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Performance Evaluation of Multicast Transmission on MPLS Network Using PIM SM

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Abstract: Internet has changed our lives. The multitude of applications that Internet offers demand better network resource utilizations. This paper aims to evaluate the performance of Protocol Independent Sparse Mode (PIM-SM) multicasting protocol over Multi-Protocol Label Switching (MPLS).MPLS is now the De-facto standard for many carrier and service provider networks. MPLS is a simple and flexible solution for multiservice networks. Labels used in MPLS network for forwarding and routing packets provide indices to the routing tables enhancing the speed requirements. Hierarchical Virtual channeling imparts scalability to the MPLS networks. MPLS and Multicasting are two complementary technologies. Merging of these two technologies put forwards an efficient networking scenario that delivers solution to scalability and control overhead problems. MPLS supports multicasting. This paper details the classical features of PIM-SM signaling over MPLS. The simulator used for performance evaluation is NS2.NS2 simulations presents a clear picture of the efficiency of presented protocol in terms of throughput and the control overhead.

Keywords*:* MPLS, routing protocol, PIM,PIM-SM ,Multicasting ,FEC,LABEL,LSR,LSP,LER,ILM,NHFE,MRIB,RPT,SPT,DR

1. INTRODUCTION

The evolving network applications of this era like WWW,audio\video, on demand services, IP telephony, video conferencing,distributed network games, distance learning ,online shopping relies heavily on multicast transmissions. Multicast transmissions let transmissions from a single source to multiple destinations. Multicasting is the elegant method for these transmissions for saving network bandwidth. Multicast services send a packet to n destinations in a single transmission thereby allowing the link bandwidth to be shared. Multicast however suffers from scalability issues in regard to the overhead number of active multicast groups. The network is also affected by the number of participants in a group and the changing participants of a multicast group. This has a direct impact on the memory resources as with a router having to maintain routing states per group.

Recent researches have evolved solutions for multicast scalability issues by attempting the reduction of forwarding states by tunnelling or by forwarding state aggregation [1].The router overhead can also be reduced to a great deal by eliminating forwarding states at the routers either completely by explicitly encoding the list of destinations in data packets instead of using multicast addresses. The later solution deploys a branching router in multicast tree. This paper put forwards the solution based on the usage of PIM-SM protocol over MPLS that distributes MPLS labels for multicast routes.

MPLS is the protocol of choice for bandwidth management and quality of service requirements for IP based backbone networks. Initially MPLS was used just to forward the packets for any routing protocol with increased speed. But now MPLS is extensively used to support many other applications like service creation (VPN's), traffic engineering, network convergence and increased resiliency. MPLS can run on top of several L2 technologies like PPP/Sonet, Ethernet, ATM, FR etc. and the IP protocol at L3 level. MPLS multicast tree utilises MPLS LSP's between multicast tree branching node routers in order to reduce forwarding states and thereby resolving scalability glitches. PIM-SM is a multicast routing protocol that builds unidirectional shared trees rooted at a Rendezvous Point (RP).PIM-SM protocol creates shortest path trees per source.

1.1 RELATED WORK

The MPLS protocol was initially proposed in RFC 3031 by Rosen, E.Viswanathan, and A. Callon [1].Further a lot of study was carried out in the domain for the prospects of traffic engineering. The protocol was found to deliver better results in par with ATM and IP.The MPLS protocol was thoroughly analysed in subsequent years in regard to its positioning and MPLS.Protocol suite was further extended to Generalized Multi-Protocol Label Switching (GMPLS) to manage other classes of interfaces and switching technologies like time division multiplex, layer-2 switch, wavelength switch and fiber-switch.The protocol PIM-SM was initially put forward by RFC 2362 [8] which was further revised in RFC 4601[5].

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2. MPLS, IP MULTICASTING AND PIM-SM

2.1 AN OVERVIEW OF MPLS OPERATION

MPLS is a mechanism of directing the data from one router to another based on the MPLS header attached with it that contains labels. The routers at the edges of an MPLS domain are referred to as Label Edge Routers (LER). [1]The labelling denotes the forwarding equivalence class (FEC) to which a packet belongs. A label is a short, fixed length, locally significant identifier which is used to identify a FEC. The packets with the same label follows the same path, named as Label Switched Path (LSP).A packet is assigned to a FEC based on the destination network address. The routers are termed upstream and downstream routers in the direction of transit packet flow. The routers agree on a local binding of a label L for a particular FEC F. Both the entities agree upon an encoding technique to encode the packets with a label encapsulated header. Label bindings are assigned from the downstream entity to the upstream entity Interior routers in the MPLS domain does the label inspection and forwarding based on the label contained. Such routers are termed as Label switch Routers (LSR).

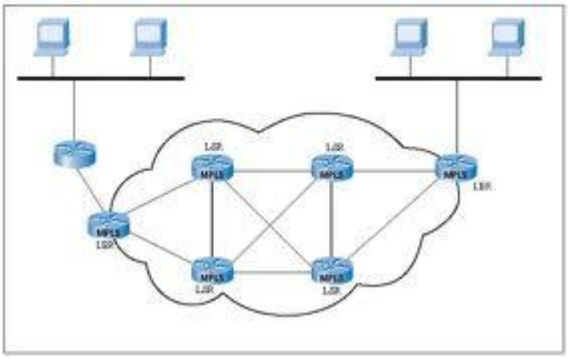

FIGURE 1: MPLS NETWORK

The routing entities use a label distribution protocol (LDP) to inform the later of the bindings it had made. HELLO messages are used by LDP to discover the peers. Initialization, Keep alive and Shutdown messages are used to maintain adjacency. Label mapping, Label Request, Label withdrawal and Label Release are the advertisement messages. Other variants are Resource reservation protocol (RSVP), constrained based LDP (CR-LDP) and RSVP Traffic Extension Routing. Routes may be formed implicitly between a pair of downstream and upstream routers. For the formation of an explicit route, CR-LDP sends an object called Explicit Route(ER). [1]Explicit Route is carried as a triple <Type, Length, Value> in the LDP Label Request message. LDP uses OSPF to set up intra domain LSP's. Downstream on demand label advertisements also use this LDP label Request message for label bindings of explicit route. Label Request contains the list of nodes in the explicit route. Labels are allocated and distributed by means of Label Mapping messages generated at the source which propagates back in reverse direction towards the source. Label distribution can be unsolicited or on-demand. A labelled packet may also contain multiplicity of labels arranged in a LIFO label stack. Next Hop Label Forwarding Entry (NHLFE) is used to forward a labelled packet.

NHLFE contains the following information:

1. The packet's next hop

2. The operation to perform on the packet's label stack; this is one of the following operations:

a) Replace the label at the top of the label stack with a specified new label.

b) Pop the label stack

c) Replace the label at the top of the label stack with a specified new label, and then push one or more specified new labels onto the label stack.

Mapping of each label to a particular NHLFE is done by Incoming Label Map (ILM).FEC to NHLFE map (FTN) maps each FEC to a set of NHLFEs. In order to forward a labelled packet, a Label Switch Router (LSR) examines the label at the top of the label stack. It uses the ILM to map this label to an NHLFE. Using the information in the NHLFE, it determines where to forward the packet, and performs an operation on the packet's label stack. It then encodes the new label stack into the packet, and forwards the result. In order to forward an unlabelled packet, a LSR analyses the network layer header, to determine the packet's FEC. It then uses the FTN to map this to an NHLFE. Routing can be implicit or explicitly defined. Implicit route allows the individual routers in a network to decide the next hop for each FEC on a hop by hop basis. Explicit routes are however to be specified at the time labels are allocated and distributed. An explicitly routed LSP may contain several or many of all the LSR's in that LSP.

2.2 IP MULTICAST AND PIM-SM

IP multicasting in an MPLS network is characterised by the following factors.

A. Source/Shared trees

IP multicast routing protocols creates two kinds of trees for multicast, namely source trees(S,G) and shared trees(*,G).Source trees create a single tree per source (S) and per multicast group (G).Shared trees on the other hand, creates a single tree per each multicast groups. Shared trees are used when labels are used to switch networks as it consumes only a single label per group as against a single label per source and per multicast group. PIM-SM supports both source trees and shared trees and each router can have both (S, G) and (*, G) entries for the same group (G). [2]

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B. Flood & Prune

Some routing protocols like PIM-DM or DVMRP, floods the multicast data for the formation of multicast tree and later performs pruning of branches which are not part of intended recipients in the addressed multicast group. PIM-SM advantageously does not flood the network and hence has limited overhead.

C. Aggregation

Unicast transmissions aggregates different destination addresses into one routing table entry .i.e., one FEC and one LSP. Multicast granularity is (S, G) for source trees and (*, G) for shared trees. [3]Hence aggregation is not defined. PIM-SM therefore does not feature aggregation.

D. Uni/Bi-directional shared trees

Bi-directional shared trees create a lot of merge points in the shared tree. Unidirectional shared trees yield just a single merge point i.e. the root of the shared tree. PIM SM supports unidirectional shared trees.

E. Encapsulated multicast data

Data towards the root is encapsulated by the source nodes of a unidirectional shared tree and non-member source nodes of a bi-directional shared tree. Data is decapsulated at the root node. PIM-SM features encapsulation.

F. Loop-free-ness

Effect of transient loops is worse in multicast. Each time multicast packets enter into a loop, the data packets are copied and sent onto its branches resulting in a worse scenario. PIM-SM is not loop free.

2.3 OVERVIEW OF PIM SM PROTOCOL

PIM SM protocol functions to perform efficient routing to multicast groups that may span wide-area and inter-domain Internet. The approach is referred to as Protocol Independent Multicast-Sparse Mode (PIM-SM) as it is not dependent on any particular unicast routing protocol, and because it is designed to support sparse groups.

PIM protocol depends on a Multicast Routing Information Base (MRIB) to fetch the next hop router to a destination subnet [5]. MRIB is populated with all the existing routes in the topology by routing protocols like MBGP.MRIB determines the next hop router to which Join\Prune messages were sent. Data is sent in the reverse direction of Join message. Rendezvous point (RP) is the root node of the distribution tree for a multicast group. This address is obtained automatically through a bootstrap mechanism, or through static configuration [6]. The phase one of the protocol formulates a distribution tree for multicast. The receivers give the consent for receiving multicast traffic by means of IGMP or MLD messages. The receiver designates one local router as a Designated Router (DR) for its contained subnet. All the DR's sent JOIN essages towards the RP for multicast transmissions. This Join message is known as a (*, G) Join since it joins group G for all sources to that group. As the (*, G) is traversed hop by hop, it instantiates multicast tree state of that group. Ultimately it reaches either RP or a router that has the Join state entry for that group. When many receivers join the group, their join messages converge at the Preforming a distribution tree. This is called as RP tree (RPT) and is a shared tree as it is shared by all the sources sending to the group. The Multicast sender sent the multicast data to the group through the DR. The DR Unicast encapsulates the data and sends them to the RP. This process is called Registering. The encapsulated packets are called PIM Register Packets. RP decapsulated the data and forwards them to the intended shared tree. The packets then follow the (*,G) multicast tree state in the routers on the RP Tree, being replicated wherever the RP Tree branches, and eventually reaching all the receivers for that multicast group.[5] The second phase of PIM-SM operation is the Register STOP operation. Encapsulation and decapsulation process at the router may be expensive. Also the journey back and forth between a RP and shared tree may take long. Hence when the RP receives a register-encapsulated data packet from source S on group G, it will normally initiate an (S, G) source specific Join towards S and RP will switch to native forwarding. Eventually the messages reach the subnet S and the packets flow towards the RP. While RP is in the process of joining source-specific packets, data packets continue to encapsulate to RP. Thus RP receives packets forwarded natively from S as well as encapsulated packets. RP now begins to discard the encapsulated copy of the packets and sends a Register STOP message to DR of the source S. The third phase of protocol is the formation of Shortest Path Tree (SPT). The phase results in optimisation of the forwarding paths. This is done to achieve low latency and an efficient bandwidth utilisation. The route through RP may not always be appreciable. It may cause significant delays by detouring of paths. DR may initiate a transfer from shared tree to source specific SPT by using an (S, G) join message. Data packets then flow from S to the receiving nodes following the (S, G) entry. The receiver thus receives two copies of data, one following RPT and other from SPT. When traffic starts arriving from SPT, it sends a PRUNE message towards the RP known as (S, G, rpt) prune. It instantiates a state indicating that the traffic from S for G should not be propagated in that direction. Thus the shortest path tree is formed.

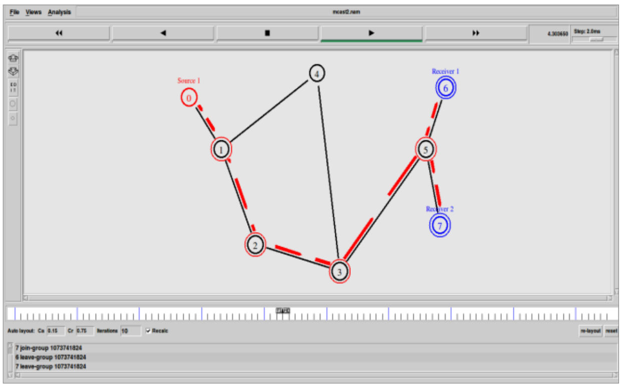

FIGURE 2: Experimental Topology

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2.4 LABEL DISTRIBUTION FOR PIM-SM

PIM is used to combine MPLS label distribution with the distribution of (*, G) join state, (S, G) join state, or (S, G) RPT -bit prune state. Thus an LSR attached to a multicast network will never have to send more than one copy of a given multicast data packet out that interface. It becomes possible for a receiver of a labelled packet to identify the label without knowing the transmitter is if the interface support data link multicasts. Labels and multicast routes are sent together in a single message.

An LSR that supports multicast sends PIM Join/Prune messages on behalf of hosts that join groups. It sends Join/Prune messages to upstream neighbouring LSRs toward the RP for the shared-tree (*, G) or toward a source for a source-tree (S, G). Labels are distributed by being associated with addresses in the join list or the prune list. [3].

3. SIMULATION OF MULTICAST TRANSMISSION USING PIM SM OVER MPLS

We consider a network scenario comprising of 8 nodes numbered from node 0 to node 7.Node 0 is the source that generates CBR network traffic to receiver nodes, node 6 and node 7.Node 1 is the rendezvous point of the group. Node 6 and node 7 join and leave group during the simulation period for the multicast. We simulate the network merging PIM SM multicasting on MPLS in NS2.

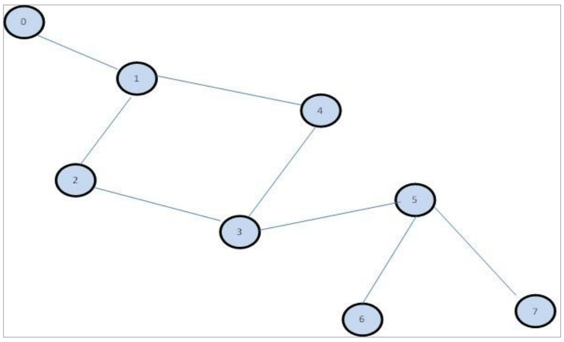

FIGURE 3: Multicast MPLS PIM-SM simulation

3.1 SIMULATION

We analyse the performance of the proposed protocol in regard to packet delivery ratio (PDR) and normalised overhead (NOH).The simulation results indicate the efficiency of the proposed technique over the traditional networking strategy.

The following parameters have used in the configuration:
Simulator: NS-2.35
Simulation time: 10ms
Access-link bandwidth: 1.5 Mbps
Access-link delay: 10 Ms
Packet size: 1460 (in bytes)
Queue management: Drop Tail in the access link.
Total Simulation time is considered 10 unit times.

3.2 RESULTS

The simulation results are plotted in an Xgraph to render throughput comparison with clarity. The PIM-SM over MPLS network was found to have an edge over the traditional network. The throughput for MPLS with PIM-SM was very much higher in comparison to traditional network. Excellent packet delivery ratio was found in MPLS with PIM-SM as against traditional networks. Also the percentage of dropped packets was substantially reduced. MPLS over PIM-SM require smaller congestion window size.

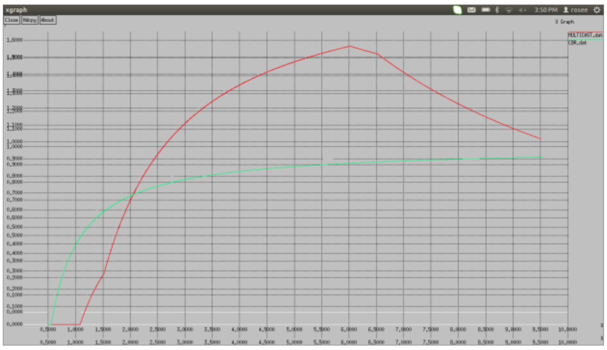

FIGURE 4: Throughput comparison of MPLS on PIM SM multicast protocol with Traditional routing protocol

4. CONCLUSION

The implication of the PIM-SM protocol has been studied in detail. The simulation results prove the validity of the aforesaid efficiency of the designed network. Simulation results indicate improved bandwidth utilisation by the reduction of dropped packets in comparison with the traditional network protocols. Multicast applications are sure to take advantage of the proposed protocol in lieu of its bandwidth requirements. The quality of service guaranteed by the proposed network is worth mentioning for the superior uses of multimedia and other emerging applications of the era. On the whole this paper is an indicative of the efficiency of multicast traffic engineering over unicast traffic engineering. MPLS was at its onset used by service providers. But now, the astronomical growth of internet has forced the enterprises to adopt the same for its superior quality.

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