PERFORMANCE OF PREMIUM SERVICE IN QOS IP NETWORK

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ABSTRACT

The QoS IP network concept is presently under definition and testing phase. The objective of this network is to provide a variety of communication services to meet multi-service network requirements, as it was effectively made in the case of ATM. This paper investigates, so called, Premium service defined inside the DiffServ architecture and designated for streaming-oriented applications, like audio or video based. The Premium service should guarantee low packet delay as well as low packet losses. Two approaches for providing this service in the network are considered, which are based on PQ (*Priority Queuing*) or WFQ (*Weighted Fair Queuing*) schedulers. Their performances are compared in term of such parameters as maximum jitter, mean packet delay and packet loss ratio. A simplified analysis of Premium service is also included.

1 INTRODUCTION

The present IP-based network uses the IPv.4 protocol and offers packet transfer in *best effort* way. It means that no QoS (*Quality of Service*) parameters are satisfied. Therefore, such network is not so suitable for transferring packets belonging to applications requiring some guarantees with respect to packet delay and packet losses. The excellent examples of such applications are voice or video.

However, introduction of QoS into IP based network requires a new network architecture concept. Currently, the most promising solution forced by the IETF (*Internet Engineering Task Force*) organisation for such architecture is called DiffServ (*Differentiated Services*) [BERNET 99], [BLAKE 98], [NICHOLS 98]. This architecture assumes that the network supports a number of network services with different both QoS objectives and corresponding PHB (*Per Hop Behaviour*) mechanisms. Examples of PHB mechanisms proposed by IETF are EF [JACOB 99] (*Expedited Forwarding*), AF [HEIN 99] (*Assured Forwarding*) and BE (*Best Effort*).

Investigated in this paper Premium service is designated for transferring packets requiring guarantees with respect to such parameters as packet delay and packet loss ratio. This service has been defined by using EF PHB mechanism. Two approaches for providing this service in the network are considered, which are based on PQ (*Priority Queuing*) or WFQ (*Weighted Fair Queuing*) schedulers. Their performances are compared in term of such parameters as maximum jitter, mean packet delay and packet loss ratio.

Organisation of the paper is as follows. Short description of Premium service is included in section 2. The performance of this service is discussed in section 3. After theoretical considerations, some exemplary numerical results illustrating the service performances are presented. Finally, the conclusions are outlined.

2 DESCRIPTION OF PREMIUM SERVICE

For the purpose of multi-service QoS IP-based core network the *DiffServ* architecture is submitted. On the basis of the information carried by the packet header (in the DS codepoint field), the router determines appropriate PHB for the packet service. Three types of the PHB are discussed: EF , AF and BE. The Premium service was designed to guarantee both low packet delay and packet losses. Such QoS objectives are only available by using EF PHB mechanisms.

The Premium service is mainly designated for handling streaming-oriented applications (like audio and video) and, as a consequence, should offer something like "virtual leased line" in the IP-based network, similarly to the role played by the CBR (*Constant Bit Rate*) service in ATM network. For this service, the network should allocate an appropriate volume of bandwidth in each link inside the network. The access to the Premium service should be controlled by admission control on the basis of declarations submitted during set-up phase. Before entering the network, the submitted traffic should pass through the shaper working on the token bucket principle with parameters following the declaration.

In fact, in the near future only two network services are predicted to be implemented in the IP network. To the presently available best effort service will be added the Premium service (or a service with similar QoS objectives) designated for streaming-oriented applications. Therefore, for the purpose of this paper we limit our considerations to the above network scenario.

Exemplary IP network configuration is depicted on Fig. 1. In this network one can distinguish between the access and core sub-networks. The access network attaches the end-terminals to the edge routers (ED), in which are implemented the traffic shapers for the Premium service. The core network, which is rather of wide area type, should transfer packets between the ED routers. The core routers (CR) have no implemented shapers for the Premium traffic, as it is depicted on Fig. 3.

Two approaches for supporting Premium service in the routers are discussed (see Figures 2 and 3):

(1) PQ scheduler: the packets in the router are served on the basis of assigned priority level; in such scheme, the packets belonging to this service are stored in separate queue and served as the first. When the bandwidth allocated for the Premium service in a link is only a small percentage of the whole link bit rate (e.g. 10 %) one can expect in this case rather small packet delay values. On the contrary, by assigning significant link capacity for the Premium we increase packet delay.

(2) WFQ scheduler: the packets in the router are served on the basis of WFQ mechanism with the assigned weight value that is proportional to the allocated bandwidth for the Premium service. On the contrary to the case (1), the packets belonging to the Premium service have now access only to the dedicated bandwidth independently how percentage of this link is.

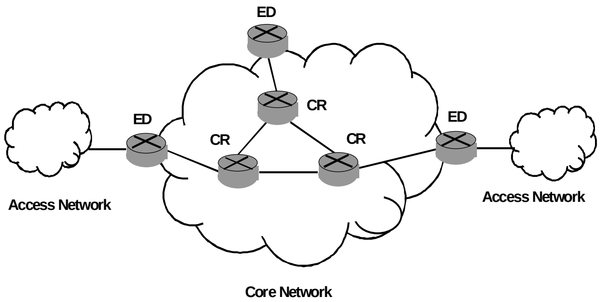

Fig. 1. Exemplary IP-based network configuration: ED- edge router, CR – core router

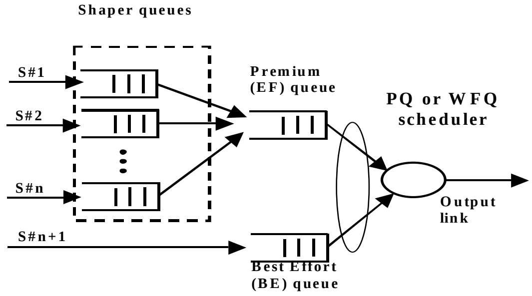

Fig.2 Serving packets from the Premium service in edge router (ED) with PQ or WFQ scheduler; S#i (i=1,2, ...,n) – streams submitted for Premium service, S#n+1- traffic served in best effort way.

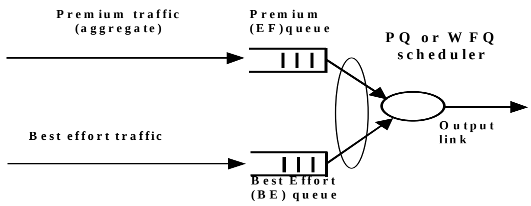

Fig.3 Serving packets from the Premium service in core router (CR) with PQ or WFQ scheduler

As it was stated before, the Premium service requires admission control and specification of the traffic contract. In the case of streaming-oriented applications, such contract is specified by the token bucket parameters that are (PBR, MBT), where PBR is the packet bit rate and MBT is the maximum burst tolerance (usually not greater than 2 packets). These parameters are also for the shaper. The shaping process is illustrated on Fig. 4.

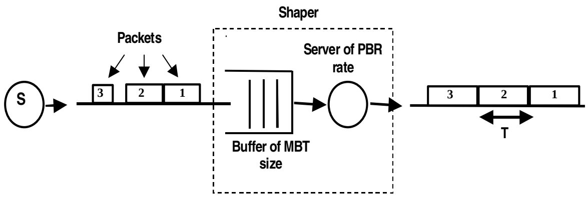

Fig. 4. Illustration of shaping process; S- traffic source, PBR[bps] – peak bit rate, T[sec] = packet_size[bits] /PBR[bps].

3 PERFORMANCE OF PREMIUM SERVICE

In this section we compare two possible implementation of the Premium service, as discussed earlier. For this purpose we assume that the sources emit packets according to their PBR declarations, what means that the traffic submitted to the shaper is transferred to the network without changes. Additionally, the packets generated by the sources arrive to the ED routers exactly in the same time what leads to the *worst case* traffic conditions.

The performance characteristics of the considered service are represented by maximum packet delay (jitter), mean packet delay and packet loss ratio. In the followed experiments we will examine the impact of number of Premium connections and packet length on the above-mentioned QoS parameters. It should be noticed that these parameters are taken into account for the admission control.

3. 1 Premium service using PQ scheduler: theoretical considerations

In this point we present rough analysis of the Premium service using PQ scheduler.

Let us assume that the Premium traffic submitted to the network is emitted by a number of identical sources, each generating constant length packets with PBR value. For this simplified case, for the tested flow we can write the following formula for the maximum expected packet transfer delay, D_{max}:

$$D_{\max}(N) = \sum_{i=1}^{N}((n_i - 1)\frac{PL}{C_i} + \frac{PLBE}{C_i}) \quad (1)$$

where:

N – number of routers along the path though the network for tested flow,

n_i (i=1,..., N) – number of running Premium connections in the i-th router,

C_i [bps] (i=1,..., N) – output link capacity in the i-th router, the tested flow though out,

PLBE [bits] – packet length of the *best effort* traffic,

PL [bits] – packet length of the Premium traffic .

The formula (1) is simplified and determines the upper bound of the packet transfer delay in the case when link bit-rates in the core network are significantly greater than the rate of aggregate flow entering the network and corresponding to the Premium service. Despite this, the formula (1) can be helpful for understanding what we really expect from the Premium service. We stress that the Premium service is well dimensioned when:

$$D_{\max}(N) \le \Delta(N) \quad (2)$$

where

$$\Delta(N) = \frac{PL}{PBR} - \sum_{i=1}^{N}\frac{PL}{C_i} \quad (3)$$

The Δ(N) parameter denotes the maximum allowed cumulative time a packet could spend in consecutive routers waiting for its transmission without disturbing the constant bit rate form of the stream, as it is illustrated on Fig. 5. When the (2) is satisfied than the Premium service offers “virtual leased line”, otherwise some additional mechanisms similar to these developed for the CBR service (like playback buffer mechanism) [ABE 99] should be implemented in the destination edge router for compensation jitter introduced by the network.

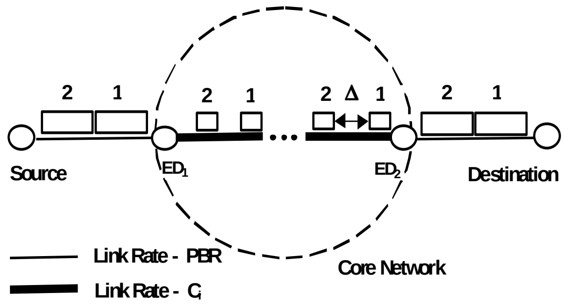

Fig. 5. Packet timing structure edge-to-edge.

Below we will show a simplified analysis of the Premium service based on the equations (1), (2) and (3). For this purpose let us assume that the Premium service traffic is equally distributed inside the core network of the full mesh structure with identical inter-router links, each of capacity C.

By simplifying (1) and (3) with additional (but realistic) assumption that N*PLBE/C << D_{max}(N) we have:

$$D_{\max}(N) \cong N*(n-1)*PL/C\,, \qquad (4)$$

$$\Delta(N) \cong PL/PBR - N*PL/C\,. \qquad (5)$$

Next, applying (2) we receive:

$$PBR*n = PT_{AG} \leq C/N\,, \qquad (6)$$

where PT_{AG} is the aggregate flow traffic emitted by single ED into the network.

Expression (6) says that for transferring given PT_{AG} traffic through the network with N hops, the necessary link capacity in the inter-router links should be not less than PT_{AG} * N. As a consequence, in the case of N=10 hops the maximum capacity dedicated for the Premium service is 10% of whole link capacity.

The condition (6) can be a bit relaxed if we assume a level of packet losses (P_{loss}). Now we have:

$$PT_{AG} \leq \frac{C}{N*(1-P_{loss})}\,. \qquad (7)$$

The above considerations can be prolonged for the case when Premium service is implemented using WFQ scheduler. As one can conclude, in this case it is practically impossible to satisfy the equation (2) keeping high bandwidth utilisation dedicated by the scheduler to serve Premium traffic.

3.2 Numerical results

In this section we will present some numerical results illustrating the performances of two implementation scenarios of Premium service:

- case no.1: Premium traffic is served in routers with the highest priority using PQ scheduler,
- case no.2: Premium traffic is served in routers using WFQ mechanism with strictly dedicated bandwidth (determined by assigned weight value).

The assumed tested network topology is very simply and consists of single ED router fed by the traffic generated by a number of Premium sources (see Fig.6). The reasons for choosing such network configuration are as follows:

- We can restrict our considerations to the Premium traffic only; in fact, the impact of other traffics carried by the network on the quality of Premium traffic is limited. For instance in the case no.1, additionally the service time of single packet serving with other PHB can extent the considered delay packet characteristics only (see formula (1)). In the case no. 2, WFQ algorithm suffers the flow isolation.
- For the Premium service performances, the case of ED router is more rigorous that the case of CR router [FUDA 00].

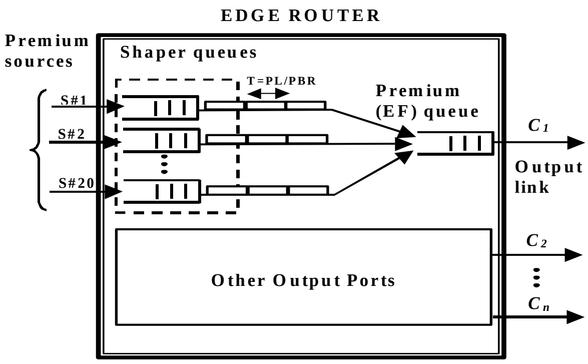

Fig. 6. Assumed tested configuration: PL – Packet Length (in bytes), PBR – Peak Bit Rate (in bps), C_i (i=1,...,n) – i-th output link rate (in bps), T=PL/PBR (in sec)

For the experiments the following traffic conditions were assumed:

- The Premium service is dedicated for a specified application, so the traffic submitted to this service is generated by homogenous sources;
- The application is voice over IP; each source emits traffic with parameters (PBR=27 kbps, PL=k* 68 bytes), k=1 or 2;
- Link capacity (C_1) is 2 Mbps and for the Premium service dedicated bandwidth is 567 kbps (27.6% of link capacity); therefore, the maximum number of running connections is 21;
- Number of running connections is limited to 20 (to avoid overload conditions for the case no.2);
- Packets generated by each Premium source arrive to the ED router in the same time.

The performance characteristics are represented by maximum delay (D_{max}(.)), mean packet waiting time (m) and packet loss probability (P_{loss}). Notice that D_{max} (.) is equivalent to the packet delay jitter. The numerical results were received under assumption that the Premium sources are synchronised and each of them starts to emit packet in the same time. These are the worst case conditions.

Case no.1: Premium traffic is served in router with the highest priority

The obtained results for the case no.1 are shown in Tables 1 and 2. Two options are assumed for the packet length, PL=68 bytes and PL= 136 bytes.

Tab.1 : The obtained results for the case no.1 : PBR = 27 kbps, PL = 68 bytes

Buffer size (k*68bytes)	Mean packet delay [ms]	Maximum packet delay jitter ($D_{max}(1)$) [ms]	Packet loss prob. (P_{loss})	Number of hops for $D_{max}(N) \leq \Delta(N)$
20*68	2,58	5,17	0	3
18*68	2,45	4,90	0,05	3
16*68	2,18	4,35	0,15	4
14*68	1,90	3,81	0,25	4
10*68	1,36	2,72	0,45	6
4*68	0,54	1,09	0,75	14

Tab.2 : The obtained results for the case no.1 : PBR = 27 kbps, PL = 136 bytes

Buffer size (k*136 bytes)	Mean packet delay [ms]	Maximum packet delay jitter ($D_{max}(1)$) [ms]	Packet loss prob. (P_{loss})	Number of hops for $D_{max}(N) \leq \Delta(N)$
20* 136	5,17	10,34	0	3
18*136	4,90	9,79	0,05	3
16*136	4,35	8,70	0,15	4
14*136	3,81	7,62	0,25	4
10*136	2,72	5,44	0,45	6
4*136	1,09	2,18	0,75	14

On the basis of the presented results one can conclude as follows:

- The required buffer size to avoid packet losses is equal to the number of running connections multiplied by packet length; therefore, the maximum jitter value is proportional to the maximum buffer size;
- The maximum as well as mean packet delay are proportional to the packet length;
- Decreasing buffer size leads to significant growing of packet loss ratio.

Case no.2: Premium traffic has dedicated (isolated) capacity on the outgoing link

The obtained results for the case no.2 are included in Tables 3 and 4.

Tab.3 : The obtained results for the case no.2 : PBR = 27 kbps, PL = 68 bytes

Buffer size (k*68 bytes)	Mean packet delay [ms]	Maximum packet delay jitter ($D_{max}(1)$) [ms]	Packet loss prob. (P_{loss})	Number of hops for $D_{max}(N) \leq \Delta(N)$
20*68	9,11	18,23	0	1
18*68	8,63	17,27	0,05	1
16*68	7,68	15,35	0,15	1
14*68	6,72	13,43	0,25	1
10*68	4,80	9,59	0,45	1
4*68	1,92	3,84	0,75	4

Tab.4 : The obtained results for the case no.2 : PBR = 27 kbps, PL = 136 bytes

Buffer size (k*136 bytes)	Mean packet delay [ms]	Maximum packet delay jitter ($D_{max}(1)$) [ms]	Packet loss prob. (P_{loss})	Number of hops for $D_{max}(N) \leq \Delta(N)$
20* 136	18,23	36,46	0	1
18*136	17,27	34,54	0,05	1
16*136	15,35	30,70	0,15	1
14*136	13,43	26,86	0,25	1
10*136	9,59	19,19	0,45	1
4*136	3,84	7,68	0,75	4

The results from the Tab.3 and 4 say that in the considered case of Premium service implementation one can expect essentially greater delay values than for analogous traffic conditions in the case no.1. (compare Tables 1 and 2). This effect was expected since now the Premium service has dedicated and isolated bandwidth. Notice, that now the allowed number of hops in the network is essentially limited, as it was indicated by theoretical analysis provided in section 3.1.

4 CONCLUSIONS

The Premium service in the future QoS IP network is dedicated for guaranteed bandwidth traffic with similar requirements as supported by CBR service in the ATM network. The paper examined two approaches for building such service, using different accessible in the routers scheduling mechanism from the point of view of the service performances. The first approach assumed that the Premium traffic is served with the highest priority with limitation for the maximum bandwidth from the link designated for this traffic. On the contrary, in the second investigated approach an isolated bandwidth was dedicated for the Premium service. As it was expected the first analysed approach gives much better results with respect to such parameters as mean and maximum packet delay and the same level of packet loss probability and number of allowed hops in the network. On the basis of the obtained, theoretical and exemplary included numerical results, the solution for the considered service based on WFQ scheduler is limited. On the other hand, assuming PQ scheduler the volume of submitted Premium traffic is bounded by the number of hops in the network and bit rate of inter-router links.

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