Table of Contents

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Priority-Based QoS Mechanism for Multiple Multicast IPTV Streams

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ABSTRACT
Current IPTV mostly operates in dedicated network, which is costly and has limited number of subscribers due to the geographical limitation where subscribers need to be located relatively close to IPTV providers. With a proper Quality of Service (QoS) mechanism of IPv6, IPTV providers can utilize Internet optimally to get more ubiquitous subscribers while maintaining the Quality of Service (QoS). In this paper we propose QoS mechanism based on priority and take into account the number of subscribers. We use IPv6 extension header for QoS structure and queuing and scheduling algorithms to handle the QoS of multiple multicast streams in IPTV network. Our simulation using NS-3 simulator shows acceptable throughput and delay of the proposed mechanism.

Categories and Subject Descriptors
D.4.8 [**Performance**], *simulation.*

General Terms
Algorithms, Measurement, Performance, Design, Experimentation

Keywords
IPTV, IPv6, Multiple Multicast Streams, QoS Mechanism, number of users, IPv6 QoS extension header.

1. INTRODUCTION
A convergence of two prominent network technologies, which are Internet and television network, as known as Internet Protocol Television (IPTV), gains popularity in recent years, as in July 2008 Reuters' television survey reported that one of five American people watched online television [1]. With the availability of higher speed Internet connection, the IPTV becomes greatly supported for better view.

Current IPTV is mostly operated in dedicated network, which is costly and has limited number of subscribers due to the geographical limitation where subscribers need to be located relatively closer to IPTV providers [2]. In order to reduce the operation cost as well as obtaining more ubiquitous subscribers while maintaining the Quality of Service (QoS), a proper QoS mechanism for IPTV network is prominently required.

Getting more subscribers means we need more unique IP addresses. Unfortunately, the current IPv4 address spaces will be running out soon. The solution to this problem is the use of IPv6 protocol. IPv6 not only providing a huge address spaces, but it also has more features, such as security, simple IP header for faster routing, extension header, mobility and (QoS) [3,4]. The use of QoS in IPv6 needs to utilize attributes of flowlable or traffic class of IPv6 header.

Besides delivering IPTV's unicast video on demand (VoD), an IPTV provider also serves multiple channels where each channel sends a multicast stream. On the other hand, IPTV's subscribers may view more than one different channel which can be from the same or different IPTV providers. Therefore, each multicast stream (channel) may have different number of subscribers.

Existing QoS mechanism only considers fix QoS attribute. The QoS attribute is pre-defined and determines the priority of the packet in each intermediate router. Meanwhile, IPTV provider needs to broadcast multiple multicast streams (channels). With regards to the various numbers of users joining multiple multicast streams, then the QoS for each multicast stream would be differentiated appropriately.

The current IPv6's QoS mechanism cannot be implemented on multiple multicast streams, even though it is with the use of Per Hop Behavior (PHB) on each router [5,6,7], because the multicast stream will be treated as a same "quality of service" on each router, regardless the number of users of the multicast stream behind routers. This is due to the fact that routers only refer to a single QoS value of the flowlabel

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or traffic class attributes of IPv6 header for all multicast stream delivery.

This paper proposes a priority-based QoS mechanism to overcome the multiple multicast IPTV stream. The mechanism utilizes IPv6 QoS extension header and QoS algorithm based on priority with considering the up to date number of subscribers. Furthermore, we verify the proposed mechanism through simulation using NS-3 simulator, which focuses on delay and throughput [8,9]. We use 5 mathematical functions/models to exhibit the effects of the various numbers of users to QoS performance. We also implement three probability levels to demonstrate how the proposed mechanism places the packet into an appropriate priority level queue with a probability.

2. THEORETICAL BACKGROUND AND RELATED WORKS

The growth use of multimedia services, which sends streams, need to consider about its QoS which is a form of network performance measurement. In general, QoS measurement parameters include delay, jitter, packet loss rate (or throughput) and bandwidth. This measurement is conducted by conditioning network, easily using differentiated service on certain traffic and chosen users [10].

There are two main types of QoS, which are Integrated Services (IntServ) and Differentiated Services (DiffServ). They employ policies for traffic flowing in the network. IntServ preserves quality of service on end-to-end basis [11], while DiffServ preserves quality of service on Per-Hop-Behavior (PHB) basis. IntServ is not scalable for bigger network, but DiffServ is [12]. IntServ is implemented as flow basis, whereas DiffServ is configured as per hop by hop.

In IPv6 header, QoS element can be defined in attributes of either flowlabel or traffic class. Flowlabel attribute is likely used for defining QoS with IntServ basis determining traffic flow. QoS for DiffServ is defined on DSCP (Differentiated Service Codepoint) in traffic class attribute. This can determine per-hop behavior of a packet travel to source to destination [3]. In multiple multicast streams on which every multicast stream is treated differently for different ubiquitous users.

Based on the policy applied on a router, each incoming datagram can be treated differently. IntServ is too complex to be implemented in which a network should reserve the same quality of service for a datagram travelling from source to destination. In contrast, DiffServ is easier to employ. It can perform as PHB basis, in which a network only reserves the quality of service based on the network condition on each link.

Meanwhile, Imran has evaluated an Italian IPTV with an IP network monitoring and analysis tool. It shows that the Italian IPTV, which encodes high definition television standards into a broadcasted MPEG-2 system streams with about 280 Mbps, has an excellent quality of service with no packet loss and low delay [2]. It is certainly because the bandwidth of the network is very huge and the close distance between the IPTV provider and its users.

The other related work on IPTV's QoS is about multicast tree forms and sizes. Dolev, et al [13] has observed two findings. Firstly, most multicast trees are committed as a form Single Source Multicast (SSM) with Shortest Path Tree (SPT). The other finding is that by observing 1000 multicast clients the sizes of multicast trees are mostly about 6 hops in average [13]. It means that most clients are concentrated and close to the multicast source.

3. PRIORITY-BASED QoS MECHANISM

The proposed mechanism consists of two parts: IPv6 QoS extension header and QoS algorithm based on priority with considering the up to date number of subscribers. We define a QoS value for a packet of a channel in such a way that the more number of users subscribe to the channel/multicast stream, the higher priority we give to that channel. This is to consider fairness among the channels: the most subscribed channel will get highest priority.

3.1 IPv6 QoS Extension Header in Multicast Stream Packet

Each multicast stream's packet of data needs to carry the IPv6 QoS header in order to enable intermediate routers to operate QoS mechanism based on priority. We use the extension header of IPv6 as shown in Figure 1.

IPv6 QoS header, which is derived from standard IPv6 extension header format, maintains an array of QoS structures. QoS structure contains 3 attributes: network address (64 bits), netmask (4 bits) and QoS value (4 bits). Network address attribute is an address of the next link connected to the router. Netmask attribute is used for simplifying the number of QoS structures by masking the same network address in such a way that one autonomous system will be having one QoS structure. QoS value attribute is the value of priority level calculated with formula in Equation 1.

$$QoS_{value} = \left\lfloor \frac{N_{dw}}{N_{tot}} \times N_{priolevels} \right\rfloor \tag{1}$$

Where,

N_{dw} : Number of all users underneath a router.
N_{tot} : Number of total users requesting the streams.
$N_{priolevels}$: Number of QoS priority levels (queues).

N_{dw} and N_{tot} values are computed on the fly. The server will notice all routers to update their N_{dw} and N_{tot} values once new subscribers join or leaving multicast groups. We set 16 (0 to 15) different values for $N_{priolevels}$ for multicast traffic only or 17 values if there is unicast traffic which is placed in the lowest level. The higher value of Npriolevels the higher priority we provide. Based on the QoS_{value}, an intermediate router knows how to prioritize in forwarding an incoming multicast stream packet.

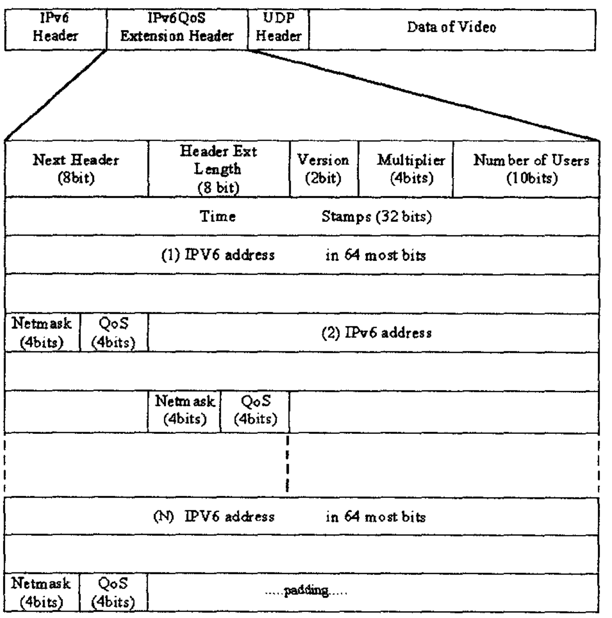

Figure 1. IPv6 QoS Extension Header.

3.2 QoS Algorithm on Intermediate Routers

QoS algorithm works as Queuing and Scheduling algorithm to run a forwarding policy to perform DiffServ. We assume every connected link to a router has different independent queuing and scheduling. Thus, any incoming multicast stream can be copied into several queuing and scheduling process.

The algorithm for queuing and scheduling consists of three parts as follows.

a. Switching and queuing any incoming stream

This process aims to place the stream into appropriate priority level queue by reading the QoS structure in IPv6 QoS extension header. The algorithm for switching and queuing is shown in Figure 2.

When an IPv6 multicast packet comes into a router and its IPv6 QoS header is extracted from the packet, then the capacity of all queues for the next link is checked for availability. If the capacity is full, then the packet is simply dropped. Otherwise, if the capacity is greater than predefined "criteria level", by using a probability with regard to its QoS value for corresponding next link, the packet is either dropped or placed into appropriate priority queue level. The criteria level is determined by network administrator. When the capacity is greater than this criteria level, the algorithm operates the probability mechanism of placing the packet into priority queue level and it is based on its QoS value. The probability works in such a way that a packet with highest QoS value has probability to be dropped, whereas a packet with lowest QoS value has probability to be placed into the lowest priority level queue. If the capacity is less than the criteria level, the packet is immediately put into appropriate priority queue level.

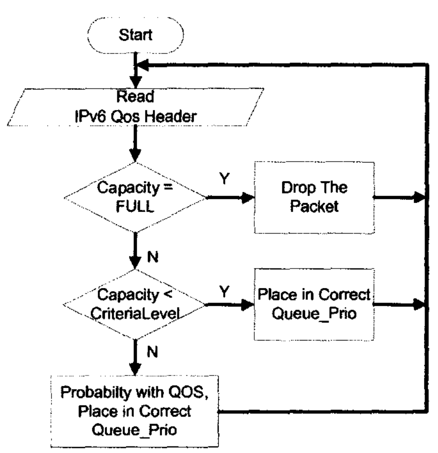

Figure 2. Switching and Queuing Algorithm

b. Queues

Queues consist of N number of priority levels queue. Every level is a queue which can hold incoming multicast stream to be forwarded. The priority levels queue is based on QoS structure (also number of users and multiplier fields) in IPv6 QoS header. These queues are shown in Figure 3.

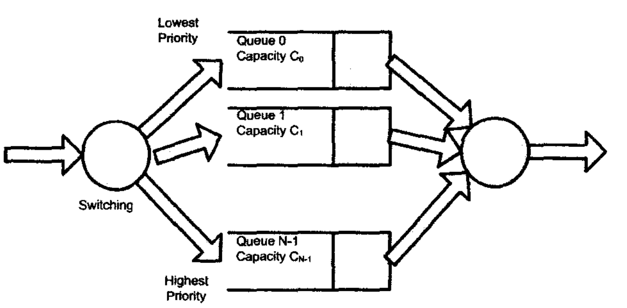

Figure 3. Priority Level Queues

c. Scheduling

Scheduling for datagram forwarding is to select a queue from which a dequeuing process to forward a queued multicast datagram to corresponding link occurs. The algorithm is shown in Figure 4.

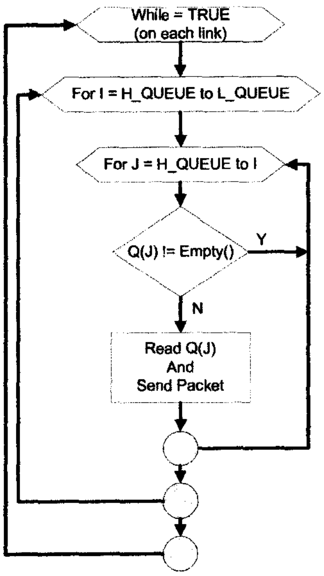

Figure 4. Scheduling Algorithm

The scheduling works by sending one by one packet located from highest priority queue level (H_QUEUE) to the lowest priority queue level (L_QUEUE). The highest queue level has more priority to be sent than the lowest priority queue level. Therefore, more packets are coming out from the highest priority queue level.

4. EXPERIMENTS

The experiments are conducted by using NS-3 network simulator to measure IPTV performance with regard to QoS measurements (delay and throughput). Experiment set up includes configuring network topology, setting up QoS mechanism for each router, and configuring five mathematical function models to represent the models of the numbers of users joining multicast streams. Due to storage limitation we set each simulation experiment is executed for about 6-7 seconds and produces about 2250 packets of data in both unicast and multicast. Running the experiment for 6-7 seconds is not too short, because after 2 seconds the traffic already filled up the queue capacity because we use UDP traffic (not burst traffic) which has constant rate. In other words we can create a queue during the first 2-3 seconds of each experiment.

4.1 Network Topology

The network topology for the simulation is configured as shown in Figure 5. This network topology's tree is with the size of 4 hops, given that the most multicast trees are about 6 hops in average [13].

Each link shown in Figure 5 is configured with 150 Mbps, except those which are for local area network (LAN1, LAN2 and LAN3) and L01. Some links are not necessary, as the multicast tree does not create any "loop".

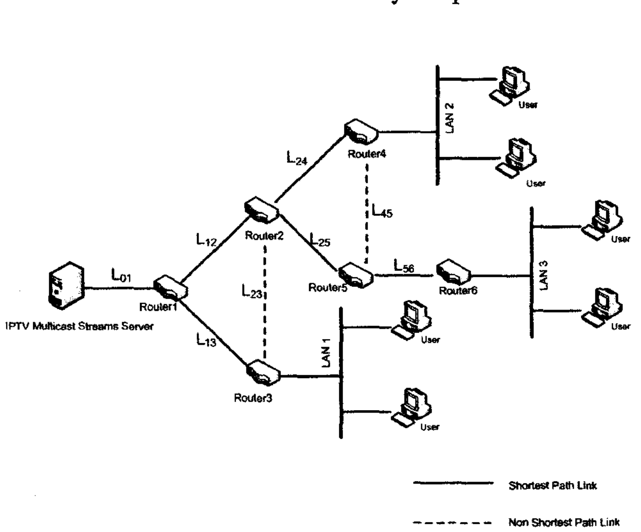

Figure 5. Network Topology

We assume an IPTV Multicast Stream Server generates about 50 multicast streams and 8 unicast traffics to represent IPTV channels and VoDs, respectively. Each multicast stream and unicast traffic is generated as CBR of 3 Mbps. Therefore, the total of bandwidth required to send all traffic is greater than the available bandwidth capacities of links. Consequently, some traffic will not be forwarded by a router.

4.2 Setting Up QoS Mechanism on Routers

Each router in this simulation equips with the QoS algorithm configuration. In addition, we use probability levels to examine the influence probability factor to the QoS performance.

Probability level determines when we start using a probability to place packet of data into priority level queue. When probability level is set to *n*%, it means that if *n*% of total of all queue size is occupied after using priority of QoS value, then the next incoming packet will be placed into an appropriate priority level queue based on probability of its QoS structure. We use three probability levels: 0%, 70% and 100%. Probability level 70% represents a mix between using priority and probability with a tendency to employ priority mechanism. In other words, it is to show that priority is more important than the probability. Meanwhile probability level 0% is merely using probability, whereas probability level 100% is purely implementing priority.

The probability level treats an incoming multicast packet in such a way that a packet with the lowest QoS value has possibility to be placed into queue (lowest priority level).

Accordingly a packet with a highest QoS value has also possibility to be dropped.

4.3 Models of the Numbers of Users

To simplify the evaluation of QoS measurement, the numbers of users for multicast streams are indirectly modeled into five mathematical functions/ models (constant, positive linear, negative linear, positive exponential, and negative exponential). Each model defines how the numbers of users which are represented by QoS priority levels are related to the number of multicast streams. Table 1 shows the five models including the number of multicast streams for each QoS priority level used in our experiment. For instance, the positive exponential model has exponentially increase number of multicast streams (see the 5th column of Table 1): There are no multicast streams with QoS priority level 0,1,2,3,5,7,9,11,13,15. One multicast stream has QoS priority level 4, two multicast streams have QoS priority level 6, and so on. This is the case where the multicast stream with high number of subscribers has a higher QoS priority level.

Table 1. Five Mathematical Function Models for Number of Multicast Streams

QOS Priority Level	Number of Multicast Streams (as mathematical function models)				
	Constant	Positive Linear	Negative Linear	Positive Exponential	Negative Exponential
0	3	0	14	0	24
1	3				
2	3	2	12	0	12
3	3				
4	3	4	10	1	6
5	3				
6	3	6	8	2	3
7	3				
8	3	8	6	3	2
9	3				
10	3	10	4	6	1
11	3				
12	3	12	2	12	0
13	3				
14	3	14	0	24	0
15	3				
Total multicast streams	48	56	56	48	48

5. RESULTS AND ANALYSIS

The graphs in Figures 7, 8 and 9 show the average delay for each multicast channel. We number the multicast channel (we called it multicast address) with order, the bigger the address, the higher the priority.

For the 0% probability level we found that the delay for all multicast addresses are almost same for each subscriber model (see Figure 7).

For 100% probability level, similar result is obtained as for 70% probability level (see Figure 9).

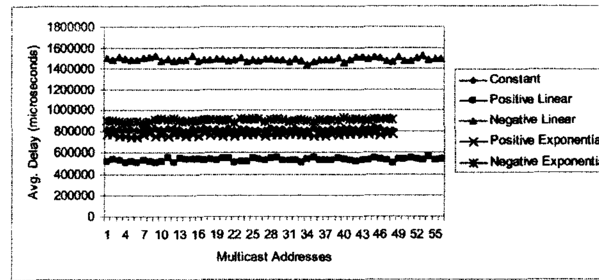

Figure 7. Average Delay of Nodes Receiving Multicast Streams with Probability Level 0%

As for the 70% probability level, average delays are low for higher multicast addresses. It means that queuing and scheduling works well for high number of subscribers (see Figure 8).

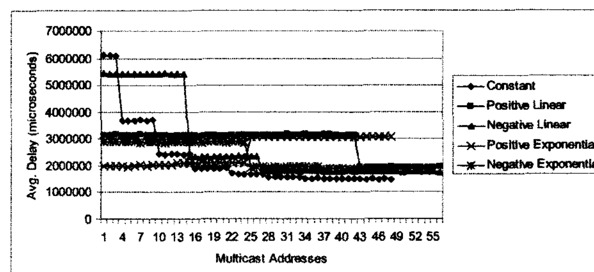

Figure 8. Average Delay of Nodes Receiving Multicast Streams with Probability Level 70%

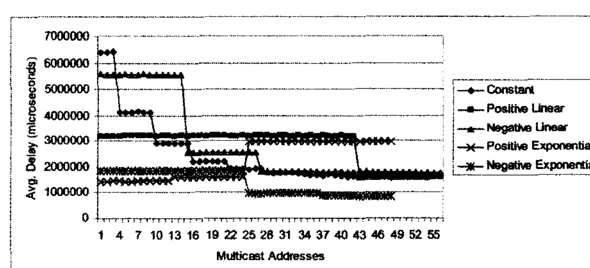

Figure 9. Average Delay of Nodes Receiving Multicast Streams with Probability Level 100%

The graphs in Figures 10, 11 and 12 show the throughput for each multicast channel. We measure the throughput in term of percentage, relative to the actual available bandwidth of the links. We also number the multicast channel (we called it multicast address) with order.

The throughputs of multicast streams for all probability level show similar trend which is constant for all subscriber models except for 100% probability level with negative exponential subscribers model (see Figure 10, 11 and 12). However, the average throughput of 70% probability level is the highest. For 100% probability levels have no throughput for negative and positive exponential models because the queues quickly filled up by multicast streams which always have higher priority.

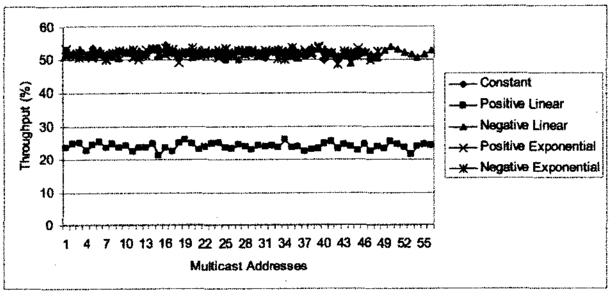

Figure 10. Throughput of Nodes Receiving Multicast Streams with Probability Level 0%

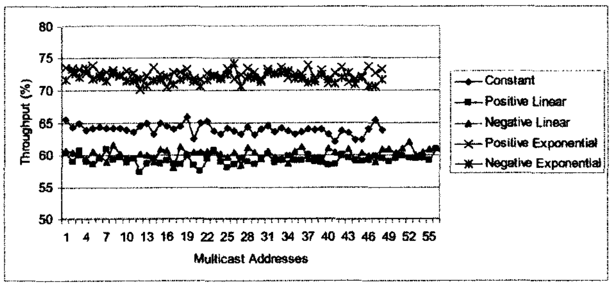

Figure 11. Throughput of Nodes Receiving Multicast Streams with Probability Level 70%

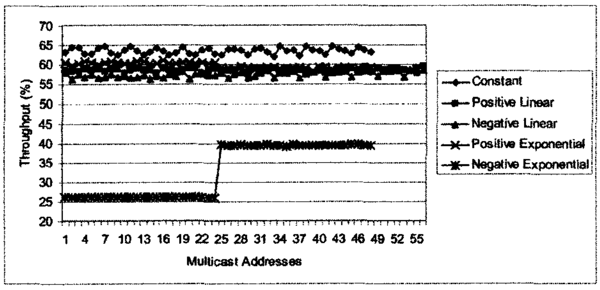

Figure 12. Throughput of Nodes Receiving Multicast Streams and Probability Level 100%

6. CONCLUSION AND FUTURE WORK

The proposed QoS mechanism for IPTV network works well and provides a good performance while still entertain unicast traffic in the network. The QoS mechanism considers number of users as an attribute for determining QoS value in such a way that the multicast streams/channels with different number of subscriber will get a fair priority. With this mechanism, IPTV providers do not need to lease dedicated network for their operation which is in turn reduce their operational cost and at the same time be able to support ubiquitous subscribers while maintaining the Quality of Service (QoS).

The configuration of the experiment is scalable because we can configure the total generated traffic according to the links capacity. As such, this simulation can accommodate recent HD IPTV services which generate more than 1GB traffics.

In our simulation we use CBR for outgoing packet stream. However, due to the various length of QoS extension header, the outgoing datagram is not constant. As such for the future work we plan to simulate dynamic data rate. Another future work is to consider the usage of policy based QoS for simulating multi IPTV providers' environment to provide fairness among the providers.

7. ACKNOWLEDGMENTS

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