Paper

A comparison of ATM and IP QoS network capabilities for handling LAN traffic with QoS differentiation

Andrzej Bęben, Wojciech Burakowski, and Piotr Pyda

Abstract — Now, a network operator must choose between two packet switched technologies for providing QoS in WAN networks, which are ATM and IP QoS [3, 4, 9]. As ATM has reached the maturity with capabilities for offering a number of different network services (i.e. CBR, VBR, ABR, UBR, GFR), the IP QoS with network services like expedited forwarding, assured forwarding, etc. is still at developing phase but nevertheless is commonly regarded as capable to guarantee in near future similar QoS level as ATM. This paper tries to compare the efficiency of the mentioned technologies (in case of IP QoS network the AQUILA network concept [1, 2] is investigated) for handling traffic generated by LANs with QoS differentiation. This is extremely required since the applications running in LAN differ in QoS requirements and emitted traffic profiles (streaming, elastic). Therefore, a classification process of outgoing LAN traffic into predefined sub-streams should be performed at the entry point to WAN network (edge ATM switch or IP router). Furthermore, particular sub-streams are submitted to adequate WAN network service, available in ATM or IP QoS. The paper presents the experimental results, measured in the test bed, corresponding to QoS level and QoS differentiation provided by ATM and IP QoS core. For this purpose, a set of representative applications currently available to a LAN user was selected demanding from the core different QoS level. They correspond to streaming applications like VoIP with QoS objectives represented mainly by packet delay characteristics and elastic applications controlled by TCP protocol with minimum guaranteed throughput/goodput as target.

Keywords — traffic control, IP QoS, asynchronous transfer mode.

1. Introduction

A variety of applications in a LAN environment is now available. Apart from traditional data computer oriented applications with data transfer controlled by transmission control protocol (TCP), like file transfer protocol (FTP), Telnet, e-mail, world wide web (WWW), a user would also like to use new Internet applications, like voice over IP (VoIP), videoconferencing, etc., which are based on transferring voice or/and video. Let us remark that data transfer usually tolerates even large packet delays and, therefore, can be effectively served by e.g. IP best effort network. On the contrary, for satisfying users, the voice/video should be transferred with low packet delay and low packet losses. As a consequence, the packet flow outgoing from a LAN becomes heterogeneous with respect to quality of service (QoS) requirements for packet transfer in WAN network. Therefore, a WAN network should have capability for providing QoS differentiation. This directly leads to offering by network a number of network services (NSs), differing in QoS objectives. For instance, the file transfer should be handled by a NS aimed at throughput guarantees, while voice transfer demands a NS guaranteeing low packet delay and low packet losses.

Currently, two network technologies offering a set of NSs are available, that are ATM [7, 8, 9] and IP QoS [3, 4]. The ATM currently offers 6 native ATM NSs, i.e. constant bit rate (CBR), real time variable bit rate (rt-VBR), non-real time variable bit rate (nrt-VBR), unspecified bit rate (UBR), available bit rate (ABR), guaranteed frame rate (GFR). Each of them is designated for handling specified type of traffic (streaming, elastic) with assumed QoS objectives (concerning to cell/frame loss and/or delay) and has its own traffic control rules (traffic contract specification and policing, admission control). Among them, the UBR service only does not require traffic flow control mechanisms, since was designed as a best effort service. The rest of NSs provides QoS guarantees and requires the user to make some traffic declarations during set-up phase.

Let us remark that ATM NSs were specified with paying attention rather on types of possible traffic occured in the network while with loosely focus on the traffic generated by applications. As a consequence, since applications available in LANs are IP-oriented, a mapping between IP and ATM is needed, covering such aspects like QoS and traffic contract definitions (between packet and ATM cell level), encapsulation, connection set-up, etc.

An alternative for ATM is the IP QoS concept, which is regarded as more promising solution for seamless inter-working with IP-based applications. For the IP QoS two architectures were proposed: (1) integrated services (IntServ) [4] and (2) differentiated services (DiffServ) [3]. As IntServ architecture suffers from scalability and can be implemented in rather small networks, DiffServ approach suits well for building WAN networks. Therefore, we focus on DiffServ network concept, more specifically on its representative implementation provided inside AQUILA IST European project [1, 2]. For now, four types of packet flows have been recognised as typically emitted by applications available to a LAN user and requiring QoS guarantees. They are as follows: (1) streaming constant bit rate (e.g. VoIP), (2) streaming variable bit rate (e.g. video applications), (3) elastic, produced by greedy long-live TCP or TCP-like sources (e.g. FTP), and (4) elastic, non-greedy short-live TCP sources (e.g. WWW). In this spirit, four QoS NSs have been defined and implemented in AQUILA: premium CBR (PCBR) for traffic (1), premium VBR (PVBR) for traffic (2), premium multimedia (PMM) for traffic (3), and premium mission critical (PMC) for traffic (4). Each network service is optimised for specific type of packet flows and has its own traffic control mechanisms, including admission control. In addition, standard (STD) service for best effort traffic is also provided. Obviously, one can find some similarities between NSs available in ATM and IP QoS (AQUILA). Anyway they differ in this that ATM NSs operate on cells (53 bytes packets) while NSs in IP QoS take into account packets of different length. This gives rather some advantages for ATM due to better multiplexing and simplest switching.

The investigated network is ATM/IP QoS core interconnecting a number of LAN Ethernet networks, as depicted in Fig. 1. The core offers different NSs, according to used technology. Let us assume that a LAN user is interested in getting adequate QoS from the network depending on the type of application he uses. This can be achieved only by traffic classification mechanism implemented in the edge device (edge router or edge ATM switch) and, furthermore, submitting selected traffic flow to appropriate NS, available in the core.

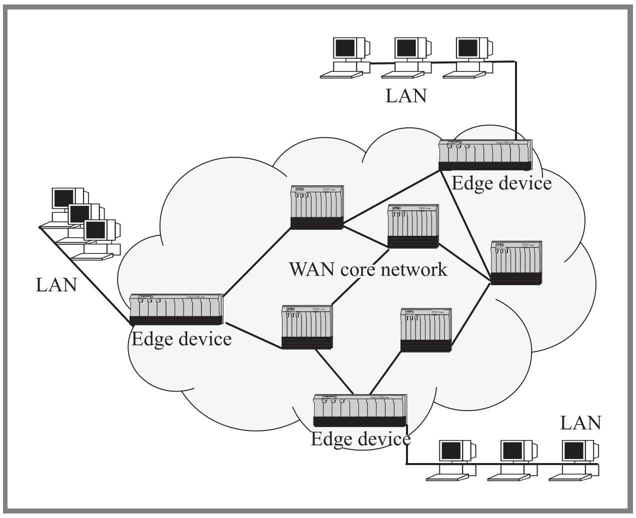

Fig. 1. Network architecture.

The paper presents the experimental results, measured in the test bed, corresponding to QoS level and QoS differentiation provided by ATM/IP QoS core. For this purpose, a set of representative applications currently available to a LAN user was selected demanding from the core different QoS. They correspond to streaming applications like VoIP with QoS objectives represented mainly by packet delay characteristics and elastic applications controlled by TCP protocol with minimum guaranteed throughput/goodput as target.

The paper is organised as follows. Characterisation of traffic profiles and QoS demands corresponding to applications available in LAN is presented in Section 3. Section 2 summarises network services available in ATM and IP QoS and compare them from the point of view of supported traffic profiles and QoS objectives. Furthermore, Section 4 introduces us to mapping rules of LAN traffic into network services with associated mechanisms like traffic classifiers, shaper and schedulers. The measurement results, showing effectiveness of ATM and IP QoS network services for handling LAN traffic with QoS differentiation are included in Section 5. Finally, Section 6 summarises the paper.

2. Types of applications in LAN

Now, a LAN user has access to a variety of applications. Table 1 shows proposed classification of applications with respect to QoS requirements [5, 6, 9] and type of emitted traffic. It assumes four types of applications classes, which are:

- Class 1: emitting elastic sporadic traffic, e.g. WWW, e-mails, etc. The applications send short messages with data flow controlled by TCP. A user is interested in short transfer time/transaction time.

- Class 2: emitting elastic bulk traffic, e.g. file transfer by FTP. The data transfer lasts relatively long (say minutes). A user wants to transfer the file in predictable time interval.

- Class 3: emitting streaming variable bit rate, e.g. video, VoIP. A user is satisfied with such application if no significant packet transfer delay and packet loses will occur. For instance, in the case of VoIP similar QoS is expected as in telephone network.

- Class 4: emitting streaming constant bit rate, e.g. virtual leased line (VLL). In this case, a circuit emulation service is required.

Concluding, a user is satisfied with applications available in LAN if the core network would guarantee adequate quality of packet transfer. This can be achieved by best effort network but only if it is significantly over-dimensioned. Other solution is to support by core a number of NSs, each of them supporting QoS level appropriate for given application.

Table 1
Application classes

Applications	Required bit rate [kbit/s]	QoS requirements		Application class
		allowed packet transfer delay	allowed packet loss rate	
WWW	Up to 100	Medium	Low	Elastic sporadic traffic
E-mails	Up to 50	High	Low	
Chatting	A few	High	Low	
Telnet	A few	Medium	Low	
Data base access	A few	High	Low	
FTP	Up to 1 000	High	Low	Elastic bulk traffic
Virtual reality environment	Up to 128	Medium	Low	Streaming variable bit rate
Video on demand	Up 512	Medium	Low	
Video broadcasting	Up to 3 000	Low	Low	
Videoconferences:				
– video	–n*128	Low	Medium	
– audio	–8–32	Low	Medium	Streaming variable or constant bit rate
IP telefony	Up to 64	Low	Medium	
VLL	Up to 2 048	Low	Low	Streaming constant bit rate

3. Application classes versus network services in ATM and IP QOS

Summarising, we have from one side a number of application classes and from other side a set of NSs supported by core. Therefore, the problem is mapping applications into adequate NSs in the way satisfying user. Let us recall, that the available NSs in ATM and IP QoS are slightly different. Table 2 shows the proposed mapping assumed for the experiments. Although in ATM we have 6 NSs, we had to limit our interest to 4 NSs only (i.e. CBR, rt-VBR, nrt-VBR and UBR), since the implemented in a switch ABR as well as GFR services are not available to applications. Corresponding to AQUILA IP QoS, the tested NSs are premium CBR, premium VBR, premium multimedia, premium mission critical and STD.

Table 2
Proposed mapping between application classes and NSs in ATM and IP QOS

Application class	ATM network service	IP QoS network service
Elastic sporadic traffic	nrt-VBR	Premium mission critical
Elastic bulk traffic	nrt-VBR	Premium multimedia
Streaming variable bit rate	rt-VBR	Premium VBR
Streaming constant bit rate	CBR	Premium CBR

The proposed mapping takes into account the traffic profiles produced by particular application classes jointly with QoS requirements and capabilities of NSs. For simplifying experiments with ATM, we have merged both elastic traffic classes into single one assigned to nrt-VBR service. A justification for doing it is that the data flow in elastic traffic is controlled by the same protocol, TCP. The nrt-VBR is designed for guaranteeing assumed cell loss ratio (and in non-direct way – TCP throughput) while cell transfer delay is not an objective. In the case of streaming variable/constant bit rate classes the mapping into adequate NSs is more obvious. The variable/constant bit rate traffic is submitted to rt-VBR/CBR in ATM or premium VBR/premium CBR in AQUILA IP QoS. The QoS objectives for the considered NSs are almost the same as QoS application requirements. Notice, that the NSs mentioned above require the user to set-up the connection with appropriate traffic declarations, corresponding to the single or double leaky/token bucket parameters. They are the peak bit rate and/or the sustained bit rate jointly with the maximum burst sizes.

4. Mechanisms for splitting LAN traffic into particular network services

Handling traffic generated by a LAN with requirements for QoS differentiation in the core, and as consequence, splitting it into appropriate NSs, demands implementation of additional mechanisms in the edge ATM switch or IP router. These mechanisms should allow us for: (1) setting up appropriate connection/reservation in a core, and (2) LAN traffic classification into sub-streams and mapping them into the established connections inside adequate NSs.

A connection in the core can be set-up by network operator or on demand by a proxy agent. Classification process will allow us for selecting the traffic sub-streams and then

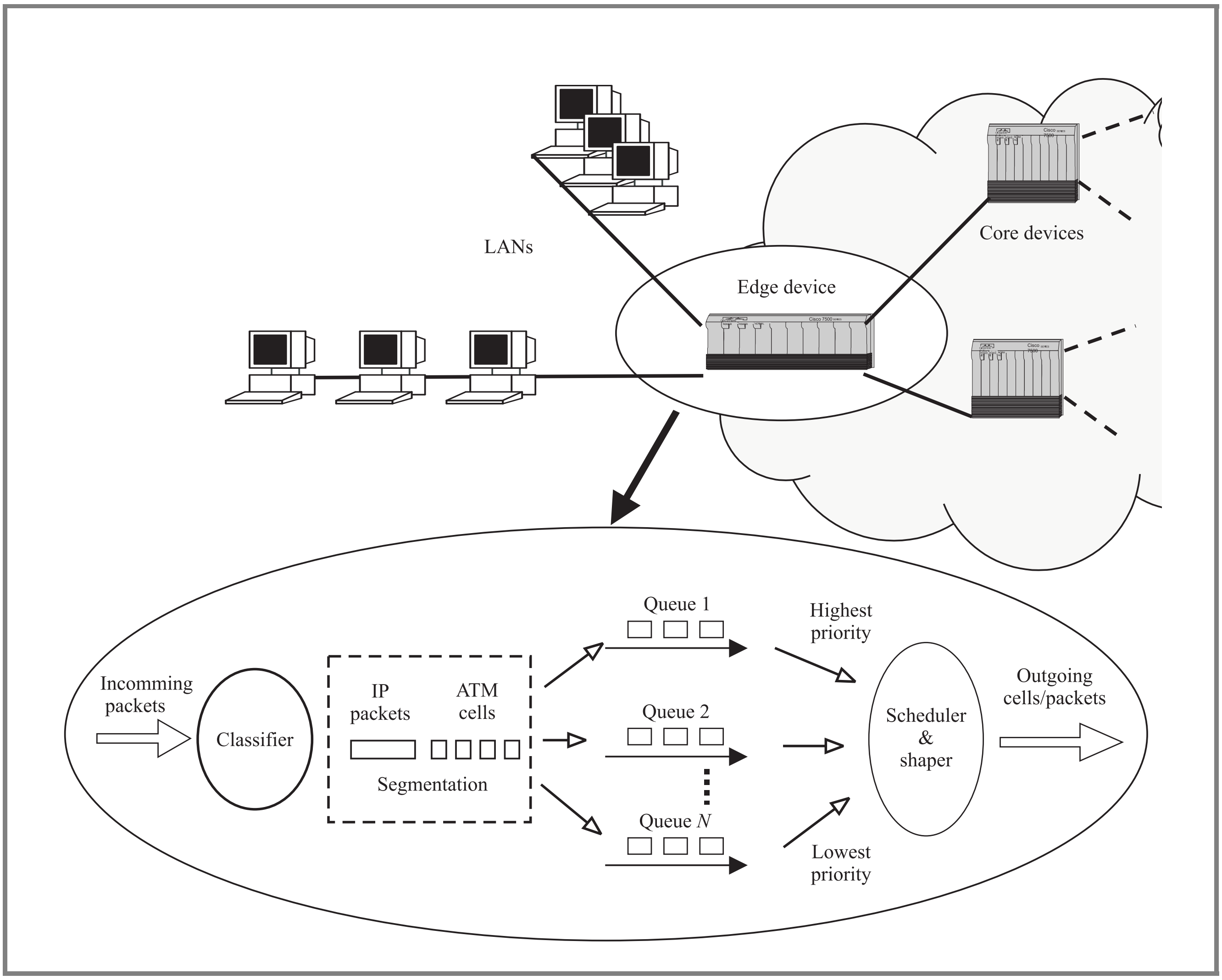

Fig. 2. Scheme for handling LAN traffic.

transferring it by the established connections belonging to a given NS. Let us remark, that each of the traffic substreams before submitting to the core should be shaped in accordance to assumed traffic contract. Figure 2 shows the scheme for traffic handling in the edge device.

First, outgoing LAN traffic is submitted to a classifier for splitting it in accordance to QoS demands (or equivalently, according to assigned NS). This process can be done on the basis of address information included in IP packet header, TCP/UDP segment header etc. Anyway, this requires implementation of a classification table, which should be updated each time a connection is set-up/released. After the classification process, the IP packets are switched to the appropriate input queues in the scheduler, governing access to the core link. Additionally, in case of ATM a packet segmentation process into ATM cell format is performed. The queues in scheduler are associated with a given NS. Usually, in ATM switches we have priority queuing (PQ) or like-PQ schedulers [9], allowing us for assigning priority in such a way that the highest is assigned to CBR, lower to rt-VBR, next to nrt-VBR and the lowest to UBR. In IP routers the most popular is the weighted fair queuing (PQ-WFQ) scheduler [1], as assumed e.g. for AQUILA IP QoS. The PQ-WFQ gives similar prioritization of traffic submitted inside premium CBR, premium VBR, premium multimedia, premium mission critical and STD.

5. Measurement results

This section presents comparative measurement results corresponding to QoS differentiating of traffic generated between LAN networks carried by ATM and IP QoS core. More specifically, we will focus on the quality perceived by a LAN user using different applications. The applications selected for the tests are VoIP, e-mails and FTP. The experiments were carried out in a test bed. The tested network is of the bottleneck type, as depicted in Fig. 3. It consists of two ATM switches (MARCONI ASX200BX), connected by direct E1 ATM link, 1.9 Mbit/s. To each

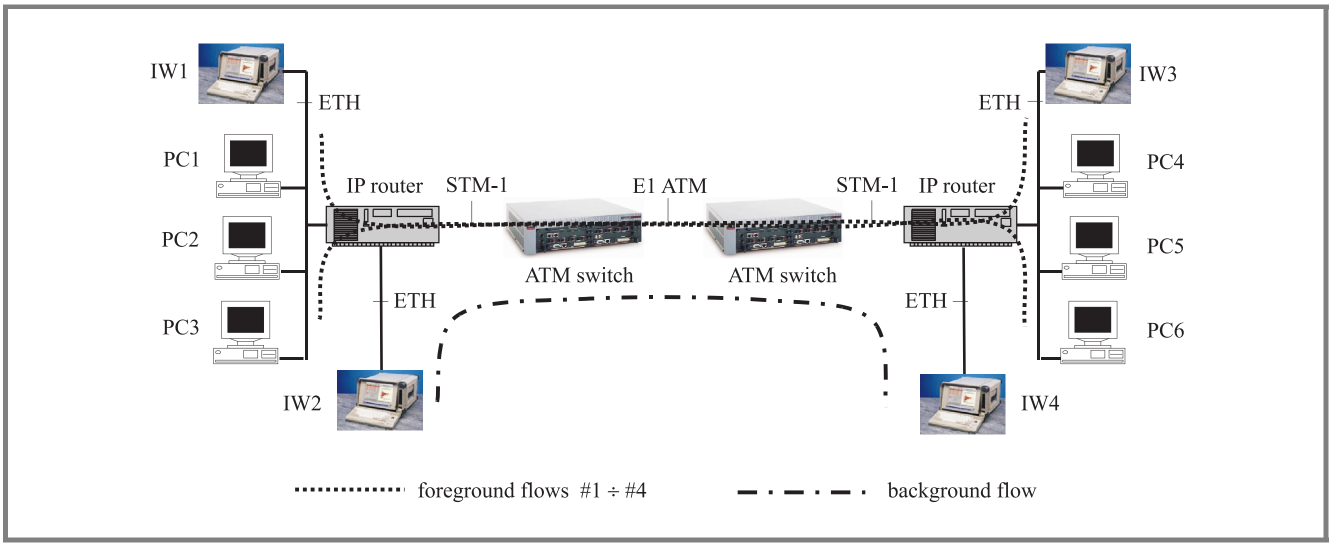

Fig. 3. Tested network.

ATM switch a LAN network is attached, containing IP router (CISCO 3640) as a gateway for 3 user terminals, PC1–PC3 (PC4–PC6), and 2 traffic generator/analysers (InterWatch 95000), IW1–IW2 (IW3–IW4).

Two network scenarios were considered, which are:

1. ATM scenario, where traffic is differentiated in ATM switch for further submitting to earlier established connections inside NSs available in ATM, i.e. CBR, VBR and UBR. In this case, the IP router performs simple packet forwarding only without applying any QoS features. It can be treated as completely transparent.

2. IP QoS scenario, where traffic is differentiated in IP router for further submitting to earlier established connections inside NSs available in IP QoS, i.e. premium CBR, premium VBR, premium multimedia, premium mission critical and STD. In this case, a single ATM connection is designated for whole IP traffic. So, the ATM is transparent.

The assumed foreground and background traffic flows carried by bottleneck link are the following:

- Flow #1, produced by UDP controlled application which requires low packet losses and low packet transfer delay, like VoIP, is established between traffic generator/analysers IW1 and IW3. This traffic is of constant bit rate type with 64 kbit/s in the peak. In this case we assume short IP packets of 53 B (bytes) size for a fair comparison between ATM and IP QoS.

- Flow #2, produced by "non-greedy" TCP source using application sending 10 kB messages, like e-mail, is established between terminals PC1 and PC4. This traffic is shaped according to contract with the peak rate PR = 100 kbit/s, the sustained rate SR = 100 kbit/s, and burst size BS = 10 kB. The packet size is 1 500 B.

- Flow #3, produced by "greedy" TCP source using application transferring large files of 5 MB, like FTP. This flow is established between terminals PC2 and PC5 and its traffic is also shaped to the same contract as for flow #2 with packet size also fixed to 1 500 B.

- Flow #4, is exactly the same traffic as flow #3, but established between terminals PC3 and PC6.

- In addition, the background traffic is submitted into best effort service, UBR in ATM and STD in IP QoS. This traffic is of constant bit rate type with the peak rate 2 Mbit/s, produced between pair of traffic generator/analysers, IW2 and IW4. The presence of this traffic produces overload in the bottleneck link 1.9 Mbit/s.

Table 3 summarises the assumed for experiments traffic flows, with specification concerning traffic contact parameters and affiliation to network services in ATM and AQUILA IP QoS. The NS affiliation follows the consideration included in Section 3 (see Table 2).

The measured parameters are:

– for TCP-controlled flows #2, #3 and #4, throughput and goodput,

– and for UDP-controlled flow #1, packet transfer delay characteristics: max packet transfer delay (max PTD), peak-to-peak packet delay variation (PDV) and packet loss rate (PLR).

The reported measured results were collected after 10 independent measurement intervals each of 5 min. They are presented with 95% confidence intervals. For each scenario, two experiments were performed, with and without background traffic.

Table 3
Types of flows assumed for experiments

Flows	Connection	Traffic contract	Assigned ATM network service	Assigned AQUILA IP QoS network service
Flow #1	IW1–IW3	Constant bit rate with peak rate 64 kbit/s	CBR	Premium CBR
Flow #2	PC1–PC4	Variable bit rate with peak rate 100 kbit/s, sustained rate 100 kbit/s, maximum burst size 10 kB	nrt-VBR	Premium mission critical
Flow #3	PC2–PC5	Variable bit rate with peak rate 100 kbit/s, sustained rate 100 kbit/s, maximum burst size 10 kB	nrt-VBR	Premium multimedia
Flow #4	PC3–PC6	Variable bit rate with peak rate 100 kbit/s, sustainable rate 100 kbit/s, maximum burst size 10 kB	UBR	STD
Background flow	IW2–IW4	Constant bit rate 2 Mbit/s	UBR	STD

Table 4
Comparative measurement results for ATM versus IP QoS core scenario

Scenario 1: ATM core										
Test case	flow #1			flow #2		flow #3		flow #4		
	max PTD [ms]	PDV [ms]	PLR [%]	throughput [kbit/s]	goodput [kbit/s]	throughput [kbit/s]	goodput [kbit/s]	throughput [kbit/s]	goodput [kbit/s]
Without background traffic	2.12	0.71	0*	$73.2 \div 76.7$	$69.7 \div 74.2$	$79.8 \div 90.1$	$77.2 \div 85.4$	$77.2 \div 83.6$	$74.9 \div 81.4$
With background traffic	2.2	0.91	0*	$73.1 \div 76.5$	$68.9 \div 73.5$	$79.7 \div 89.7$	$76.8 \div 84.8$	—	—
Scenario 2: IP QoS core									
Test case	flow #1			flow #2		flow #3		flow #4	
	max PTD [ms]	PDV [ms]	PLR [%]	throughput [kbit/s]	goodput [kbit/s]	throughput [kbit/s]	goodput [kbit/s]	throughput [kbit/s]	goodput [kbit/s]
Without background traffic	8.5	8.3	0*	$69.3 \div 72.7$	$67.2 \div 69.5$	$85.6 \div 88.9$	$83.4 \div 86.3$	$78.4 \div 81.4$	$76.6 \div 79.1$
With background traffic	8.9	8.4	0*	$68.7 \div 71.8$	$65.4 \div 69.0$	$84.4 \div 87.5$	$78.8 \div 81.3$	—	—

* No packet losses were observed, — flow starvation was observed.

The measurement results obtained for Scenarios 1 and 2, and corresponding to foreground flows #1÷4 are collected in Table 4. One can observe that for both considered scenarios the impact of background traffic submitted to best effort service, UBR in ATM or STD in IP QoS, on traffic handled by other NSs (guaranteeing a given QoS level) is negligible, as it was expected. Comparing ATM and IP QoS, we conclude as follows:

- QoS level experienced by flow #1, related with real-time data, is worst in case of IP QoS than ATM. Let us recall that in IP QoS scenario, we mix packets of 53 bytes with packets of 1 500 bytes. Therefore, the packets from flow #1 could experience relatively large delay despite that they are handled with the highest priority. This is due to the packets multiplexing scheme applied in IP routers. So called, residual packet service time in no-preemptive service discipline, as it is in PQ or PQ-WFQ schedulers, could be essential in the presence of long size packets generated by e.g. TCP-controlled applications. This is not observed in ATM, where cells multiplexing scheme is applied.

- The values of achieved goodput in case of TCP-controlled flows #2 and #3 stay on the same level in IP QoS and ATM scenarios. This result was expected. The greater values of throughput/goodput than guaranteed by traffic contract were reached for flows #2 and #3 in both scenarios. This is due to non-dropping but marking policy for TCP-controlled flows and higher priority for nrt-VBR/premium multimedia service than for UBR/STD in ATM and IP QoS, respectively. So, one can conclude that two services nrt-VBR and premium multimedia give similar QoS level.

- In both scenarios, the essential starvation of QoS experienced by flow #4 in observed, when the background traffic is on. This result was expected since for the UBR as well as STD services the lowest priority was assigned and no traffic control mechanisms are applied.

Concluding, the IP QoS can assure similar QoS level as achieved by ATM for TCP-controlled traffic. However, for streaming traffic the CBR service in ATM is more efficient than premium CBR service in IP QoS.

6. Summary

The paper reports the measurements results corresponding to a comparison between ATM and IP QoS in providing QoS differentiation for traffic generated by LAN users. In both cases, this requires implementation of additional functionality corresponding to traffic classification, shaping, connection set-up and mapping between application classes and network services at the entry point to the core network. First observation is that QoS differentiation is possible to be reached by using both considered technologies. The different QoS objectives for streaming and elastic flows can be met by using appropriate ATM or IP QoS network services. More precisely, for streaming flows the low packet transfer delay and low packet loss rate are guaranteed by CBR service in ATM or by premium CBR service in IP QoS. However, due to packet multiplexing scheme in the latter case, the observed packet delays are greater. For elastic flows, the QoS objectives expressed by TCP goodput are achieved in both cases.

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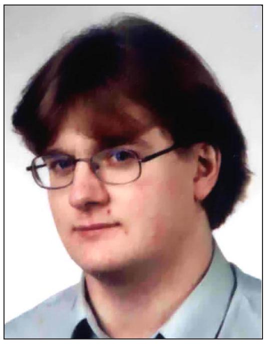

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