Ethernet, QoS, Classes of Service, simulations

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SUPPORTING DIFFERENT CLASSES OF SERVICE IN ETHERNET SWITCHES WITH SHARED BUFFER ARCHITECTURE

This paper deals with the problem of assuring strict QoS guarantees for connections going through from Ethernet access network. The motivation of this paper was the problem identified during the FP6 IST EuQoS project, which showed that, despite high link capacities, Ethernet access network might be the reason of QoS deterioration in odd cases. The primary reason precluding target QoS level is the lack of appropriate QoS differentiation and traffic isolation mechanisms in some Ethernet switches. For instance, the shared buffers and priority schedulers seem to be not sufficient to guarantee strict QoS. That's why a new solution was proposed for these cases. This solution relied on additional traffic control mechanisms available in some Ethernet switches. The proposed approach was evaluated by simulations studies for TCP and UDP traffic.

1. INTRODUCTION

New demands for using multimedia applications over the Internet, such as videoconferences, tele-medicine, tele-education etc., have caused considerable research to develop the Internet into multi-service networks offering QoS (*Quality of Service*) guarantees. One of the projects focusing on these issues was the FP6 IST EuQoS [9]. The key objective of this project was to design, research, prototype and test a new system, called the EuQoS system, which assures strict end-to-end (e2e) QoS quarantees at the packet level in multi-domain, heterogeneous environment. To provide strict e2e QoS guarantees in multi-domain heterogeneous network, we require assured QoS in each part of the network: core domains as well as access domains, therefore, during the EuQoS project researches, we studied also the approach for supporting QoS in the Ethernet access network.

So far, a lot of effort was put to assure QoS guarantees in Ethernet access network. However, some solutions do not provide strict QoS, as EtheReal [18], which is throughput oriented and only supports best effort traffic, or stochastic approach presented in [4], which only yields average delay performance bound. Other approaches, as [13] and [7] require additional cost of hardware and/or software modification. Solutions proposed in [6] and [3] do not override the IEEE specifications and rely on standard Ethernet switches with priority scheduling, but require a separate queue for each priority class. Unfortunately, typical Ethernet switches currently offered by vendors own only a common buffer, which is shared by all priority classes. It may lead to the violation of QoS

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guarantees of high priority traffic in case when the whole Ethernet switch buffer is occupied by low priority traffic.

In this paper we present an approach to assure strict QoS guarantees in the Ethernet access network. We assume the use of currently accessible Ethernet equipment, with shared buffers, priority scheduler and traffic control mechanism similar to WRED (*Weighted Random Early Detection*). No further modification of switch software or hardware is necessary.

The rest of the paper is organized as follows: Section 2 describes the main problem treated in this paper, i.e. the assurance of target QoS level in Ethernet access network with switches, which contain shared buffers. In Section 3 the proposed solution is presented while in Section 4 it is evaluated by a series of simulations. Section 5 summarizes the paper.

2. STATEMENT OF THE PROBLEM

The approach for assuring QoS in multi-domain networks, which has been applied in the EuQoS project, bases on the implementation of end-to-end Classes of Service (e2e CoSs) [5] dedicated to handle packets generated by respective type of application, e.g. VoIP (*Voice over IP*). Roughly speaking, the e2e CoS corresponds to the network capabilities for transferring the packets belonging to selected connections with assumed QoS guarantees. These QoS guarantees are expressed by the following metrics (as defined in [10]): (1) IP packet loss ratio IPLR, (2) IP packet transfer delay IPTD and (3) IP packet delay variation IPDV.

Within the IST EuQoS project, five e2e CoSs have been defined: Telephony, RT Interactive, MM Streaming, High Throughput Data (HTD) and Standard (STD) CoSs, according to different types of traffic profiles generated by the different applications studied in EuQoS. The maximum values of QoS metrics (i.e. IPLR, IPTD and IPDV) for each e2e CoS one can find in [11].

To implement these e2e CoSs, adequate CAC (*Connection Admission Control*) algorithms were designed (to limit the QoS traffic) and appropriate QoS mechanisms like schedulers, shapers, policers etc., available in network elements were used. Only in the case of Standard CoS there is neither CAC function performed nor the QoS parameters are guaranteed since this CoS is intended to provide similar service as Best Effort network, i.e. without guarantees in the QoS parameters.

The implementation of e2e CoSs runs into different obstacles when considering each of possible access network technologies i.e. WiFi, UMTS, xDSL or Ethernet. In our paper we focus on the problem of Ethernet access network. In this technology the primary mechanism to differentiate traffic is Priority Scheduler, practically available in almost every switches. The 802.1p specification (which is a part of IEEE 802.1D [8]) defines 8 priority classes, and EuQoS project proposed the mapping between them and end-to-end EuQoS CoSs as presented in table 1.

Table 1. Mapping between end-to-end EuQoS CoSs and Ethernet priority classes.

e2e EuQoS CoS	Telephony, RT Interactive	MM Streaming, High Throughput Data	Standard
Ethernet priority class	Voice	Controlled Load	Best Effort
802.1p priority value	6 (high)	4	0 (low)

The mapping shown in table 1 implies that the traffic from STD CoS is served with the lowest priority in comparison with other e2e EuQoS CoSs. Unfortunately, typical Ethernet switches do not support per class buffer but only a common one, which is shared by all CoSs including STD CoS. Although this buffer is quite large – usually thousands of packets, the fact it is shared poses the main problem [15]. Since CAC function, by definition, does not control the amount of traffic submitted to

STD CoS, it is possible that this traffic overloads the network and fully occupies the Ethernet buffer. This situation may deteriorate IPLR metric of other CoSs, since the arriving packets from other CoSs will be dropped due to the lack of room in shared buffer space. The mechanism of shared buffer combined with the priority scheduling has been symbolically shown in fig. 1 by using model of Drop Tail queue at the entrance to the Ethernet buffer but Priority Scheduler at the exit.

It is worth mentioning that IPTD and IPDV metrics, in spite of the shared buffer, will never be influenced since once a packet enters into the shared buffer, it is scheduled to the transmission according to the priority rules and, hence the traffic from STD CoS cannot delay the packets from other CoSs [11]. Thus, the problem of assuring appropriate performance of e2e EuQoS CoSs in Ethernet network is mainly the problem of controlling traffic from STD CoS and preventing it from occupying too much buffer space avoiding, in this way, the packet losses due to shared buffer space.

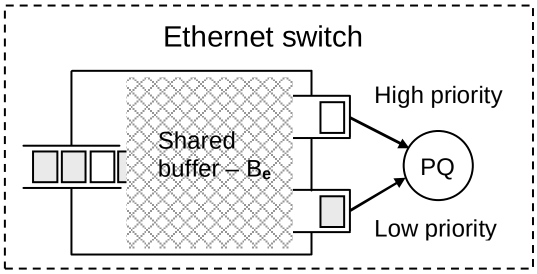

Fig. 1. Model of shared buffer in Ethernet switches.

3. THE PROPOSED SOLUTION

The main idea to alleviate the problem outlined in section 2 relies on controlling the buffer space occupied by each CoS. In this way, we assure the isolation between the different CoSs. First of all, we distinguish between the CoSs, for which we guarantee some level of QoS (we refer to them as QoS CoSs) and the STD CoS, for which we do not guarantee any level of QoS. Such a classification is caused because we may apply different methods for controlling the occupancy of the buffer space for QoS CoSs and for STD CoS. In the first case, as any of the connections belonging to the QoS CoSs must pass the CAC function, the amount of the occupied buffer space can be controlled by appropriate resource provisioning and configuration of the CAC function. However, in the case of STD CoS the approach described above is not possible because the connections belonging to this CoS are not controlled by CAC function. To control the volume of this traffic and the shared buffer occupancy due to it, we propose a solution designed to switches that support traffic control mechanism similar to WRED. The desired isolation of CoSs might be achieved when the size of the common Ethernet buffer B_e is able to accommodate the whole buffer space required by the QoS CoSs (B_{QoS}) and by the STD CoS (B_{STD}). It means that the Ethernet switch buffer size should meet the following condition: $B_e > B_{QoS} + B_{STD}$. More precisely, for each QoS CoS (i.e. for each Ethernet priority class associated with it) we can dedicate the buffer size $B_{i\text{-}j}$ (j=1,..,7) taking into account the adequate QoS requirements. For example, for Telephony CoS we design rather short buffers to guarantee low IPDV values. This buffer size $B_{i\text{-}j}$, together with dedicated capacity $C_{i\text{-}j}$ is later used by RA (*Resource Allocator*), the control module responsible for performing CAC algorithm and resource reservations, to calculate the CAC limit for the given output port i for particular CoS j. Since all originating and terminating connections which use these CoSs must pass the CAC function performed in the RA module, we can control the volume of the traffic offered to each QoS CoS within each output port (see fig. 2).

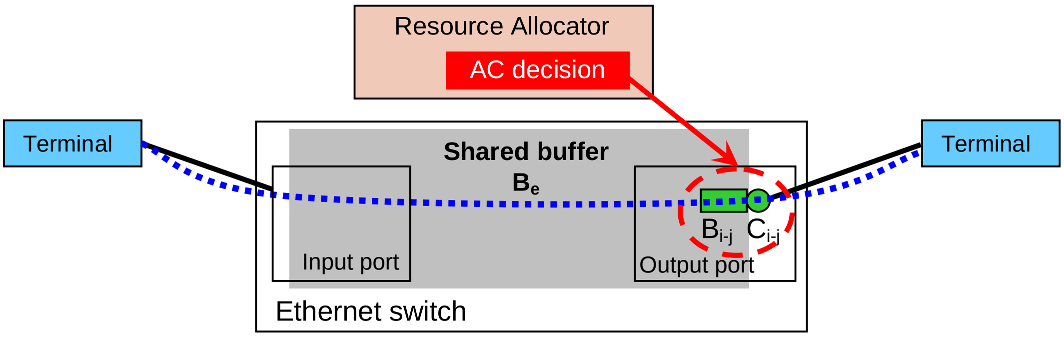

Fig. 2. Resource Allocator (RA) module controls the volume of the traffic by performing CAC algorithm for dedicated resources: buffer size B_{i-j} and capacity C_{i-j}.

The CAC algorithm used by RA module in Ethernet access network depends on the CoS it is used for. In general, the requirements for IPLR and mean IPTD determine the maximum admissible load ρ_{max} that can be accepted in given QoS CoS. The maximum admissible load $\rho_{max,IPTD}$ that satisfies the requirement for mean IPTD is determined based on the Pollaczek-Khintchin formula:

$$\rho_{\max,\,IPTD} = \frac{2(IPTD - T_{prop} - \frac{L}{C})}{2IPTD - 2T_{prop} - \frac{L}{C}} \quad (1)$$

where T_{prop} denotes the propagation delay (which also contributes to mean IPTD), L denotes the packet length (in bits) and C denotes the fraction of link capacity dedicated to the given QoS CoS.

On the other hand, the requirement for target IPLR determines another value of the maximum admissible load, namely $\rho_{max,IPLR}$. The lower of these two values is finally considered as the maximum admissible load ρ_{max} to the given QoS CoS:

$$\rho_{\max} = \min[\,\rho_{\max,\,IPTD}\ ;\ \rho_{\max,\,IPLR}\,] \quad (2)$$

For Telephony CoS, the value of $\rho_{max,IPLR}$ is calculated based on the dedicated buffer size B_{i-6}, and the target IPLR value according to the algorithm described in [17]. The value of B_{i-6} is determined from the provisioned capacity C_{i-6} and the requirement on the IPDV value, which is defined as an upper bound of the maximum packet queueing delay.

In the case of STD CoS the approach described above is not possible because the connections belonging to this CoS are not controlled by CAC function. To control the volume of this traffic and the shared buffer occupancy due to it we propose a solution which is designed for switches that support traffic control mechanism similar to WRED. For example, such mechanism is available in Super Stack 4 5500 Ethernet switch which was a part of EuQoS test bed. As recognized in the relevant technical documentation [2], this WRED mechanism lets us set the queue threshold $Q_{th,i-j}$ and the dropping probability $P_{drop,i-j}$ for each output port i and each Ethernet priority level j independently. Furthermore, it works in the following way: when a new packet arrives, the corresponding output port i and associated Ethernet priority level j are determined, then the size of the adequate queue Q_{i-j} is compared with the earlier configured threshold $Q_{th,i-j}$. If the queue size is below than $Q_{th,i-j}$ the packet is queued in the common buffer, otherwise it is dropped with probability $P_{drop,i-j}$. In comparison with WRED mechanism known from routers, where the two queue size thresholds are specified and the dropping decisions are worked out on the basis of the avaraged queue size, it is a kind of simpliefied version with only one queue size threshold and the packet drop desicions based on the instantenous queue size.

The main idea of the proposed solution is that by setting the appropriate threshold $Q_{th,i\text{-}0}$ for the queue $Q_{i\text{-}0}$ associated with STD CoS (j=0) on the output port i and the related dropping probability $P_{drop,i\text{-}0}$, we are able to drop the excessive traffic and, in this way, we tend to keep the buffer occupancy (due to STD CoS on this output port) below the value $Q_{th,i\text{-}0}$. This is suited for STD CoS since, on one hand, it has no guarantees about IPLR, IPTD nor IPDV values and, on the other hand, it carries mainly TCP controlled traffic with possibly greedy behavior tending to grab all the available capacity and the buffer space B_e. Unfortunately, Super Stack 4 5500 lets for setting the P_{drop} value only in the range <0; 92%> [1]. It means that in the case when the thresholds are exceeded, we can never drop the whole traffic incoming to the Ethernet switch but, at the most, only the 92% of it. However, as most of the STD CoS traffic uses TCP transport protocol we assume that this method is sufficient for bounding the maximum buffer occupancy.

When the above approach is applied to all N output ports of the Ethernet switch, the total resulting occupancy B_{STD} of the shared buffer due to STD CoS traffic should stay below the value:

$$B_{STD} <= \sum_{i=1}^{N} Q_{th,i-0} \tag{3}$$

Accordingly, the remaining buffer space should be available for the traffic from QoS CoSs.

4. EVALUATION BY SIMULATIONS

The main objective of the simulation studies was to verify if the proposed solution is able to assure the target values of IPLR, IPTD, IPDV parameters for the traffic carried within particular e2e CoS when each CoS is in CAC limit and STD CoS is overloaded. An additional objective was to verify whether the QoS mechanisms available in Ethernet switch let us to control the consumption of shared buffer space, especially its occupancy due to the STD CoS traffic.

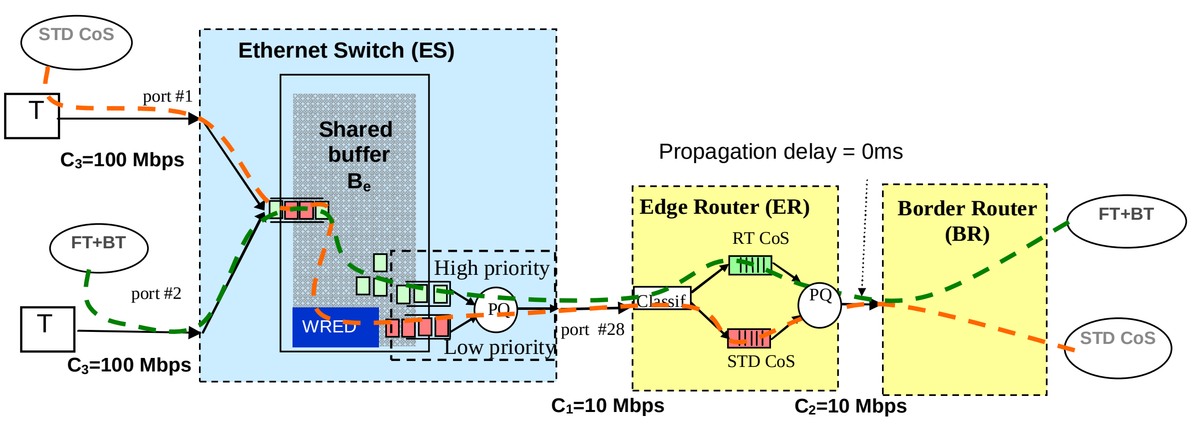

Fig. 3. Traffic scenario for testing Telephony e2e CoS

For the simulation studies we assumed the same network topology as in EuQoS test bed. Accordingly, Ethernet access network includes Ethernet Switch (ES), which connects to a number of Terminals (T) and one Edge Router (ER) which provides connectivity to the IP core (see fig. 3). ES features 28 ports, among which 27 are connected to end terminals (T) and one to ER. All the links are duplex. The Ethernet link capacities (C_1, C_3) as well as the capacity C_2 of the ER link toward

Border Router (BR) are configurable. Since we want to perform the tests in conditions when ES is a bottleneck we set the capacities C_1 and C_2 equal. To create the congestion conditions with a minimum set of terminals generating traffic (which is important when performing trials in test bed) the input links are configured with capacity 100Mbps i.e. 10 times faster than links C_1 and C_2.

We have evaluated the possibility of supporting e2e CoSs in a set of scenarios, where the traffic from only one e2e QoS CoS (Telephony, RT-Interactive, etc.) together with STD CoS traffic was present at the same time. In each test we measured relevant QoS parameters of a single traffic stream constituting so called Foreground Traffic (FT). However, for these measurements to be adequate we provoked the worst traffic conditions in the network that are allowed by CAC algorithm. It means that we loaded a tested e2e CoS to ρ_{max} value. This additional type of traffic creating CAC limit condition, we refer to as Background Traffic (BT). The FT and BT were appropriately modelled depending on the type of tested e2e QoS CoS. Due to space limitation in this paper we present only the simulation results obtained for the case of Telephony and STD CoS.

In the performed tests we differentiated between the case where the STD CoS traffic used TCP (section 4.1) or UDP (section 4.2). This differentiation is important because the applied transport protocol impacts traffic characteristics mostly due to the presence or lack of closed-loop congestion control, respectively.

The details of simulated traffic scenario are as follows. There are only two types of traffic: one representing traffic from Telephony CoS, for which we must guarantee target QoS level and the other one, which represents traffic from STD CoS. The Telephony CoS FT and BT traffic comes from the terminal connected to Ethernet port #2 and STD CoS traffic from terminal connected to port #1. The whole traffic is destined to BR across ES and ER. The propagation delay T_{prop} between ER and BR is set to 0 ms reflecting the low distances between particular elements of the Ethernet access network. The capacity dedicated to Telephony CoS on C_1 link is $C_{28\text{-}6}$=2Mbps. Packets belonging to this class are 200B long and packets belonging to STD CoS are 1500B long. FT and BT of Telephony CoS are modelled as CBR stream (parameters relevant for G.711 codec) and Poisson stream, respectively. The parameters of the WRED mechanism are the following: threshold is set to 85 pkts (and this value indicates maximum buffer space assumed for STD CoS), dropping probability is set to 0.92. The Ethernet shared buffer value is B_e=1000 pkts.

The simulation studies were performed using ns-2 platform [14]. The results were obtained by repeating the simulation tests 12 times and calculating the mean values with the corresponding 95% confidence intervals. However, the confidence intervals were not given in cases they are negligible. Each simulation test lasted for 1000 seconds.

4.1 TCP STREAMS INTO STD COS

In this test the STD CoS traffic consists of N=10 TCP greedy connections. The nominal values of QoS parameters that we assumed for the Telephony CoS in Ethernet access network are summarized in table 2 (we refer to them as to “designed values”). These values were used to determine the traffic load that we admitted into Telephony CoS.

For this test, the measured IPLR, mean IPTD and IPDV are below target designed values (see table 2). Measured IPLR equals 0 since the buffer space dedicated to Telephony CoS ($B_{28\text{-}6}$=10 packets) was much less than the whole Ethernet switch buffer size and the buffer occupancy due to STD CoS was well controlled. In fact when STD CoS traffic is TCP controlled the maximum STD CoS queue size Q_{max} (determined with probability 10^{-3}) deviates only a little from the WRED threshold which was set to 85 packets (see table 3). Thanks to TCP mechanism, after the STD CoS queue reaches WRED threshold and the new arriving packet is dropped, the TCP source slows down its sending rate letting the STD CoS queue size to decrease. The measured IPDV value was also below the designed value because Telephony CoS traffic was served with priority on the link with physical capacity 10Mbps and this value is much higher than the assumed provisioned capacity C_{28-6}=2Mbps. Also the measured mean IPTD was below the designed value but the reason was that for this simulation ρ_{max}=0.714 was determined from IPLR as a more constraining factor (see eq. 2).

Table 2. Simulation results of QoS parameters for Telephony CoS.

QoS parameter	**Designed value**	**Measured value**
IPLR	10^{-3}	0
IPTD [ms]	2.5	2.0
IPDV [ms]	8	1.3±0.1

Table 3. Simulation results of the queue size in ES.

Tested e2e CoS	**Measured queue size in ES [pkts]**		
	Parameter name Q	**Mean**	**Q_{max}: Prob{Q>Q_{max}}<10^{-3}**
Telephony	Q_{QoS}	1.1	5
STD	Q_{STD}	73±0.5	86.5±0.5

4.2 UDP STREAMS INTO STD COS

In this section we discuss two cases. Firstly, in section 4.2.1 we provide the results for the case when the WRED queue size threshold for the STD CoS is set to the desired value of queue size (we call this value as nominal threshold). Next, in section 4.2.2 we provide some guidelines how to tune the WRED threshold in order to better control the STD CoS queue size.

4.2.1 RESULTS WITH NOMINAL THRESHOLD

In this test, the STD CoS traffic consists on one CBR stream with rate equal to 100 Mbps. In these conditions, we observed that the maximum queue size Q_{max} of STD CoS traffic in Ethernet buffer is much greater than the WRED threshold at which the ES starts dropping STD CoS packets (see table 4). The reason for the long queue size, exceeded desired value of 85 pkts, is that the STD CoS packets are dropped in a probabilistic way. It means that during short periods, fewer packets than expected may be dropped and, as a consequence, it leads to uncontrolled growth of the queue. To illustrate possible IPLR deterioration of Telephony CoS traffic, we repeated the simulation keeping the size of shared buffer B_e = 95 pkts (10 pkts for Telephony CoS and 85 pkts for STD CoS), as described in table 5. In this case, the measured mean IPTD and IPDV are below target values because of the same reasons as in section 4.1, whereas IPLR is higher than designed value.

Table 4. Simulation results of queue size in ES.

Tested e2e CoS	**Measured queue size in ES [pkts]**		
	Parameter name Q	**Mean**	**Q_{max}: Prob{Q>Q_{max}}<10^{-3}**
Telephony	Q_{QoS}	0.7	5
STD	Q_{STD}	92.5±0.1	134±1.3

Table 5. Simulation results of QoS parameters for Telephony CoS (B_e=95 pkts).

QoS parameter	**Designed value**	**Measured value**
IPLR	10^{-3}	$1.2 \cdot 10^{-2}$
IPTD [ms]	2.5	2.0
IPDV [ms]	8	1.2

4.2.2 RESULTS WITH IMPROVED THRESHOLD TUNING

The simulation studies performed for Ethernet access network showed that controlling shared buffer occupancy due to STD CoS traffic by means of WRED mechanism is not a trivial task. Since the control of the occupied buffer space is crucial to provide separation between CoSs and in this way, to assure target values of QoS parameters, we must precisely control it. It means that only when STD CoS traffic is TCP controlled, we can assume that the queue size of STD CoS is well limited to the WRED threshold. In the case when this traffic is UDP we cannot assume that the STD CoS queue size is around desired WRED threshold since the simulations proved it is much above it. For this case, we need to control the queue size more precisely e.g. by setting lower value of WRED threshold to start dropping packets earlier. The question arising is the top value of WRED threshold in order not to exceed the target maximum queue size. The answer comes from the analysis of the phenomena, which is responsible for the excessively growing queue.

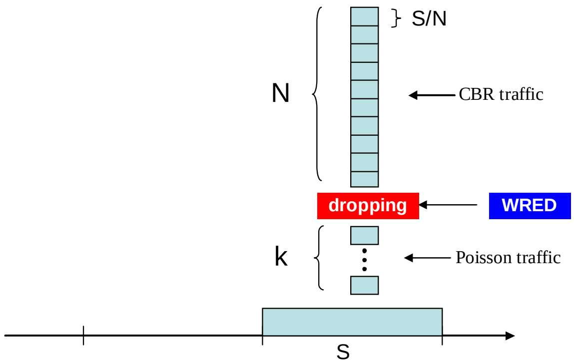

Fig. 4 Characteristics of the arriving packet stream after passing WRED mechanism

Since in the considered case, the capacity C_3 is 10 times higher than capacity C_1 and the STD CoS traffic is assumed to be CBR with rate equal to C_3 (see fig. 3), then, during the service time of each STD CoS packet on the link C_1, other 10 packets of STD CoS arrive to the output port #28. When the queue size of STD CoS packets gathered on port #28 exceeds the WRED threshold (here 85 packets), the WRED mechanism starts dropping the arriving STD CoS packets. However, it drops each of them with a probability 0.92. On average the rate of STD CoS traffic, which passes through the WRED is only 8 Mbps (i.e. 8% of incoming traffic) which guarantees that the system is stable since the total rate offered to the output port #28 equals 9.428 Mbps (8 Mbps due to STD CoS traffic and $\rho_{max}\times C_{28,6}$=0.714×2Mbps=1.428 Mbps due to Telephony CoS traffic) and stays below the service rate C_1 (10 Mbps). However, because of the probabilistic nature of WRED packet dropping, it might happen that for some period of time more packets than the foreseen average will pass through the WRED. These packets will contribute to the extensive growth of the queue beyond the WRED threshold. In order to understand how this queue grows it is necessary to characterize the stream of packets that have passed WRED. The fig. 4 illustrates the dependencies between the packet service time S on the link C_1, the original CBR packet stream (N=10 new packets during the service time S) and the stream of packets that have passed WRED (k packets out of any N arriving).

Since consecutive packets are dropped by WRED independently, the probability distribution of the number of packets that are not dropped (k out of N) is binomial:

$$\Pr ob\{k\} = \binom{N}{k} p^k (1-p)^{(N-k)}, \quad where\ k = 0,1,...,N\ and\ N = 10 \qquad (4)$$

with parameter p=0.08 (probability that WRED does not drop the packet).

For our purpose, this distribution can be replaced by Poisson distribution (with mean equal to $N \times p$) as the latter one has greater variability and thus, we can consider the results obtained with the Poisson distribution as an upper bound. After characterizing the packet stream, which contributes to the STD CoS queue, we proceed with the analysis. The starting point is the following model with two CoSs: Telephony and STD and the traffic loads ρ_1 and ρ_2, respectively (see fig. 5a).

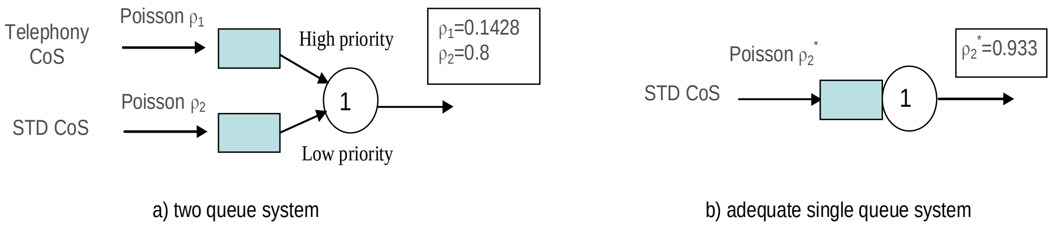

Fig. 5 The approach for analysing low priority (STD CoS) queue size

From the point of view of STD CoS traffic, we may replace the original model (fig. 5a) by a single queue system with Poisson stream as an input and appropriately recalculated ρ_2^*, which considers the impact of the high priority traffic (Telephony CoS) on the low priority one (STD CoS) [12] (see fig. 5b). The load ρ_2^* is determined basing on the following equation:

$$\rho_2^* = \frac{\rho_2}{1-\rho_1} \tag{5}$$

Next, we can approximate the STD CoS queue size probability distribution using the formula proposed in [16]:

$$\Pr ob\{Queue > x\} \approx e^{-2x\frac{(1-\rho_2^*)}{\rho_2^*}} \tag{6}$$

From (6), we can determine the target value of the queue size (X) exceeded only with some small probability P_0:

$$X = \frac{-\rho_2^* LnP_0}{2(1-\rho_2^*)} \tag{7}$$

The equation (7) gives us the information how the target value of the queue size X depends on the chosen probability P_0 and the system load ρ_2^*. If we want to assure that the STD CoS queue size in Ethernet switch will exceed the value L only with probability P_0, we have to set such a threshold T that added to additional queue growth X, offers a value not greater than L, as described in (8):

$$T + X = L \Rightarrow T = L + \frac{\rho_2 LnP_0}{2(1-\rho_1-\rho_2)} \tag{8}$$

The equation (8) provides the guideline to set the value of WRED threshold T when want the STD CoS queue size to be below L with a probability 1-P_0 in the case when the STD CoS load is ρ_2 and the load due to other CoSs (served with higher priority than STD CoS) is ρ_1.

To verify the proposed approach we repeated the simulation study described in section 4.2.1 (table 4). We assumed that the target STD CoS queue size L is 85 packets and the probability of its violation is $P_0=10^{-3}$. Since ρ_1=0.1428 and ρ_2=0.8 then, the equation (8) returns the value of the

WRED threshold T=36. Setting this value in simulation tests we obtained the results presented in table 6.

Table 6: Simulation results of queue size in ES obtained in test with improved threshold tuning.

Tested CoS	**Measured queue size in ES [pkts]**		
	Parameter name Q	**Mean**	**Q_{max}: Prob{Q>Q_{max}}<10^{-3}**
Telephony	Q_{QoS}	0.6	5
STD	Q_{STD}	43	85

5. SUMMARY

In this paper we showed that in some situations Ethernet access network might be a bottleneck in providing strict QoS guarantees, due to limited capabilities to assure traffic isolation in the shared buffer space. To cope with this problem we proposed a solution that engaged additional traffic control capabilities available in the considered Ethernet switch. The tested examples proved that our approach allows assuring target buffer space for given QoS CoS even if the network is congested by Standard CoS traffic.

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