Profile deformation of aggregated flows handled by Premium and low priority services within the Géant network

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ABSTRACT

When providing end-to-end QoS (Quality of Service), the provider of the service states to each network provider the amount of QoS traffic in the form of traffic descriptor. Nonetheless, the profile of the QoS traffic may deform by multiplexing in successive domains invalidating the traffic descriptor. Therefore, studying traffic profile deformation in the domains results crucial in QoS networks.

This paper presents an exhaustive study of Poisson traffic within the Géant network, when the traffic is sent as high or low priority traffic. These studies try to give guidelines of the range of profile deformation in large-scale core networks for QoS implementation. The characteristic of the traffic studied is the self-similarity of the traffic, since self-similarity in Poisson-in-origin traffic indicates burstiness for larger time scales, what may cause unexpected dropping of packets in the policer.

Categories and Subject Descriptors

C.4 [**Computer systems organization**] Performance of systems – design studies, performance attributes.

General Terms

Network, Performance, Design

Keywords

QoS, self-similarity, Traffic descriptor, Poisson traffic, Performance Evaluation

I. INTRODUCTION

The transmission with assured end-to-end Quality of Service (QoS) requires a Service Level Agreement between the service provider and each one of the network providers, which are involved in the end-to-end transmission. We took this approach in the framework of the 6FP IST EuQoS project [7]. The traffic descriptor (TD) tries to delineate the traffic profile and it is the technical base of the negotiation between service and network providers. The network providers may check whether the traffic at the entrance of the domain agrees with the negotiated service. At the network level, this is accomplished by introducing a policer in the ingress router to discard the abusive traffic.

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Nonetheless, the profile of the traffic submitted to successive domains may change because of multiplexing with other traffic; consequently, the traffic profile may be not in compliance with the original TD and the policer may unexpectedly drop packets. This increases the presumable Packet Discard Ratio (PDR) [17] and reduces the quality of the transmission hazarding, in this way, the QoS expectations.

Whereas profile deformation has been well studied in access networks [2], the core domain has not been generally considered. In this paper we studied the Géant network, which fulfills tasks of core network in several European projects. Specifically, we analyzed the profile deformation within the Géant network suffered by the aggregated traffic. Notice that the Poisson model is one of the traffic models for the aggregated traffic [14], [16], which is specially appropriate for high priority traffic.

The steps of the analysis were the following: *Section II* presents the measurements and analyzes the results of the experiments centering on self-similarity of the traffic as parameter of profile deformation. For the analysis, we introduced a novel method to check stationarity of the samples. In *Section III*, the file with the measured samples of the arrived traffic was used in simulations to check whether this traffic provoke longer queues than the original Poisson traffic. This was the final proof to check whether packets of the aggregated traffic may be unexpectedly dropped in the policer. The paper is closed with the conclusions in *Section IV*.

The Géant network

The Géant network has been used as an effective tool to carry traffic with QoS guarantees, since Géant network implements a QoS configuration based on DiffServ architecture [10] and almost all the routers within the network are QoS capable [1].

With the aim of separately treating the different kinds of traffic, the Géant network implements the so-called services. By submitting the different flows to different services, we expect that the traffic will receive different level of transfer (delay, loss ratio and jitter) [11], [12]. Three different services are implemented into the Géant network. These are:

(1) *Premium IP* service provides relative QoS guarantees by ensuring higher priority service in all the schedulers. This service is directed to real time traffic with requirements on delay, jitter and loss rate.

(2) *Best effort* service does not provide any QoS guarantees and by using this service, the traffic is simply transferred as well as possible. This service is the default one and it is advised for non-real time traffic.

(3) *Less than Best effort* service is the last and lowest priority service. The traffic submitted to this service use the network resources (bandwidth), which have been not used by the other two services. The *less than Best effort* service is used for traffic with low priority and large amount of information.
In the proposed scenario for the tests, we sent our traffic by using the *Premium IP* service and the *Best effort* service. When we sent the traffic by the *Best effort* service, this traffic was mixed with the rest of traffic transferring the Géant network. In the case when we sent the traffic as *Premium IP* traffic, then the traffic received a better treatment against the rest of best effort traffic in the network.

Self-similar traffic

The measured characteristics of the *Premium* and *Best effort* Poisson-in-origin traffic were related with the self-similarity. We are interested in self-similarity because it has been demonstrated that the queue length is very sensitive to the self-similar behavior of the traffic [15]. As known, the Poisson traffic is bursty for a time scale of range equal to $1/\lambda$ and it is not bursty for other time scales. Whereas, if the Poisson-in-origin traffic (i.e. traffic that originally was Poisson and whose pattern changes after transferring the network) is self-similar, then this traffic is also bursty for other time scales different to $1/\lambda$. More bursty traffic may cause, in the policer, more losses than expected for the original Poisson traffic described by the TD.
The self-similarity has been largely investigated at the first of the nineties [3], [4]. The studies, which resulted very encouraging at the first time, have fallen into oblivion due to lack of valid and simple models, which introduce self-similar behavior. Moreover, some studies have contradicted the most interesting thesis of the early studies of self-similarity returning modified old network traffic models [14]. Anyway, understanding when a traffic is self-similar results very interesting to forecast its behavior within the network.

II. END-TO-END MEASUREMENTS

As mentioned above, we were interested in investigating the traffic profile deformation of aggregated traffic submitted to high and low priority service in the Géant network. We centered on Poisson-in-origin, i.e., the ingoing traffic to the Géant network is generated by a Poisson process.
Fig. II.1 presents the measurement test bed which connects access networks of two research centers, namely Universitat Politècnica de Catalunya (UPC) and Warsaw University of Technology (WUT). The access networks were connected by the Géant Network and the National Research Networks (NRN) in Spain and Poland.
We avoided any other traffic in the peace of path situated in the universities (WUT and UPC) during the tests. This way, the traffic profile deformation was solely due to the traffic multiplexing in the Géant Network (except for the little smoothing in the profile due to links at the access domains).

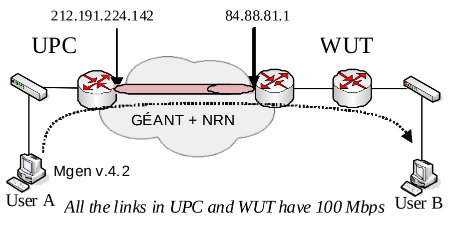

Fig. II.1 Scenario for measurements

User A generated Poisson traffic directed to User B (see Fig. II.1) with rate equal to 100 packet/s and packet size equal to 100 bytes. The traffic was marked as *Premium IP* traffic and, in the following test, as *Best effort* traffic. Remark that, before using *Premium IP* service, we were obliged to send the request to the system and, after affirmative response, the traffic transmission could initiate. User A transmitted the packets by using UDP as the transport protocol. Although the self-similarity has been especially studied with TCP traffic, it has been also stood out that the burstiness experienced at short time scales has long-range dependence even when the traffic is carried by the UDP protocol [15].
The study of self-similarity requires a big quantity of measurements to investigate the traffic at different time scales. Because of this, the experiments counted, at least, 10^7 arrived packets. The tests lasted several hours.
The self-similarity we studied by calculating the Hurst parameter H of the series of measurements. Values of Hurst parameter between 0.5 and 1.0 shows self-similarity, the more near to 1.0, the more self-similar is the traffic [8]. In this case, the traffic is long-range dependent (the values of autocorrelation for increasing lags tend to zero so slowly that their sum does not converge).
To calculate the parameter H of the measured traffic, we applied the graphical R/S analysis, which determines if the measures asymptotically behave as self-similar traffic [9]. The graphical R/S analysis is used to support the behavior shown by the graphs, which indicate the self-similarity. The R/S analysis bases on a heuristic graphical approach [13]. In fact, to calculate the value of H, it would be necessary the complete time series, which is not possible.
Even when we did not know the traffic conditions of the Géant network, we assume that the Poisson traffic submitted to the *Premium IP* service would suffer considerably fewer deformation than this one submitted to the *Best effort* service. The differences in traffic profile deformation should increase when the best effort traffic increases in the network. Anyway, the conditions on the network should be similar in both the experiments. We could not be sure about this point since we do not control the traffic within the Géant network but we assume that the conditions were similar. To confirm this point, the link was ping-ed (*Best effort* service) at the beginning of each test and we verified that the results were very similar confirming the same network conditions. Moreover, the tests were repeated in different days (4 times) and we realized that the results were very similar; this leads us to think that the tests are independent of the network conditions.
In Fig. II.2 one may observe the self-similarity trend of the *Premium IP* service traffic. As we may see, there is no reason to suspect self-similar behavior, so we did not perform the R/S analysis and accepted that this traffic has no (or minor) self-similar behavior after transferring the network.
The behavior of the *Premium IP* traffic shown in the figure is very near to the Poisson traffic. We may conclude that the traffic profile does not suffer excessive deformation when the traffic is carried by *Premium IP* service.
Fig. II.3 shows self-similarity behavior of the arrived traffic transmitted without priority (*Best Effort* service). The graphics show possible self-similar behavior of the traffic. Because of this, we applied the graphical R/S analysis, which determines if the measures asymptotically behave as self-similar traffic [9].

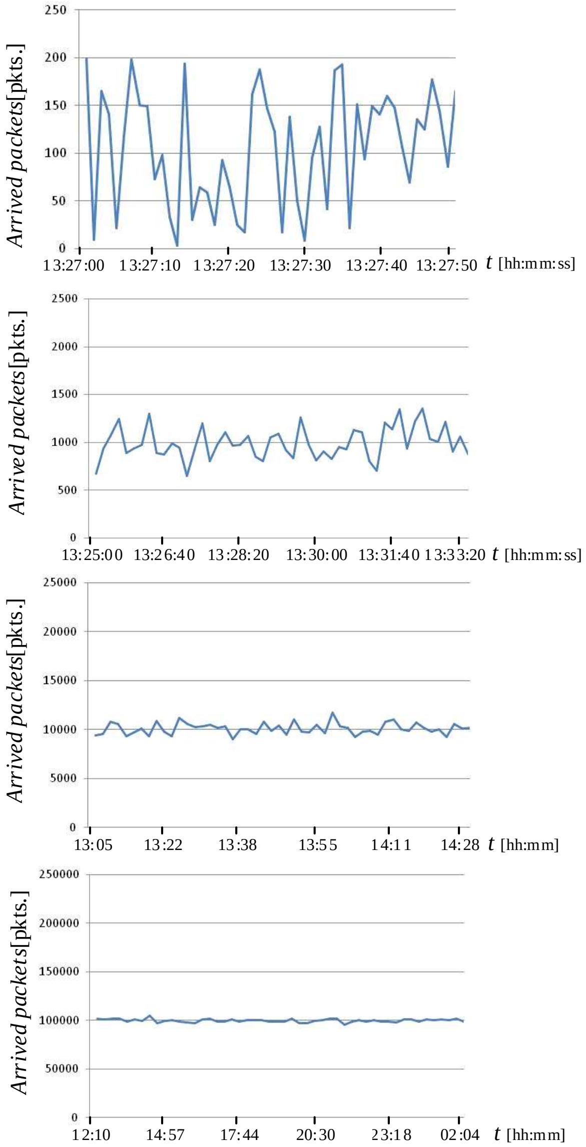

Fig. II.2 Synthesized arrived traffic submitted to *Premium IP* service

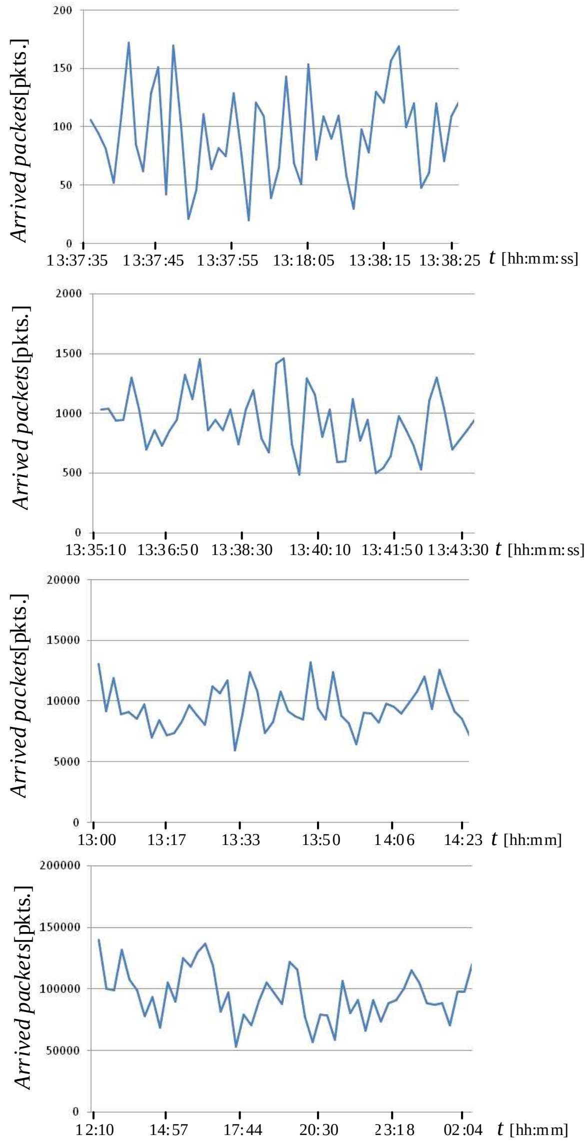

Fig. II.3 Synthesized arrived traffic submitted to *Best effort* service

As known, for a given set of measurements (h_i, i=1..N), with average $\hbar(N)$ and standard deviation S(N), the value of R/S is given by the formula (1):

$$\frac{R}{S} = \frac{\max\{0, w_1,.., w_N\} - \min\{0, w_1,.., w_N\}}{S(N)} \qquad (1)$$

Where w_k is defined by (2):

$$w_k = (h_1 + h_2 + .. + h_k) - k \times \hbar(N), \quad k = 1,.., N \qquad (2)$$

The Hurst parameter H is determined by the tendency of E[R/S] when N increases, as indicated in the formula (3):

$$E[R/S] \propto N^H, \quad as\ N \to \infty \qquad (3)$$

For our measurements, the value of E[R/S] as N increases is presented in Fig. II.4. We calculated the two parameters (A, H) in the function $f(N)=A\times N^H$ as follows:

The measurement samples make up a function, whose derivative may be approximated for each value of N as the tangent of the straight line between adjacent measurement samples. These values of the derivative (for each measured N except the last one) make up a function which should be similar to $f'(N)=A\times H\times N^{H-1}$. We used the method of least squares to find the more appropriate parameters. The other necessary function to find both the parameters we found equaling $f(N=1.2\times10^6)=104.43$, which is the first measurement sample.

The results showed a value H equal to 0.67 for traffic carried by the *Best effort* service.

The low priority traffic had more stressed self-similar behavior. This is in accordance with other studies that find self-similarity in best effort traffic [5]. Self-similarity is not observed in high priority traffic since this traffic is not influenced by the longer *Best effort* queues.

Since the measurements were performed during a long term (until 15 hours for one test), one could ask if the results are not the product of non-stationarity. It means that non-stationary behavior of the network might provoke, by oneself, bursts of traffic. For example, in an European quasi-closed environment as the Géant network, the night traffic is smaller and the peaks of traffic decrease. Other causes for non-stationarity may be the same source, but the source's computer is only dedicated to generate traffic and no other processes are active; so there are no reasons to suspect non-stationarity in such source.

To investigate whether the results might be product of non-stationarity due to cyclic nature processes (as may be night and day traffic), we proceeded as follows: we generated ON-OFF traffic, which was sent from User A to User B (see Fig. II.1) by the *Best effort* service. In the User B, we measured the length of the ON periods, If there is no stationarity in the network, then the length of the ON periods remains constant in time. If cyclical processes exist in the network, then the length of the queues along the path are more variable during heavily loaded periods of time and the length of the ON periods results more variable.

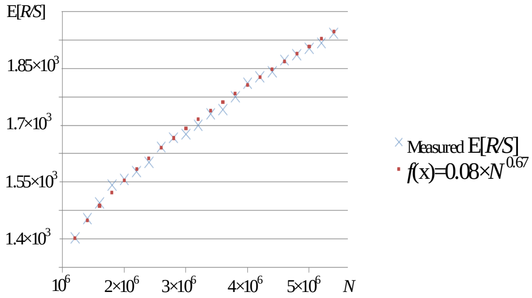

Fig. II.4 E[*R/S*] as *N*→∞ and calculation of Hurst parameter *H*

The OFF period should be much greater than the ON periods to clearly distinguish, in the arrived traffic, when the ON period finishes. In our case, the ON and OFF periods were deterministic and equal to 1 and 5 seconds, respectively.

To calculate the variability of the length of the ON periods, the following steps were taken: we measured in the User B the length of each ON period and grouped these measurements in trials of 100 samples, which arrived to the User B during 10 minutes (the length of ON periods together with OFF periods was, on average, 6 seconds). Afterwards, we calculated the variance inside these trials. Fig. II.5 shows the variance of the trials.

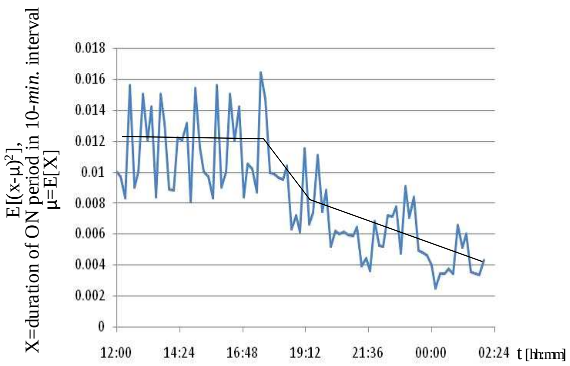

Fig. II.5 Variance of the duration of the ON periods

Fig. II.5 shows that the variance changed in time. In the night hours, the variance of the ON periods decreased because the night traffic found much emptier queues. So, we may conclude that the presented results were non stationary due to day-night cyclic process.

This conclusion might raise doubts about the self-similarity of the traffic. Nonetheless, the self-similarity is also observed for only day hours (see Fig. II.3), it means that, if we took only day measurements, the traffic would behave also with self-similar characteristics. In the previous section, we calculated the Hurst parameter *H* considering samples from both day and night times. When we calculated the Hurst parameter considering only day traffic (the measurements during 5 hours, from 12:00 until 17:00), then the value of *H* decreased only until *H*=0.63, i.e. self-similarity remains.

III. SIMULATION RESULTS

In this paragraph, we investigate whether the burstiness provoked by the profile deformation in the Géant network was stressed enough to provoke unexpected drop of packets by the policers situated at the ingress of the next domain. For this purpose, we introduced the file with the measurement samples (*Premium IP* and *Best effort* traffic) in a simulation scenario with one processor with deterministic service time t_D and infinite queue. We compared the queue length with the M/D/1 system with the same service time t_D and arrival rate λ=100 packet/s (as the measured traffic). If the queue length distribution of the measurement file scenario was longer-tailed than the M/D/1 system, then we should conclude that the policer would drop more packets than expected.

In the simulations, t_D could take any value but it had to be the same for all the simulations. We chose t_D= 0.008 s/packet to obtain a value of load in the system ρ=0.8. The queue was "observed" when a new packet arrived to the queue. These are the values presented in Fig. III.1, which shows queue length values for the *Best effort* traffic, *Premium IP* traffic and M/D/1 system. The two sub-figures of Fig. III.1 represent the same distribution curve, but the top sub-figure shows the low values of the queue length (until 20 packets), instead the bottom sub-figure represents the tail of the distribution (more than 40 packets queue length).

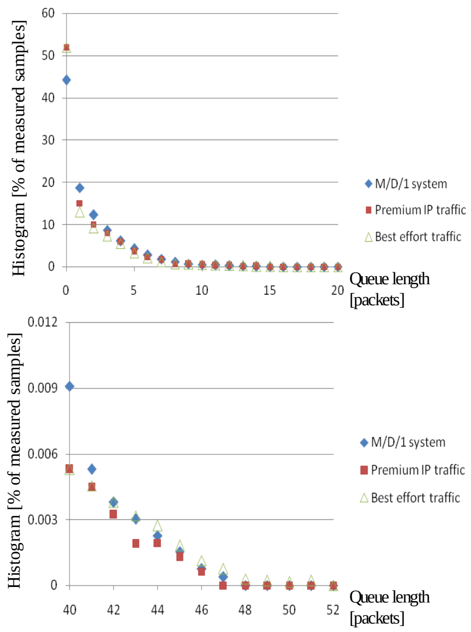

Fig. III.1 Queue length distribution of arrival packets

In Fig. III.1 (bottom) we may see the long range dependence of the *Best effort* traffic, since the distribution decreases more slowly than exponential M/D/1 curve.

Table III.1 presents the values of mean queue length for each traffic, as well as the values of queue length *Q*, for which the queue was longer than *Q* with a probability *p*. The values of $p=10^{-3}$ and $p=10^{-4}$ are typical for QoS traffic.

TABLE III.1. MEAN VALUES OF QUEUE LENGTH AND QUEUE LENGTH FOR WHICH THE QUEUE WAS LONGER THAN Q WITH A PROBABILITY 10^{-3} AND 10^{-4}.

	M/D/1 *Q [packets]*	*Premium IP* *Q [packets]*	*Best effort* *Q [packets]*
Mean value	1.61	1.49	1.52
$P(q>Q)=10^{-3}$	14	11	12
$P(q>Q)=10^{-4}$	40	34	37

For typical values of loss ratio in IP QoS networks, the value *Q* of the M/D/1 system is longer than for the *Best effort* or *Premium IP* network. This means that no *Premium IP* and no *Best effort* traffic would suffer unexpected drops in the policer, which was prepared to accept Poisson traffic with the same rate. Note that, for low values of *p*, we can approximate the value *Q* to the value of the policer's queue length (finite queue). The causes we may find in the fact that the traffic transferring the network experiences smooth of the profile due to service time in the hosts and link capacities. This way, two packets cannot arrive at the same moment as it may occur in the pure Poisson traffic (M/D/1 system). We may conclude that the smoothing experienced by the traffic in the links has more influence in the traffic profile deformation than the self-similar behavior of the Géant network.

In [6], Norros analytically compared the queue length of the M/D/1 system with a model of one processor with deterministic service time and arrival self-similar traffic. The self-similar traffic was the fractional Brownian model for a Hurst coefficient equal to ½. Moreover, he provided formulae for the queue distribution of this system SS/D/1 (SS is this particular case of self-similar traffic). The mean of the queue length may be longer than the M/D/1 system depending on the parameters of the Brownian model. Anyway, Norros does perform a theoretical study and does not consider the practical effects of the network into the profile deformation (smoothing and long-range dependence). In our measurement-approach, we may see the real effect of the network in the profile deformation and we may conclude that, for typical (QoS-typical) values of policers, the arriving traffic should not experience more losses than expected.

IV. CONCLUSIONS

Before drawing inferences, we should warm that the results are taken from specific measurements in a concrete scenario.

In our paper, it was demonstrated that *Premium IP* traffic bears fewer deformation in its profile than the traffic, which transfers the Géant network by using the low priority service.

Other important conclusion is that the Poisson traffic transferring the network with the *Best effort* service, losses the Poisson shape and becomes self-similar. Self-similarity is not observed for *Premium IP* traffic, which preserves the short range dependence.

By comparing the measurement samples with the M/D/1 model, we wanted to understand whether the traffic after transferring the network is more sensitive to dropping by the policer. The results showed that the self-similar tendency of the traffic is counteracted by the smoothing of the network. A policer designed for a drop probability *p* in the case of pure Poisson ingoing traffic (for values of *p* in the range of work of QoS studies, i.e. 10^{-3} and 10^{-4}), would not drop more packets when the ingoing traffic is the traffic that transferred a network like Géant network, even if this traffic was carried by the *Best effort* service.

Further studies should be directed to generalize the results for other networks and other Traffic Descriptors.

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