PACKET LOSS PROBABILITY FOR DIFFSERV OVER HETEROGENEOUS MPLS MULTICAST NETWORKS : A SIMULATION STUDY

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Abstract

In this paper, we present a Fair Share Policy (FSP) that utilizes Differentiated Services to solve the problems of QoS and congestion control when reliable FEC/ARQ multicast is adopted. Simulation programs are used to evaluate the Fair Share Policy. The results should provide insights into the comparisons between homogeneous IP multicast networks, homogeneous MPLS multicast networks and heterogeneous MPLS multicast networks using the same FSP when DiffServ are adopted and when reliable FEC/ARQ multicast is considered. This comparison will be based on the residual packet loss probability.

Keywords: ***Heterogeneous, MPLS, IP; Residual loss.***

1. INTRODUCTION

MPLS is an Internet Engineering Task Force (IETF) standard [1]. It replaces the IP forwarding by a simple label lookup mechanism. MPLS offers a vehicle for enhanced network services such as Quality of Services (QoS)/ Class of Service (CoS), Traffic Engineering and Virtual Private Networks (VPNs). IP multicast in MPLS networks is still an open issue [2-3].

On the other hand, the IETF DiffServ working group is looking at a more scalable model and more likely to be easier to implement than IntServ/RSVP model [4-5].

In order to provide QoS in group communications, a hybrid Forward Error Correction/ Automatic Repeat Request (FEC/ARQ) strategy should be used. In this case, when FEC fails to correct errors at the receiver the receiver sends a NAK to the sender to retransmit the data in error [6].

It would be interesting to compare QoS performance of IP and MPLS multicasting, given their particular constraints [7-8]. In regular IP multicasting only overhead pertaining to IP multicast tree should be established, while in MPLS multicasting we have to add also the corresponding MPLS multicast tree establishment times and control packets. In this paper, we evaluate the QoS performance for a complete binary tree in the three cases of homogeneous IP, homogeneous MPLS and heterogeneous MPLS multicast networks. We also consider Differentiated Services; i.e. traffics with different priority classes.

2. THE SIMULATION MODEL

FSP is not a call admission rather it is a traffic policing mechanism. In FSP, packets are discarded in case of congestion differently at each queue according to source priority and the maximum number in the queue [7-8]. Our simulation model is shown in Fig. 1. In this model, a typical IP or MPLS router and our FSP traffic policing mechanism process three independent sources corresponding to different input traffic classes. Source 1 is assigned the highest priority, then source 2 and finally source 3. The following assumptions are used:

1- The arrival of packets is assumed to be Poisson.
2- FSP uses non pre-emptive priority queuing and FIFO for the same priority packets.
3- The arrival probabilities are α_1, α_2 and α_3 for each source respectively.
4- Service probabilities for different queues are β_1, β_2 and β_3.

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5- Average queue sizes are $E_1(n)$, $E_2(n)$ and $E_3(n)$.
6- Maximum buffer sizes are max_1, max_2 and max_3.
7- Total router buffer size is fixed i.e. ,
$B = max_1 + max_2 + max_3$ where max_p (p=1,2,3) is calculated as: $max_p = \frac{Pr_p}{\Sigma_p Pr_p} * B$ where Pr_p is source p priority.
8- All of MPLS or IP routers on the subject Internet are identical in providing source and traffic conditions.
9- All packets are of the same length and consist of L=500 bytes.

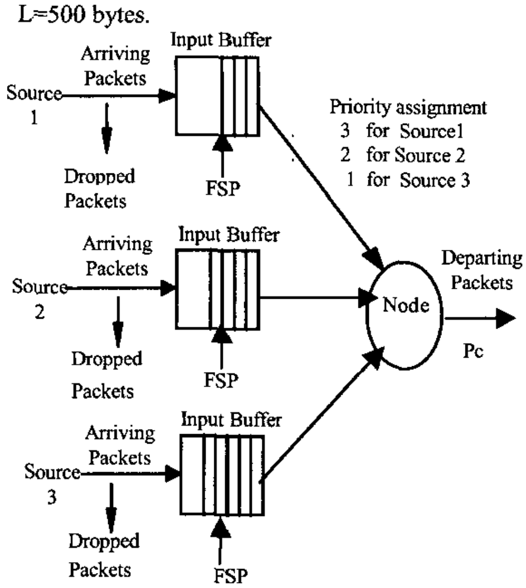


Fig.1 The simulation model

2.1 Heterogeneous MPLS Networks

In this paper, three different types of multicast networks will be compared. In the homogeneous IP multicast network, all routers are IP routers. In the homogeneous MPLS multicast network, all routers are MPLS routers while in the heterogeneous MPLS multicast network, the network is assumed to be MPLS network but still having some IP routers. The number and location of these IP routers in this MPLS network will create the different situations. Each different situation may create up to four types of routers in the MPLS heterogeneous network as would be explained in this section. In this type of network, we can have no IP router in the network (homogeneous MPLS case), 1 IP router in the network, 2 IP routers in the network, or 3 IP routers in the network.

These IP routers can be located anywhere in the network (in our example a complete 31 nodes binary tree is taken) except the root, which is the sender or the Rendezvous Point router. In any case ,there will be up to four types of routers:

1- IP (type1) router, which is a regular IP router.

2- ME (type 2) router, which is an MPLS router with extra processing due to more packet processing is needed at the MPLS router because the downstream router is an IP router.

3- EI (type 3) router, which is either an egress or ingress router with extra processing due to the overhead of tunnel establishment and maintenance and also due to more packet processing is needed because of the IP routers, which reside in between EI routers.

4- M (type 4) router, which is a regular MPLS router.

Fig. 2 shows one situation when 2 IP routers exist at levels 4 and 5 in an MPLS binary network with depth (D = 5.

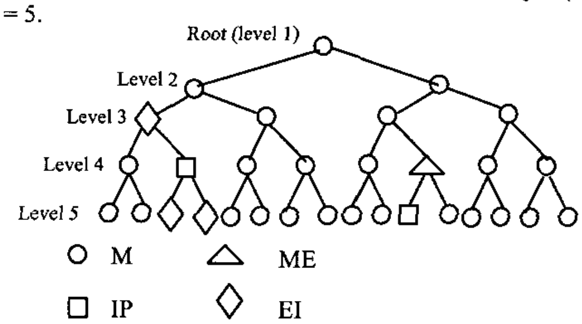


Fig. 2 2 IP routers in a heterogeneous MPLS network

2.2 Input/Output Buffer Characteristics

Each source p (p=1,2, or 3) has limited input buffer. A packet arriving at a particular input buffer goes directly to the output buffer provided that the input buffer is empty (i.e. no previous packets waiting in that input buffer) and there are no packets waiting from higher priority traffic. Otherwise, the packet will be waiting in the input buffer until the preceding packets are served (if there are any). A packet arriving at a particular buffer is rejected (dropped) if the corresponding buffer is full. For example, packets from source 3 will be served only when the buffers corresponding to source 1 and source 2 (which have higher priority) are all empty.

Packets in the input buffers are statistically multiplexed into an infinite output buffer. The output channel transmits packets from the output buffer at a fixed bandwidth rate. In the simulation programs, an output link rate of 1Gbit/s is used, which equals to 250,000 packets/s for 500 bytes packet length.

2.3 Different Source Arrivals

For IP routers (type 1), the source arrival probability α is actually a composite one; for instance α_1 (for source 1) can be written as: $\alpha_1 = \tau\alpha_1^1 + \alpha_1^2$.

α_1^1 is the intrinsic arrival probability at the application layer (on top of IP layer), α_1^2 is the extra arrival probability due to IP control overhead used to establish the IP multicast tree. The above equation can be rewritten in terms of α_1^1 as:

$$\alpha_1 = \tau\alpha_1^1 + \xi_1\alpha_1^1 \qquad \xi_1 = \frac{\alpha_1^2}{\alpha_1^1} \tag{1}$$

Where ξ_1 is IP control overhead factor (or IP factor) and τ is the IP processing time factor (or processing factor).

Similarly for MPLS routers (type 4), α_1 can be written as: $\alpha_1 = \alpha_1^1 + \alpha_1^2 + \alpha_1^3$

Where α_1^1 and α_1^2 are the same as in the case of IP networks; α_1^3 is the extra arrival probability due MPLS control overhead used to establish MPLS multicast paths or tree.

α_1 can be rewritten in terms of α_1^1 as:

$$\alpha_1 = (1+\xi_1+\xi_2)\alpha_1^1 \qquad \xi_2 = \frac{\alpha_1^3}{\alpha_1^1} \tag{2}$$

Where ξ_2 is the MPLS control overhead factor (or MPLS factor).

For ME routers (type 2), α_1 can be written as:

$$\alpha_1 = (1+\xi_1+\xi_2+\xi_3)\alpha_1^1 \qquad \xi_3 = \frac{\alpha_1^4}{\alpha_1^1} \tag{3}$$

Where ξ_3 is ME factor.

For EI routers (type 3), α_1 can be written as:

$$\alpha_1 = (1+\xi_1+\xi_2+\xi_4)\alpha_1^1 \qquad \xi_4 = \frac{\alpha_1^5}{\alpha_1^1} \tag{4}$$

Where ξ_4 is EI factor.

3. HYBRID FEC/ARQ OPERATION

In this paper, Reed-Solomon code RS (n,k), which is a well known FEC technique [6], is used with n=255, k=223 and 8-bits symbol. Every code word contains 255 code word bytes, of which 223 bytes are data and 32 bytes are parity. The Hybrid FEC/ARQ procedure can be summarized as follows:

1- Keep a counter for each source packet to the number of lost bytes (erasures) and the number of bytes in error.

2- At the reception of a packet at the router; if there is no room, then a packet would be discarded. Since the discarded packet is actually an interleaved packet, therefore only one byte from each source packet (before interleaving) will be lost. Increment each source packet counter by 1.

3- An FEC assumed number that represents FEC ability to correct errors of 0.98 is used. After calling the FEC function to generate a random number say of 0.99, since the obtained random number (0.99) is greater than FEC number (0.98), then the byte is in error and the corresponding source packet counter of this byte is incremented by 1. Now assume the random number is 0.7 then byte is considered correct.

4- For each source packet, check its counter of lost bytes and bytes in error. If this counter is greater than the correction capability of the FEC operation (FEC distance), then the source packet is considered lost and a NAK for this packet is sent to the sender or Rendezvous Point to repeat sending the lost source packet .This is considered as one ARQ trial. If any router fails to receive the packet after all ARQ trials, the packet is considered residually lost. In this paper, ARQ trials of two times are used .

5- At the departure of packets from each router, an extra processing packet delay of ME factor (ξ_3=0.05) or EI factor (ξ_4=0.1) will be added if the router type found to be ME router or EI router respectively.

4. RESIDUAL PACKET LOSS PERFORMANCE MEASURE

The residual packet loss for priority traffic p (p=1,2,3) is given as:

$$\text{Ploss}_p = \left(\sum_{j=1}^{N} PL_{j,p}\right)/N \tag{5}$$

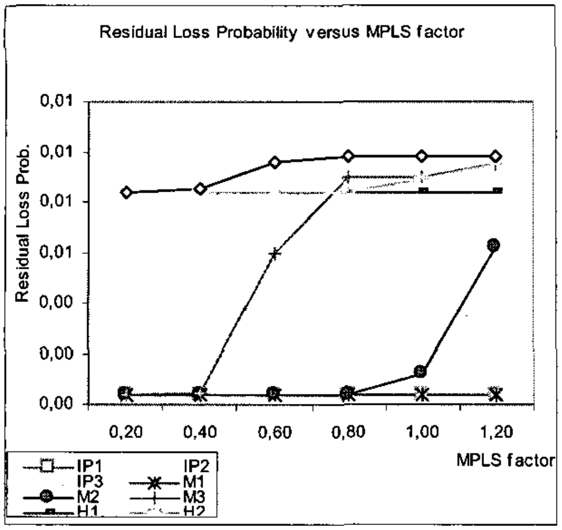
Where N is the total number of routers in the multicast network, $PL_{j,p}$ is router's j average packet loss probability for priority traffic p, which is given as:

$$PL_{j,p} = \frac{\sum_{i=1}^{T} PL_{i,j,p}}{T} \tag{6}$$

Where $PL_{i,j,p}$ is the average packet loss probability in router's j queue for iteration i and for priority traffic p. T is the total number of iterations (multicast packets sent).

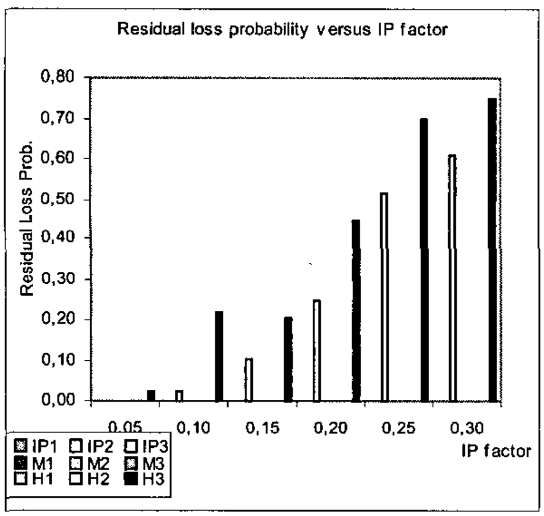
5. SIMULATION RESULTS

Figs. 3 and 4 show the performance comparisons between homogeneous IP network (with each router has IP1, IP2 and IP3 sources), homogeneous MPLS network (with each router has M1, M2 and M3 sources) and heterogeneous MPLS network (with each router has H1, H2 and H3 sources). Fig. 3 shows the residual packet loss probability for all sources versus MPLS factor. It shows that IP sources will have the best performance in terms of residual packet loss probability; on the other hand, the heterogeneous sources will have the worst performance. Fig. 4 shows the residual packet loss probability for all sources versus IP factor. It shows that MPLS sources will have the best performance in terms of residual packet loss probability; on the other hand, the heterogeneous sources will have the worst performance.



$\alpha_1^1 = 0.2, \alpha_1^2 = 0.15, \alpha_1^3 = 0.1, r = 223/255$
$D = 5, B = 30, \xi_1 = 0.2, \tau = 1.2, L = 500$

Fig. 3 Residual loss probability for all sources versus MPLS factor



$\alpha_1^1 = 0.2, \alpha_1^2 = 0.15, \alpha_1^3 = 0.1,$
$D = 5, B = 30, \xi_2 = 0.1, \tau = 1.8$

Fig. 4 Residual loss probability for all sources versus IP factor

6. CONCLUSIONS AND FUTURE WORK

In this paper, we found that when the difference in packet processing time (τ) between IP and MPLS is high and when MPLS factor is small, IP multicast will perform less efficiently than MPLS in terms of residual packet loss probability. However, when this difference in packet processing time is small IP performs very similar to MPLS. In addition to that when MPLS has higher arrival rate due to MPLS trees establishment control overhead and when the processing factor is small, IP would perform better than MPLS.

The study found that when MPLS multicast networks are mixed with some IP routers (heterogeneous network), it will perform less efficiently than homogeneous MPLS multicast networks. In addition, when the IP factor is small, the heterogeneous multicast network will perform less efficiently than IP homogeneous networks.

In addition to that, when using FEC/ARQ there would be a noticeable improvement in the residual packet loss probability for all sources compared to without using FEC/ARQ.

In the near future, other types of heterogeneous networks would be considered.

Acknowledgements

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