Paper

The IP QoS System

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Abstract—This paper shortly describes the IP QoS System which offers strict quality of service (QoS) guarantees in IP-based networks and supports a number of, so called, classes of services. Such solution requires to implement in the network a set of QoS mechanisms and algorithm working on packet, connection request and provisioning levels. Furthermore, we require signaling system for informing the network about new connection request and network resource allocation capabilities for providing required resources to given connection. The IP QoS System is based on the next generation networks (NGN) and differentiated services (DiffServ) architectures and, at least for now, it is designed for single domain only.

Keywords—classes of service, DiffServ, multi-service networks, NGN, quality of service.

1. Introduction

The current Internet is working under TCP/IP protocol stack and is based on two main fundamentals, which are: the network offers only one class of service named best effort service, and the network resources are overprovisioned as possible in order to minimize packet losses and packet delays. As a consequence, the Internet providers aimed at providing to the users as fast as possible packet transfer but they are far from guaranteeing, so called, strict quality of service (QoS) that is measured by the maximum allowed values of such parameters as IP packet transfer delay (IPTD), IP packet transfer delay variation (IPDV) and IP packet loss ratio (IPLR).

On the other hand, the network capabilities of packet transfer determine the range of applications the users may use with appropriate satisfaction. The lack of guaranteeing strict QoS for packet transfer constitutes the main barrier in introducing, e.g., streaming applications as video on demand (VoD), voice over IP (VoIP), video teleconference (VTC) or e-health teleconsultations. In addition, the network operators may get additional profit if they are able to offer strict QoS instead best effort connections. Concluding, the QoS in the Internet is strongly required for its further evolution.

The recognized approach for guaranteeing strict QoS in IP-based network is the DiffServ architecture [1], [2], [3], [4]. The activities corresponding to this architecture started about 10 years ago and some prototypes were developed, e.g., by European projects. A good example is the AQUILA project [5], [6], [7], [8], which prototyped and tested the system based on DiffServ architecture. The IP QoS System that was recently prototyped and tested in Poland follows the solution from AQUILA project and enhanced it by using the elements from next generation network (NGN) architecture.

The attractiveness of the DiffServ architecture is mainly caused by:

- it allows to provide a number of classes of service differing in handling of traffic profiles as well as in QoS guarantees,
- each classes of service is designed for handling traffic generated by some types of applications,
- per flow handling is necessary only in the border routers while the core routers see only aggregated flows,
- it is a good example of scalable architecture.

In fact, the DiffServ architecture was designed for a single domain but we can observe the activities for extending this architecture for the whole network, as e.g. in EuQoS project [9], [10], [11].

The organization of the paper is the following. In Section 2 we describe the mechanism we need to introduce in the network in order to guarantee strict QoS for packet transfer. The IP QoS System is presented in Section 3. Section 4 concludes the paper.

2. Mechanisms and Algorithms Required to Guarantee Strict QoS in the Network

In order to guarantee a quality for transfer of packets emitted by an application to the network, we need to apply a set of mechanisms, named QoS mechanisms, and algorithms that operate at different levels in the network. These mechanisms and algorithms we can classify to the following categories:

- for handling packets in the routers (time scale – miliseconds),

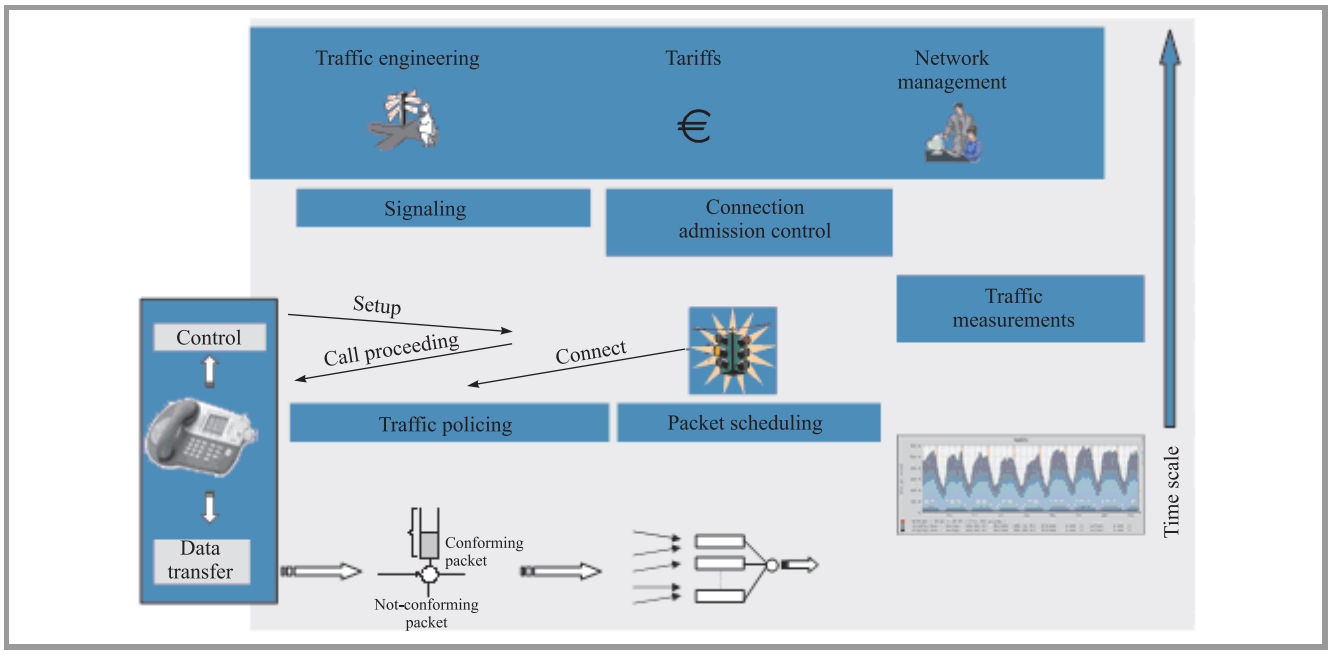

Fig. 1. Required mechanisms and algorithms in the network for providing QoS.

– for establishing/releasing the connections (time scale – seconds or minutes),

– for network dimensioning (time scale – hours or days).

These new set of mechanisms are shown in Fig. 1.
In this section, we briefly describe each of the above group of mechanisms and algorithms.

2.1. QoS Mechanisms at the Packet Level

In order to guarantee strict QoS for a given packet stream, we need to assure its adequate handling in routers. A set of available QoS mechanisms at the packet level is named as per hop behavior (PHB) mechanisms. This set contains such mechanisms as:

– classifier for distinguishing between packets belonging to different classes of service and for sending packets to appropriate path of handling,

– policer for monitoring contracted traffic profile,

– optionally, marker for indicating not conforming packets (they may be discard or send if allowed link capacity, depending on applied algorithm),

– scheduler for managing access to the link when more than one packet in the queues,

– shaper for shaping traffic, if it is needed.

Thanks to the above mechanisms, we may send a packet before the another ones even if this packet arrived later to the system.

2.2. QoS Mechanisms at the Call Level

When a new connection request is sent to the network, first of all we need is to check if we have enough spare network resources for establishing new connection with assuring adequate QoS. The new request is submitted to a given class of service, for which we have earlier, during provisioning phase, allocated an amount of resources. The resources dedicated to a class of service are the buffer size and the link capacity in each output link in the routers. So, we check the availability of spare resources using connection admission control (CAC) function. In general, CAC is a function of such parameters as number of running connections, already accepted volume of traffic (declared or measured), network resources allocated to the class of service and the traffic declarations of new request.
It is worth to mention that performing CAC function is the fundamental for assuring strict QoS. It allows us to control volume of traffic in the network and to avoid network overloading. Unfortunately, this means that some of new requests may be rejected. In addition, for performing CAC we require to implement a signaling system in the network.

2.3. Resource Provisioning (Traffic Engineering)

In a classical approach, before performing CAC function we need to allocate network resources (link capacities, buffers) for all supported classes of service. In addition, we need to specify the nodes in the network, in which we perform the CAC. It would be not practical case to perform CAC in all routers on the path between source and destination since in the case of Internet we have too many connections running in parallel and, as a consequence, the signaling traffic is too high. So, the reasonable solution is to select the routers when the CAC is performed (the best is minimize

the number of these routers) and to overprovision the rest of the network.

3. IP QoS System

In this section we present some details about the IP QoS System that we have recently prototyped and tested in Poland.

The IP QoS System is a proposal for assuring strict QoS guarantees in a single domain network. It follows the DiffServ and NGN architectures [12], [13] and [14]. The architecture of the system is depicted in Fig. 2. It assumes

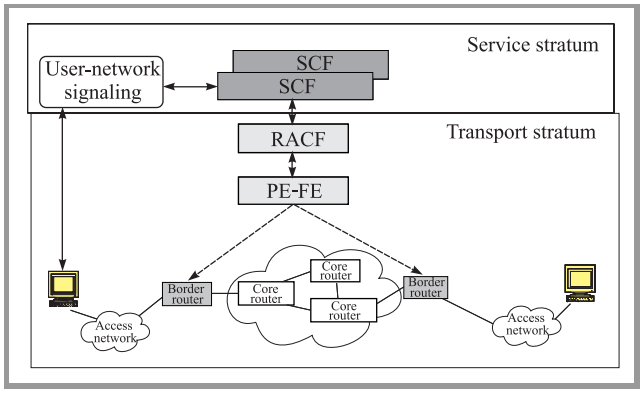

Fig. 2. The architecture of the IP QoS System.

two meta-layers that are: service stratum responsible for service management, and transport stratum responsible for packet transfer in the network. The functions performed by service stratum are called as service control functions (SCF) while the functions performed by transport stratum are resource and admission control function (RACF) as well as policy enforcement functional entity (PE-FE) for setting PHB mechanisms in the border routers.

Figure 3 shows the scenario for establishing connection in the IP QoS System. For establishing the connection, the user/the application sends its request to the network (message "1"). This request is handled by the application server. Next, this request is further send to the server responsible of resource management (message "2"), which checks if the required resources are available. When we have sufficient volume of resources, then it sends the messages to the border routers (messages "3" and "4") for the purpose of tuning

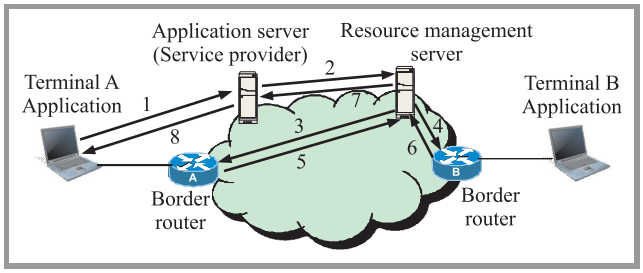

Fig. 3. Scenario for establishing connection in the IP QoS System.

the PHB mechanisms (classifier, policer). After the positive answers from the border router are received (messages "5" and "6"), then the resource management server sends the acknowledge message (message "7") to the service server. Next, this server sends the information to the users/the application of setting the required connection (message "8"). It is essential for the DiffServ architecture that the per-flow operations are performed in the border routers only while in the core routers the operations are performed per aggregated flows.

The details about the control access to the network resources one can find in [14].

3.1. Traffic Management in the IP QoS System

In order to guarantee strict QoS we establish a number of specialized classes of service [8], [15] in the IP QoS System. The term "class of service" expresses the network capabilities to transfer traffic according to a priori specified conditions with respect to maximum allowed values of parameters IPTD, IPDV and IPLR. The IP QoS System supports the classes of service in a single domain network between each pair of the border routers. A given type of application submits its packet stream to a predefined class of service. The classes of service are regarded as globally well known. Since in the IP QoS System the classes of service are supported only in a single domain, we define them in the context of the "end to end" classes of service as specified for multi-domain network and described in [4], [15]. In particular, in the area of a single domain, in one class of service we can merge a number of "end to end" classes of service with similar QoS guarantees. Table 1 shows the list of the classes of service implemented in the IP QoS System with its characteristics of QoS guarantees that are expressed by the maximum allowed values for IPTD, IPDV and IPLR.

Let us recall that in order to establish a given class of service in the network we need:

- to set the values of parameters of the PHB mechanisms that is necessary for assuring adequate handling of submitted traffic and isolation between traffic belonging to different classes of service,
- to allocate an amount of network resources for this class,
- to apply adequate CAC algorithm to control volume of submitted traffic.

In the IP QoS System we perform CAC function only in the ingress border routers while the core network is overprovisioned as it is shown in Fig. 4. It means that the packet delays and the packet losses in the core should be significantly less comparing to the packet delays and losses in the ingress border routers. The above is true only when traffic carried by the network is closed to this allowed by the CAC function. If submitted traffic is rather low then the packets crossing the ingress border routers also experience low

Table 1
Mapping between types of applications jointly with "end to end" classes of service and classes of service in the IP QoS System, QoS guarantees and traffic profiles

Type of application	Classes of service "end to end"	Classes of service in the IP QoS System	QoS requirements			Traffic profile
			IPLR	IPTD (mean value)	IPDV	
VoIP	Telephony	Real time (RT)	10^{-3}	100 ms	50 ms	(PBR, PBRT)*
Interactive games	RT interactive					
Video on demand	MM streaming	MM streaming	10^{-3}	1 s (not critical)	Not critical	(PBR, PBRT)
File transfer protocol (FTP)	High throughput data	High throughput data (HTD)	10^{-3}	1 s (not critical)	Not critical	(PBR, PBRT)
	Standard	Standard (STD)	Not critical	Not critical	Not critical	Arbitrary

* peak bit rate (PBR), peak bit rate tolerance (PBRT), parameters of the token bucket mechanism.

losses and delays comparing with assumed QoS guarantees. Notice that the assumption about core overprovisioning is not critical since in the core we do not perform CAC and, what is also important, usually the link capacities of the core links are rather higher comparing to the link capacities in the access. Furthermore, such overprovisioning we do not have to do for standard class of service.

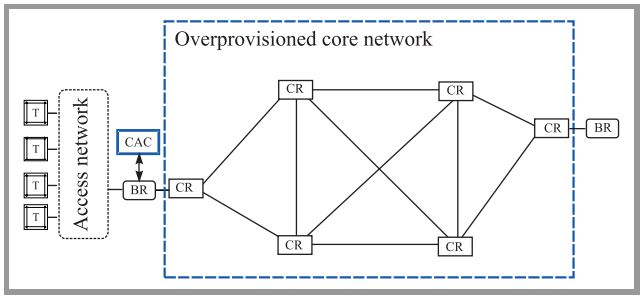

Fig. 4. Traffic management in the IP QoS System: BR – border router, CR – core router, T – terminal CAC – function responsible for admitting/rejection of new connection request.

Now, we explain the rules we have assumed for the network dimensioning. For the sake of simplicity, let we take into account network when traffic offered to classes of services guaranteeing QoS (all classes except STD one), in the further part of the text called as QoS classes of service (or QoS traffic), for all relations ingress-egress border routers is the same and all attached border routers are connected to the core with the links of the same capacity, say C. So, in order to assure core overprovisioning, for QoS traffic we can take part of capacity C, named C_{QoS} ($C_{QoS} < C$) as it is illustrated in Fig. 5. Furthermore, we need to decide which types of connections we have in the system. We can consider two alternative solutions. The first solution is to maintain "point to point" connections between a pair of ingress-egress border routers with allocated link capacities between them. Unfortunately, such approach leads to

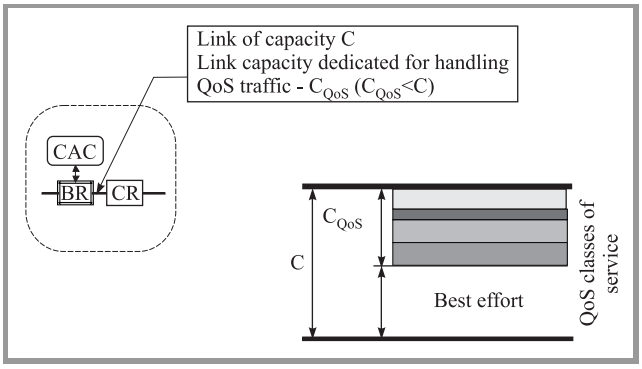

Fig. 5. The partitioning of the link capacity between the border and core routers among the classes of service and STD class of service.

partitioning of the link capacity connecting given ingress border router with core (the link of capacity C_{QoS}) between the directions to the rest of the egress border routers. As a consequence, in the case of temporal QoS traffic fluctuations with respect to which egress border router traffic is submitted, we can expect high level of new connection request losses. Apart this, when we distribute the link capacity between too many directions we lost multiplexing gain. The alternative solution is to maintain the connections "point to any". In this case, we allocate the whole capacity C_{QoS} to handle QoS traffic submitted to a given ingress router without distinguishing the target egress border routers. Such approach is applied in the IP QoS System as illustrated in Fig. 6.

Figure 7 shows a simple example with two ingress and two egress border routers illustrating the applied rule for overprovisioning the core. If we allocate C_{QoS} capacity on the link connecting given ingress border router with the core, then we need to allocate the C_{QoS} capacity on each path connecting this ingress border router to all egress border routers. Of course, such approach leads to the overpro-

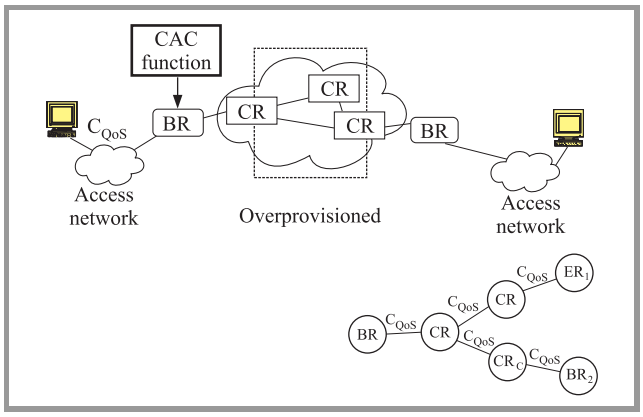

Fig. 6. The concept of the overprovisioning of the core.

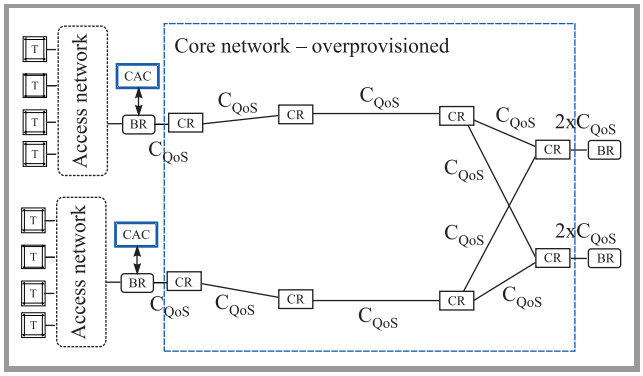

Fig. 7. Example of core overprovisioning in the case with 2 ingress border routers and 2 egress border routers.

visioning of the core. On the other hand, for the incoming traffic to a given egress border router we need to have $(N-1)$ C_{QoS} link capacity, when N border routers are connected to the core. In order to increase this capacity, we need to apply the CAC also in the egress border routers.

4. Summary

The paper provided an overview of the IP QoS System, its architecture and applied approach for traffic control and traffic engineering. The IP QoS System provides strict QoS guarantees by supporting a number of QoS classes of service. Comparing to best effort network, it requires to implement new mechanisms and algorithms at the packet, call request and network provision levels.

The System IP QoS is currently prototyped and tested. Its application to the network depends on the network operators.

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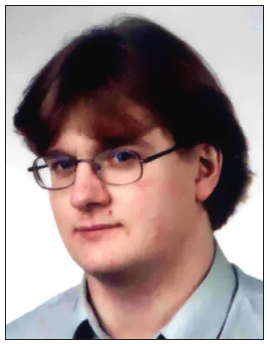

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