RP this show redundancy within the network in case of any RP failure.

5.3 VERIFICATION OF FAILOVER WHITHIN THE NETWORK
To verify that the failover is well configured within the prototype PIM Sparse-Dense Mode network using AUTO-RP, the lo0 of Router3 should be shutdown to simulate a RP failure. Then the command SHOW IP PIM RP MAPPING is used on both R2 and R3 to verify if a new RP as been elected for multicast group **227.1.4.1, 227.1.4.2** and **227.1.4.3**

Result Of "Show Ip Pim Rp Mapping" On R1 Which Is A Mapping Agent

```
ROUTER1#SH IP PIM RP MA
ROUTER1#SH IP PIM RP MApping
PIM Group-to-RP Mappings
This system is an RP-mapping agent (Loopback0)

Group(s) 227.1.4.1/32
  RP 10.0.1.3 (?), v2v1
    Info source: 10.0.1.3 (?), elected via Auto-
          Uptime: 02:30:42, expires: 00:00:28
Group(s) 227.1.4.2/32
  RP 10.0.1.3 (?), v2v1
    Info source: 10.0.1.3 (?), elected via Auto-
          Uptime: 02:31:00, expires: 00:00:30
Group(s) 227.1.4.3/32
  RP 10.0.1.3 (?), v2v1
    Info source: 10.0.1.3 (?), elected via Auto-
          Uptime: 02:31:18, expires: 00:00:21
Group(s) 227.1.4.4/32
  RP 10.0.0.6 (?), v2v1
    Info source: 10.0.0.6 (?), elected via Auto-
          Uptime: 02:31:49, expires: 00:00:21
  RP 10.0.0.4 (?), v2v1
    Info source: 10.0.0.4 (?), via Auto-RP
          Uptime: 02:34:57, expires: 00:00:23
Group(s) 227.1.4.5/32
  RP 10.0.0.6 (?), v2v1
    Info source: 10.0.0.6 (?), elected via Auto-
          Uptime: 02:32:25, expires: 00:00:25
  RP 10.0.0.4 (?), v2v1
    Info source: 10.0.0.4 (?), via Auto-RP
          Uptime: 02:35:40, expires: 00:00:30
ROUTER1#
```

Result Of "Show Ip Pim Rp Mapping" On R2

```
ROUTER2#sh ip pim rp ma
ROUTER2#sh ip pim rp mapping
PIM Group-to-RP Mappings

Group(s) 227.1.4.1/32
  RP 10.0.1.3 (?), v2v1
    Info source: 10.0.1.1 (?), elected via Auto-RP
          Uptime: 00:20:31, expires: 00:02:22
Group(s) 227.1.4.2/32
  RP 10.0.1.3 (?), v2v1
    Info source: 192.168.12.14 (?), elected via Auto-RP
          Uptime: 00:20:49, expires: 00:02:04
Group(s) 227.1.4.3/32
  RP 10.0.1.3 (?), v2v1
    Info source: 10.0.1.1 (?), elected via Auto-RP
          Uptime: 00:21:07, expires: 00:02:42
Group(s) 227.1.4.4/32
  RP 10.0.0.6 (?), v2v1
    Info source: 10.0.1.1 (?), elected via Auto-RP
          Uptime: 02:41:11, expires: 00:02:25
Group(s) 227.1.4.5/32
  RP 10.0.0.6 (?), v2v1
    Info source: 10.0.1.1 (?), elected via Auto-RP
          Uptime: 02:41:29, expires: 00:02:09
ROUTER2#
```

Result Of "Debug Ip Auto-Rp" On R1 Which Is A Mapping Agent

```
ROUTER1#  DEBUG IP PIM AUto-rp
PIM Auto-RP debugging is on
ROUTER1#
*May 28 18:07:20.226: Auto-RP(0): Received RP-announce packet of length 54, from 10.0.0.6, RP_cnt 1, ht 31
*May 28 18:07:20.226: Auto-RP(0): Update (227.1.4.4/32, RP:10.0.0.6), PIMv2 v1
*May 28 18:07:20.226: Auto-RP(0): Update (227.1.4.5/32, RP:10.0.0.6), PIMv2 v1
*May 28 18:07:20.226: Auto-RP(0): Received RP-announce packet of length 54, from 10.0.0.6, RP_cnt 1, ht 31
*May 28 18:07:20.226: Auto-RP(0): Update (227.1.4.4/32, RP:10.0.0.6), PIMv2 v1
*May 28 18:07:20.226: Auto-RP(0): Update (227.1.4.5/32, RP:10.0.0.6), PIMv2 v1
*May 28 18:07:20.246: Auto-RP(0): Received RP-announce packet of length 54, from 10.0.0.4, RP_cnt 1, ht 31
*May 28 18:07:20.246: Auto-RP(0): Update (227.1.4.4/32, RP:10.0.0.4), PIMv2 v1
*May 28 18:07:20.246: Auto-RP(0): Update (227.1.4.5/32, RP:10.0.0.4), PIMv2 v1
*May 28 18:07:20.246: Auto-RP(0): Received RP-announce packet of length 54, from 10.0.0.4, RP_cnt 1, ht 31
*May 28 18:07:20.246: Auto-RP(0): Update (227.1.4.4/32, RP:10.0.0.4), PIMv2 v1
*May 28 18:07:20.246: Auto-RP(0): Update (227.1.4.5/32, RP:10.0.0.4), PIMv2 v1
*May 28 18:07:22.726: Auto-RP(0):                                          10.0.1.3, RP_cnt 1, ht 31
*May 28 18:07:22.726: Auto-RP(0): Update (227.1.4.2/32, RP:10.0.1.3), PIMv2 v1
*May 28 18:07:22.726: Auto-RP(0): Update (227.1.4.3/32, RP:10.0.1.3), PIMv2 v1
*May 28 18:07:22.726: Auto-RP(0): Update (227.1.4.1/32, RP:10.0.1.3), PIMv2 v1
*May 28 18:07:22.726: Auto-RP(0): Received RP-announce packet of length 60, from 10.0.1.3, RP_cnt 1, ht 31
*May 28 18:07:22.730: Auto-RP(0): Update (227.1.4.2/32, RP:10.0.1.3), PIMv2 v1
*May 28 18:07:22.730: Auto-RP(0): Update (227.1.4.3/32, RP:10.0.1.3), PIMv2 v1
*May 28 18:07:22.730: Auto-RP(0): Update (227.1.4.1/32, RP:10.0.1.3), PIMv2 v1UNDEB
*May 28 18:07:26.630: Auto-RP(0): Build RP-Discovery packet
*May 28 18:07:26.630: Auto-RP:  Build mapping (227.1.4.1/32, RP:10.0.1.3), PIMv2 v1,
*May 28 18:07:26.630: Auto-RP:  Build mapping (227.1.4.2/32, RP:10.0.1.3), PIMv2 v1.
*May 28 18:07:26.630: Auto-RP:  Build mapping (227.1.4.3/32, RP:10.0.1.3), PIMv2 v1.
*May 28 18:07:26.630: Auto-RP:  Build mapping (227.1.4.4/32, RP:10.0.0.6), PIMv2 v1.
*May 28 18:07:26.630: Auto-RP:  Build mapping (227.1.4.5/32, RP:10.0.0.6), PIMv2 v1.
*May 28 18:07:26.630: Auto-RP(0): Send RP-discovery packet of length 78 on Vlan1 (2 RP entries)
*May 28 18:07:26.630: Auto-RP(0): Send RP-discovery packet of length 78 on Vlan2 (2 RP entries)U
*May 28 18:07:26.630: Auto-RP(0): Send RP-discovery packet of length 78 on Vlan3 (2 RP entries)
*May 28 18:07:26.630: Auto-RP(0): Send RP-discovery packet of length 78 on Vlan4 (2 RP entries)
*May 28 18:07:26.630: Auto-RP(0): Send RP-discovery packet of length 78 on Loopback0(*) (2 RP entries)G ALL
*May 28 18:07:30.226: Auto-RP(0): Received RP-announce packet of length 54, from 10.0.0.6, RP_cnt 1, ht 31
*May 28 18:07:30.226: Auto-RP(0): Update (227.1.4.4/32, RP:10.0.0.6), PIMv2 v1
*May 28 18:07:30.226: Auto-RP(0): Update (227.1.4.5/32, RP:10.0.0.6), PIMv2 v1
*May 28 18:07:30.226: Auto-RP(0): Received RP-announce packet of length 54, from 10.0.0.6, RP_cnt 1, ht 31
*May 28 18:07:30.226: Auto-RP(0): Update (227.1.4.4/32, RP:10.0.0.6), PIMv2 v1
*May 28 18:07:30.226: Auto-RP(0): Update (227.1.4.5/32, RP:10.0.0.6), PIMv2 v1
*May 28 18:07:30.246: Auto-RP(0): Received RP-announce packet of length 54, from 10.0.0.4, RP_cnt 1, ht 31
*May 28 18:07:30.246: Auto-RP(0): Update (227.1.4.4/32, RP:10.0.0.4), PIMv2 v1
*May 28 18:07:30.246: Auto-RP(0): Update (227.1.4.5/32, RP:10.0.0.4), PIMv2 v1
*May 28 18:07:30.246: Auto-RP(0): Received RP-announce packet of length 54, from 10.0.0.4, RP_cnt 1, ht 31
```

From the "show ip pim rp mapping" on R2 and R3 and the "debug ip pim auto-rp" on R3, it can be seen that R4 which has ip address **10.0.1.3** on lo0 and was the backup RP for multicast group **227.1.4.1, 227.1.4.2** and **227.1.4.3** as now been elected as the RP for the three multicast groups. This shows that the failover is properly configured and working as expected.

5.4 Verification Of Multicast Traffic Flow Using Show Commands

Show command are very useful when verifying multicast traffic flow and are also helpful in troubleshooting. Some show commands used in the prototype network and their output are discussed below.

5.4.1 Show IP PIM Neighbor

This command can be used to verify PIM neighbour adjacencies. It is also useful when troubleshooting to find out the status of PIM neighbours to know their version, PIM mode and timer. It can also be used to verify a missing or an inactive neighbour. The output of the command when issued on R2 is shown below.

```
ROUTER2#
ROUTER2#sh ip pim ne
ROUTER2#sh ip pim neighbor
PIM Neighbor Table
Neighbor           Interface              Uptime/Expires     Ver    DR
Address                                                             Prio/Mode
192.168.12.1       FastEthernet0/0        03:37:13/00:01:34  v2     1 / S
192.168.32.1       FastEthernet0/1        03:37:03/00:01:29  v2     1 / S
ROUTER2#                                                            Animal Video
```

The above screenshot identifies two PIM neighbours with IP addresses of **192.168.12.1** and **192.168.32.1** which were discovered on interfaces fa0/0 and fa0/1 of R2. It also shows that the neighbours are operating on PIM version2 and have respective uptimes of **3hours37minutes13seconds** and **3hours37minutes3seconds** and expiry times of **1minute34seconds** and **1minute29second** after which the

routers will have to refresh and update PIM statuses. Both PIM neighbours have default priority of **1** and are state refresh capable. This is shown by **S** in the mode column. State refresh is used in dense mode for routers to resend prune messages at 3minutes interval to prevent flooding while conserving bandwidth.

5.4.2 Show IP PIM Interface

This command shows necessary information about all configured router interfaces for PIM on a router. It is used to verify if the correct PIM mode is running on the router interface and to check if the router has the correct number of neighbours. The output of the command when issued on R2 is shown below.

```
ROUTER2#sh ip pim int
ROUTER2#sh ip pim interface

Address            Interface          Ver/    Nbr    Query  DR      DR
                                      Mode    Count  Intvl  Prior
192.168.12.2       FastEthernet0/0    v2/SD   1      30     1       192.168.12
.2
192.168.32.2       FastEthernet0/1    v2/SD   1      30     1       192.168.32
.2
ROUTER2#
```

The screenshot above shows that interfaces Fa0/0 and Fa0/1 are configured for PIM Sparse-Dense Mode using PIM version2 and with unicast IP addresses **192.168.12.2** and **192.168.32.2**. The neighbour count displayed above shows the number of PIM neighbour connected to each interface. And it can be seen that only one PIM neighbour is connected to each interface. Both interfaces also have a priority of 1 each with query interval of 30 each.

VI.   Interpretation Of The Multicast Routing Table

In multicast routing, multicast traffics within the network are always recorded in the Multicast Routing Table (MRT) of a multicast router. This table is made up of the Source Tree and The Shared Tree information.

Source Tree: this provide information of traffic flow from source directly to destination and it's also referred to as Shortest Path Tree (STP) because it follows the shortest path from source to destination. It's denoted in the MRT as (S,G) where S is the unicast address of the source and G is the multicast group address.

Shared Tree: this provides information of traffic flow from the RP to destination. Here traffics from many sources are directed to the RP and only the RP will have the information of the sources unicast addresses. It's denoted by (*,G) in the MRT.

Issuing "**show ip mroute 227.1.4.2**" command on R2 it displays the contents of the router MRT for that unique multicast group 227.1.4.2. This can be seen below.

```
COM2 - PuTTY
.2
ROUTER2#sh ip mro
ROUTER2#sh ip mroute 227.1.4.2
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report, Z - Multicast Tunnel
       Y - Joined MDT-data group, y - Sending to MDT-data group
Outgoing interface flags: H - Hardware switched, A - Assert winner
 Timers: Uptime/Expires
 Interface state: Interface, Next-Hop or VCD, State/Mode

(*, 227.1.4.2), 00:37:27/stopped, RP 10.0.1.5, flags: SJPC
  Incoming interface: FastEthernet0/1, RPF nbr 192.168.32.1
  Outgoing interface list: Null

(192.168.1.2, 227.1.4.2), 00:37:27/00:02:58, flags: JT
  Incoming interface: FastEthernet0/0, RPF nbr 192.168.12.1
  Outgoing interface list:
    FastEthernet0/1, Forward/Sparse-Dense, 00:37:27/00:02:09, A

ROUTER2#
```

From the screenshot above, (192.168.1.2, 227.1.4.2) represents the (S, G) where 192.168.1.2 is the unicast address of PC1 (server for client2) and the 227.1.4.2 is the unique multicast group address for the stream. The (S, G) also shows that R1 with IP address 192.168.12.1 is an upstream neighbour connected to Fa0/0 of R2 and its directly connected to the source of the stream. It can also be seen that the incoming interface for (S, G) traffic is Fa0/0.

The (*, 227.1.4.2) represents the (*, G) where 227.1.4.2 is the unique multicast group address through which the stream is being delivered. It can also be seen that the stream in coming in through Fa0/1 of R2 from 192.168.32.1 which is seen as an upstream neighbour. It also shows that R3 with address 10.0.1.5 is the RP. The "00:37:27/stopped" shows that the (*, G) entry was sent 37minutes27seconds ago and that the expiry timer had been stopped. This is because a better path for the video was found. The MRT also shows that PIM Sparse-Dense Mode is being used by the stream

Issuing the "**show ip mroute**" command displays the entire contents of the router's MRT for all existing multicast groups. This includes the (S, G) and (*, G) entries for each group.

```
ROUTER2#
ROUTER2#sh ip mroute
IP Multicast Routing Table
Flags: D - Dense, S - Sparse, B - Bidir Group, s - SSM Group, C - Connected,
       L - Local, P - Pruned, R - RP-bit set, F - Register flag,
       T - SPT-bit set, J - Join SPT, M - MSDP created entry,
       X - Proxy Join Timer Running, A - Candidate for MSDP Advertisement,
       U - URD, I - Received Source Specific Host Report, Z - Multicast Tunnel
       Y - Joined MDT-data group, y - Sending to MDT-data group
Outgoing interface flags: H - Hardware switched, A - Assert winner
 Timers: Uptime/Expires
 Interface state: Interface, Next-Hop or VCD, State/Mode

(*, 227.1.4.2), 00:40:12/stopped, RP 10.0.1.5, flags: SJPC
  Incoming interface: FastEthernet0/1, RPF nbr 192.168.32.1
  Outgoing interface list: Null

(192.168.1.2, 227.1.4.2), 00:40:11/00:02:53, flags: JT
  Incoming interface: FastEthernet0/0, RPF nbr 192.168.12.1
  Outgoing interface list:
    FastEthernet0/1, Forward/Sparse-Dense, 00:40:11/00:02:24, A

(*, 227.1.4.4), 00:08:41/stopped, RP 10.0.0.6, flags: SJPCF
  Incoming interface: FastEthernet0/1, RPF nbr 192.168.32.1
  Outgoing interface list: Null

(192.168.32.3, 227.1.4.4), 00:08:42/00:02:52, flags: PFT
  Incoming interface: FastEthernet0/1, RPF nbr 0.0.0.0
  Outgoing interface list: Null

(*, 224.0.1.39), 03:06:20/stopped, RP 0.0.0.0, flags: DC
  Incoming interface: Null, RPF nbr 0.0.0.0
  Outgoing interface list:
    FastEthernet0/1, Forward/Sparse-Dense, 03:06:23/00:00:00
    FastEthernet0/0, Forward/Sparse-Dense, 03:06:23/00:00:00

(10.0.0.4, 224.0.1.39), 01:20:31/00:02:50, flags: T
  Incoming interface: FastEthernet0/1, RPF nbr 192.168.32.1
  Outgoing interface list:
    FastEthernet0/0, Forward/Sparse-Dense, 01:16:27/00:00:00, A
```

VII. Conclusion

Deployment of multicast routing within a network is highly cost effective and can be used for Video streaming to different client devices. PIM Sparse-Dense Mode is of better advantage since it combines the functions of both Sparse and Dense mode. Therefore implementing multicast routing within existing network will prevent money spent on subscription for the proprietary TV channels and therefore offer free TV channels to customers.

References

[1]. B. Cain, S. Deering, I. Kouvelas, B. Fenner, A Thyagarajan, (2002). Internet Group Management Protocol, Version 3, , RFC 4604.
[2]. Minoli, D. (2008). IP Multicast with Applications to IPTV and Mobile DVB-H. Hoboken: John Wiley and Sons.
[3]. Paul, S. (2011). Digital Video Distribution in Broadband, Television, Mobile and Converged Networks: Trends, Challenges and Solutions. West Sussex: John Wiley and Sons.
[4]. Cisco.com (2005). IP Multicast in Cable Networks - Cisco Systems [online] Available at: http://www.cisco.com/en/US/technologies/tk648/tk828/technologies_case_study0900aecd802e2ce2.html [Accessed: 18 May 2013].
[5]. Simpson, W. (2008) Video Over IP: IPTV, Internet Video, H.264, P2P, Web TV, and Streaming: A Complete Guide to Understanding the Technology. 2nd ed. Oxford: Elsevier Inc.
[6]. Handley, C. Perkins, E. Whelan, (2000). Session Announcement Protocol. M RFC 2974
[7]. Cisco.com, (2012). IP Multicast Technology Overview - Cisco Systems [online] Available at: http://www.cisco.com/en/US/docs/ios-xml/ios/ipmulti_pim/configuration/12-4t/imc_tech_oview.html#GUID-8168D184-0F45-4EAA-B9C0-68403809DE77
[8]. D. Estrin, D. Farinacci, et al., June (1998). Protocol Independent Multicast-Sparse-Mode (PIM SM): Protocol Specification. RFC 2362,
[9]. Doyle, J. and Carroll, J. (2001). Routing TCP/IP, Volume II. Indianapolis: Cisco Press
[10]. ARIANIT MARAJ and ADRIAN SHEH, (2011). The necessity of multicast for IPTV streaming. Available at: http://www.wseas.us/e-library/conferences/2011/Lanzarote/TELESI/TELESI-21.pdf
[11]. Jelena Veličković, Jelena Seović and Aleksandra Smiljanić , (2014). Evaluation of the Open-Source Implementation of PIM-SM. Available at: http://www.opensourcerouting.org/wp-content/uploads/2014/08/IcETRAN_2014-Evaluation-of-the-Open-Source-Implementation-of-PIM-SM1.pdf
[12]. Cisco System, (2001). PIM Dense Mode. Available at: www.cisco.com