# Traffic investigation of priority services in IP networks

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*The paper presents an investigation of the quality of service of IP traffic flows, using different queueing disciplines. The main goal is to model the possibility of using a priority scheme, which is optimal for both the priority and non-priority served traffic flows. In case of priority queues, the model covers both cases: preemptive and non-preemptive services. Another schema is modeled, in which the preemptiveness might occur with a predefined or dynamically changed probability. A software platform to simulate the traffic flows and the store-and-forward service is created. Arriving process is modeled by exponential or Pareto distribution. The results show the possibility to use such p-preemptive serving in case of different IP traffic flows. The packet length is modeled with a fixed size, random value with exponential distribution, and bimodal distribution. The model is with infinite queue length and results are given for the packet mean waiting time for both traffic flows – low and high priority.*

***Трафично изследване на приоритетното обслужване в IP мрежи (Димитър Атамян, Северин Мирчев, Росица Голева).*** *Статията представя изследване на качеството на обслужване на трафичните потоци в IP мрежи при прилагане на различни дисциплини на обслужване. Основната цел е да се изследва възможността за въвеждане на приоритетни дисциплини, които да дават оптимални резултати при използване на приоритети за различните видове трафични потоци. В случай на приоритетно обслужване моделът обхваща двата случая: относителен приоритет (non-preemptive) - без прекъсване, и абсолютен приоритет (preemptive) - с прекъсване на обслужването на текущата заявка. Изследва се и дисциплина на обслужване, при която прекъсването на текущата заявка се извършва с предварително зададена или динамично променяща се вероятност. Създадена е софтуерна платформа за симулационно моделиране на реални потоци, както и за моделиране на реалния процес на записване и предаване на пакетите при обслужването им. Изследването е направено при експоненциално разпределение на потока от постъпващи пакети, както и с разпределение на Парето. Резултатите показват възможността за използване на абсолютен приоритет с определена вероятност в случаите на различни IP потоци. В изследването са моделирани различни разпределения на дължината на пакетите – фиксирана дължина, експоненциално разпределена случайна величина, бимодално разпределение. Моделирана е едноканална система без ограничение на дължината на опашката и са дадени резултати за средното време за чакане за два трафични потока – с нисък и висок приоритет.*

## 1. Introduction

Recent IP based networks require different quality of service (QoS). This is based on the fact that these networks provide different applications, which need their specific QoS parameters. From the very beginning of the Internet, the infrastructure and the protocols are prepared to be shared by the different applications with their specific needs. Through the years the IP networks evolved in order to provide the desired QoS in different manner. The common technique is priority serving. Any violation of the natural way of service, namely on a first-come, first-served basis might be considered as priority activation. In priority systems, the customers with higher priority are chosen for service ahead of those with lower priority no mater of their arrival time. On the level of IP packets, the protocols and the hardware provide non-preemptive priority. Preemptive priority techniques are used in IP networks, but on other layers of the traffic [1]. For example, in the MPLS networks, preemptive priorities are used on a call-setup level [2], 4G also assumes that there might be traffic flows which might interrupt (preempt) the current flows served in order to provide the desired QoS. Some techniques which provide Circuit Emulation Services – CES, using preemptive priority are known [3]. As the nature of the IP devices changes, it is important to be able to evaluate the possibilities of using the preemptive priority on the IP level and to try new priority techniques on this level. Because of the variety of traffic sources and the totally different traffic characteristics it is not so easy to obtain results. That is the reason to use the simulation modeling and to present some results and ideas in this paper.

The paper is organized in three sections, introduction and conclusion. The first section presents traffic priorities analysis in IP networks. The simulation model is shown in section two. Third section demonstrates analysis of the main results from traffic models. The paper concludes with comments on the impact of priority application and future work plan.

## 2. IP traffic flows priority

If we consider preemptive priority, the packets with this priority level are served immediately, interrupting the current lower priority packet (if any) [4]. Because of the nature of the Internet Protocol and the organization of the other TCP/IP related protocols, it is possible to implement this preemptive priority, i.e. interrupting the transmission (servicing) of the current packet and starting of the transmission of another high priority packet. This technique may be used also on lower layers like MPLS or LAN/Ethernet. With all these technologies, it is not possible to continue the transmission of the interrupted packet / frame after the completion of the higher priority one. The interrupted packet shall be retransmitted, or simply lost. Thus we can provide a minimum delay for the high priority service, but lower priority flows suffer significant delays or loses.

We propose here to implement the preemption, i.e. interruption of the lower priority flow, to occur with certain probability. This would give the chance to serve the high priority packet with less delay, and to shorten the service time for the lower priority packets.

Due to the increase of streaming and messaging services in Internet it is very important to use proper model for the simulated traffic flows [5]. Exponential distribution of the duration between the arrival moments (interarrival time) is used in classical teletraffic systems. Also exponential distribution of the service time is often used for some services. This is not a good model for all IP traffic flows, but is good in order to obtain reference results and to verify the model and the simulation techniques used. If we look closely on the IP packets, the Internet is full of applications, which use the maximum allowed packet length like file transfer, electronic mail, updates, backups. Also a lot of applications use the same packet length for all the packets in the session like some of the VoIP codecs. This allows us to model the service time with fixed packet size too. Much more precise and close to the reality is the model with bimodal distribution of the service time. We can assume the existence of packets with their maximum length, and the shortest possible packets for TCP flow control [6] like acknowledgements. Pareto distribution is proven to be more accurate for the interarrival process modelling. The results here also can be used to compare the influence of the distribution on the performance parameters of the channels. In such way, we can prove the usage of the different priority scheme.

## 3. Simulation model

The simulation is used to obtain some results and to compare the results with different interarrival and service time distribution. The arrival process in a single server queue is modeled with both distributions – exponential and Pareto, i.e. M/M/1/∞/p, M/D/1/∞/p, M/MM/1/∞/p, Pareto/M/1/∞/p, Pareto /D/1/∞/p, Pareto /MM/1/∞/p teletraffic systems according to Kendall's notation. The service time (packet length) is modeled as a random value with exponential distribution, as a fixed value or as bimodal distribution with different probability for the short and long size packets.

Two traffic flows are modeled – Fig. 1. One of them, assuming to be the main traffic flow, is considered to be "low priority", i.e. general Internet traffic, providing different multimedia or data services. The second one, "high priority" flow, is assumed to be something that needs to be served with minimum delay.

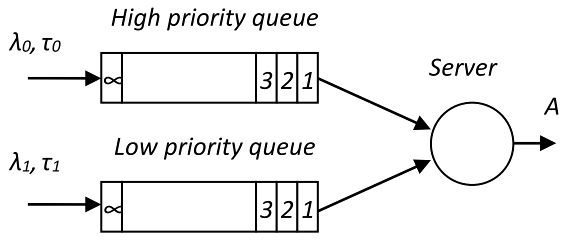


*Fig.1. Priority queue model.*

We assume the system to be loaded at about 80% of its capacity (*A* in all figures) – in such case we avoid overloading but still evaluate and expect significant result of applying the priority schema. Among all possible combination of traffic flows, we assume that for the low priority flow Pareto arrival process and bimodal departure process are enough to cover the Internet traffic behavior. For the high priority flow, we consider exponential and Pareto distributed inter-arrival times and fixed or bimodal distributed packet size.

The service of the high priority flow is modeled as non-preemptive, preemptive, and p-preemptive – interrupting the current low priority packet (if any) with a certain probability. p = 0 covers the case with non-preemptive priority, p = 1 is the case with preemptive priority. Other values between 0 and 1 cover the new suggested p-preemptive priority discipline.

Simulation software is written as a C++ application. Thus we can model exactly the store-and-forward process in nowadays IP nodes. The simulation is performed with a series of 20000 packets. First 20% of the simulated packets are used to put the model in a stationary state and avoid the errors from the initial process. The presented simulation results in this paper show the mean waiting time with acceptable precision because of the high number of generated packets.

**4. Simulation results**

An example results are shown on Fig.2. Two traffic flows are modeled. High priority traffic is modeled as about 20% of the total load. Packet interarrival times are exponentially distributed random values. For the results on Fig.2 we assume exponential distribution of the packet lengths. Results with other distributions are given later. The figure shows the expected waiting time *W,* measured in milliseconds [ms]. The results are "normalized" based on the standard IP packets and a line with 2 Mbps capacity. The two lines show the mean waiting time for the high priority traffic flow (Fig. 2a) for a total load of *A*=0.72 Erl, resp. *A*=0.82 Erl in function of the probability for the preemptive service *p*. The expected waiting time for the same total traffic load for the low priority packets is shown on Fig. 2b. Those results are truncated to reasonable values.

Using the same traffic flows with no priority the corresponding values are 10.6 ms and 20.9 ms for the "high" priority flow and two values of the total traffic, and 13.8 и 25.1 ms for the "low" priority traffic flow. Although we use a no priority scheme, the parameters of the two traffic flows are different: mean packet length of 200 bytes for the "high" priority and 1000 bytes for the "low" priority flow. These values are chosen for convenience to compare the results from this model with the results from the next two models.

These simulation models are the exact store-and-forward serving of the packets. Thus if we have a certain distribution of the interarrival times of the packets, these packets are ready to be served not on their arrival, but on the time of their complete store, which also depends on the distribution of the packet lengths. These packet lengths move, or add an offset to the arrival time for the purpose of the model of the serving device. In some cases like Wi-Fi interface the protocol adds also additional delay in packet processing depending on the configuration and load of the interface.

As explained, the priority system results significant decrease of the packets' mean waiting time with exponential distributed interarrival times and packets size as shown in Fig. 2a. First, it is true for the high priority traffic flow. The priority system results in significant increase of the mean waiting times when it concerns the low priority flows shown in Fig. 2b. Those results are obtained with parameters of the model which are more convenient to be directly compared.

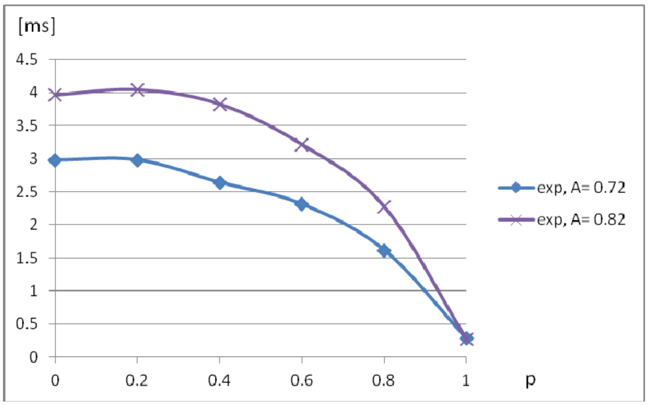


*Fig.2a. Mean waiting time for high priority traffic in M/M/1/∞/p teletraffic system.*

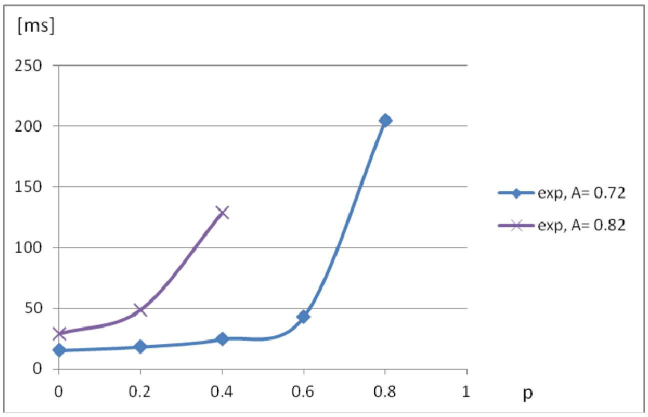


*Fig.2b. Mean waiting time for low priority traffic in M/M/1/∞/p teletraffic system.*

The same parameters of the traffic flows and the service are used to model the same priority discipline, but using fixed packet lengths 200 and 1000 bytes instead of randomly distributed exponential length, i.e. M/D/1/∞/p teletraffic system. The results are shown in Fig. 3a and Fig. 3b respectively for the two traffic flows. The model without priorities gives 4.34 ms and 4.54 ms for a total traffic load of 0.72 Erl, and 11.3 ms and 13.0 ms with a A=0.82 Erl for both flows.

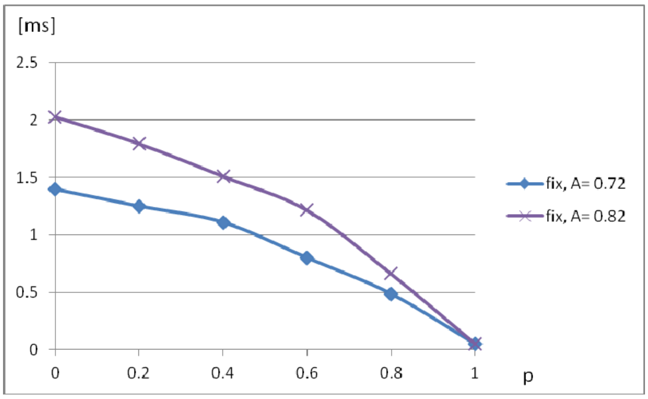


*Fig.3a. Mean waiting time for high priority traffic in M/D/1/∞/p teletraffic system.*

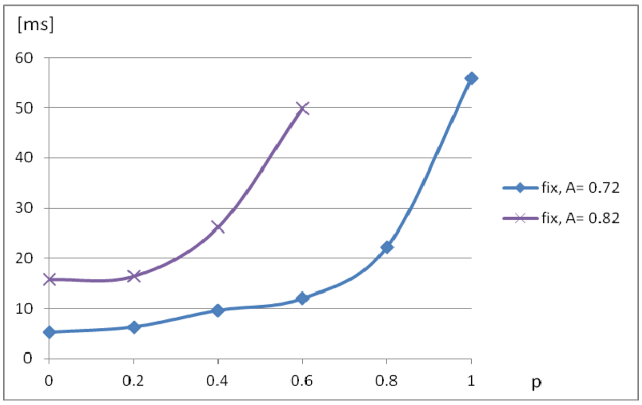


*Fig.3b. – Mean waiting time for low priority traffic in M/D/1/∞/p teletraffic system.*

As we mentioned in the beginning real Internet traffic is more closely to a bimodal distribution of the packet lengths. So more precise results are shown in Fig. 4 for M/MM/1/∞/p teletraffic system with the same exponential distribution of the arrival packets and bimodal distribution of packet lengths – 48 bytes for short packets and 1500 bytes for long packets. It is closer to real internet traffic. Again the probability of the preemptive service is in the same range from 0 to 1. Without priorities, the mean waiting times are 8.73 ms and 13.23 ms for the high priority flow and 9.74 and 14.9 ms for the low priority flow. Here we assume that we may expect long packets in the high priority flow also, for example as in the real TCP traffic. Thus we see slightly higher values for the high priority flow compared to the previous model. From the results we see that the mean waiting time is not so "sensitive", i.e. it changes more smoothly with the change of the probability of the pre-emptive serving of the high priority flow.

Common nowadays IP traffic is most closely modeled as a generalized Pareto distribution of the interarrival times of the packets. Bi-modal distribution of the packet lengths is also close to real assumptions. For the following results we use 50% of the packets to be short (64 bytes) and the remaining to be long (1500 bytes). In this environment we want to evaluate what is the influence and what is the possibility to serve "high" priority traffic, using pre-emptive queue with probability of this pre-emptiveness.

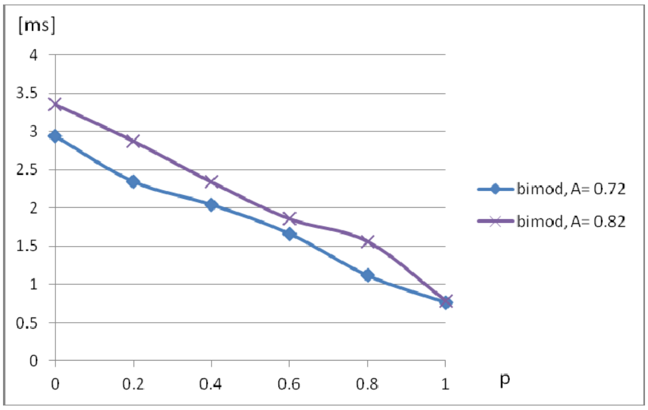


*Fig.4a. – Mean waiting time for high priority traffic in M/MM/1/∞/p teletraffic system*

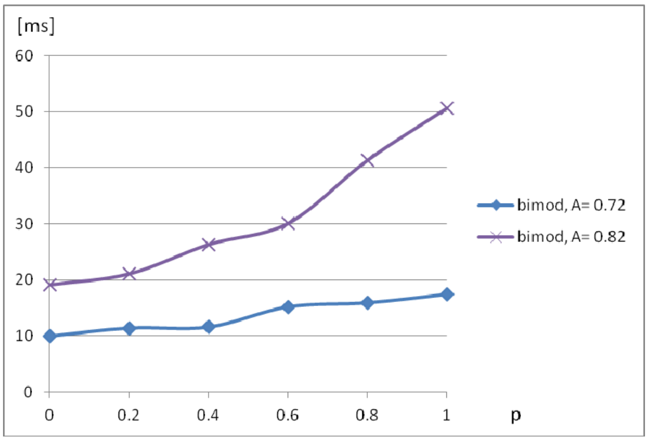


*Fig.4b. – Mean waiting time for low priority traffic in M/MM/1/∞/p teletraffic system*

We model three different cases for priority queueing. The first case is exponential distribution of the packets, but fixed packet length of 200 bytes, i.e.

M/D/1/∞/p teletraffic system. Such scenario might be close to devices, which need to transmit vital information using UDP packets, and expects almost no delays in the queues. The second case uses the same packet lengths, but interarrival times of the packets are modeled with Pareto distribution, i.e. Pareto/D/1/∞/p teletraffic system. In the third case we use again Pareto distribution for the arriving process, but the packet lengths are modeled as bi-modal distribution with the two values – 64 and 1500 bytes with 0.5 probability, i.e. Pareto/MM/1/∞/p teletraffic system. The selected teletraffic systems are applied for the high priority traffic. The low priority traffic is modelled using M/D/1/∞/p teletraffic system in all three cases.

All the results are obtained with a model with high priority traffic equal to 25% of the total load. Traffic load is changed by changing only the rate of the packets with the distribution and packet lengths that we already explained. The results show again the mean waiting time, normalized in ms, but with four different values of the total traffic *A*: 0.63, 0.72, 0.8 and 0.88 Erl. First we show the results for the high priority traffic in Fig. 5a with exponential interarrival process and fixed packet length of 200 bytes, in Fig. 5b with Pareto interarrival process and the same fixed packet lengths, and in Fig. 5c with Pareto interarrival process and bi-modal packet length distribution. We see different behavior in the last case as we have long packets for the bi-modal distribution.

The mean waiting time without priority is also evaluated but is not shown here, as the purpose of the results is to compare and to evaluate the possibility to use different probability of pre-emptivness.

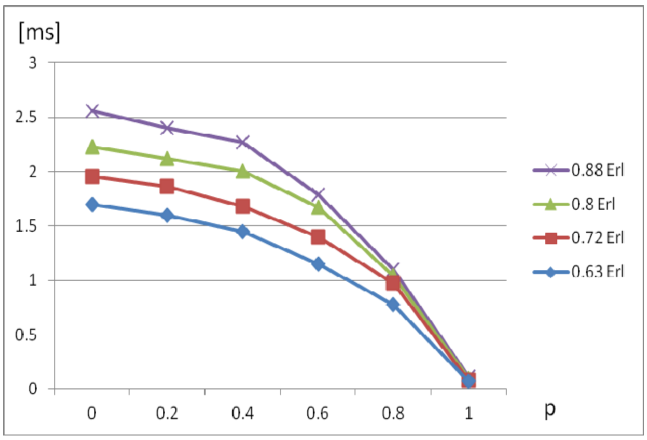


*Fig.5a. – Mean waiting time for high priority traffic with exponential interarrival process and fixed packet length.*

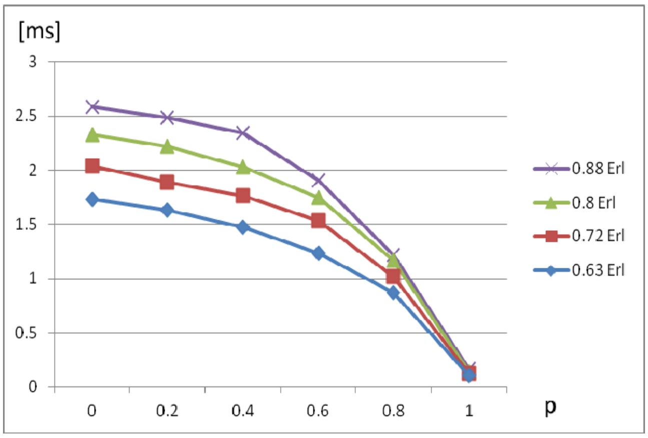


*Fig.5b. – Mean waiting time for high priority traffic with Pareto interarrival process and fixed packet length.*

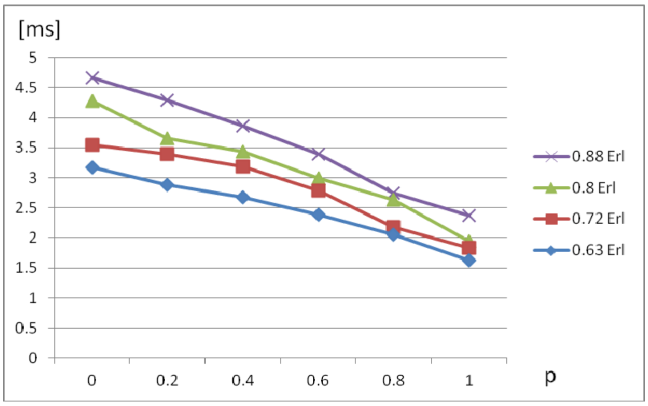


*Fig.5c. – Mean waiting time for high priority traffic with Pareto interarrival process and bi-modal packet lengths.*

As a separate graph in Fig. 6 we show the mean waiting time for the low priority traffic flow. The parameters of the low priority traffic flow are the same in all three cases, but the high priority flow is different, that's why on the figures we notate the parameters of the high priority flow, which makes the service of the low priority flow different.

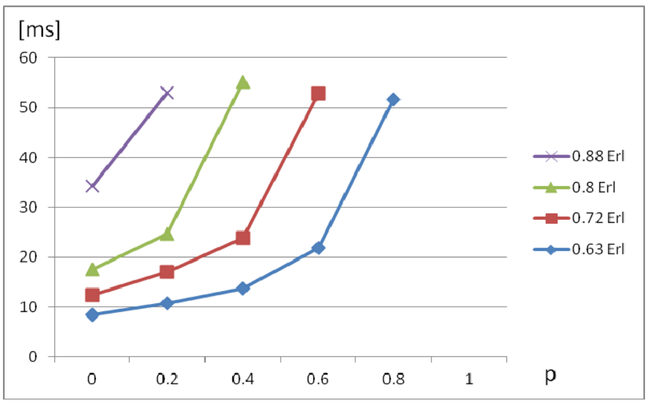


*Fig.6a. – Mean waiting time for low priority traffic with exponential interarrival process and fixed packet length.*

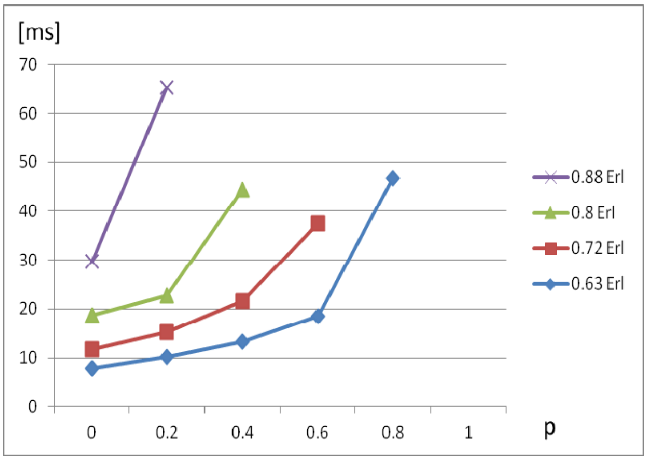


*Fig.6b. – Mean waiting time for low priority traffic with exponential interarrival process and fixed packet length.*

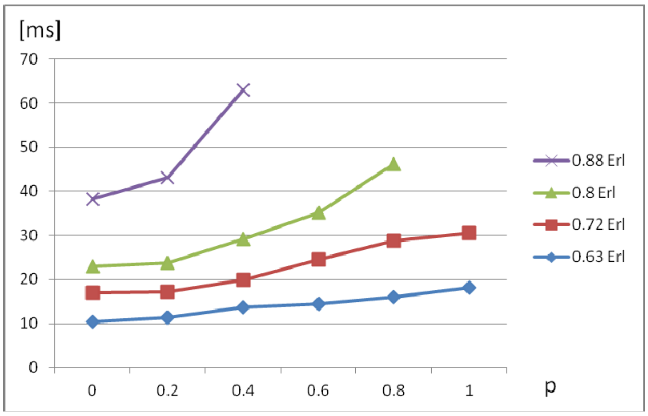


*Fig.6c. – Mean waiting time for low priority traffic with exponential interarrival process and fixed packet length when the high priority traffic is with Pareto interarrival process and bi-modal packet length.*

## Conclusion

This paper presents an investigation of the quality of service of IP traffic flows, using different queuing discipline. We modeled two priority schemas – preemptive and non-preemptive priority, and we propose a new priority schema – preemptive for the low priority flows with a probability, named here p-preemtive priority. Exact store-and-forward IP packet service is modeled. Different IP packet distribution is modeled to compare the behavior of such system. Packets interarrival process analyzed uses exponential distribution or Pareto distribution. Packet lengths are modeled using exponential distribution, fixed packet length and bi-modal distribution.

The results show the area in which the proposed priority service might be applicable. Also the results show the influence of the packet distribution over the mean time delay in different cases. Thus we may conclude that such p-probability for the pre-emptive priority is applicable, but should be used carefully for the specific type of high priority applications and packet distributions due to the high delays in low priority flows. The aim of the authors is to continue analysis of the complex teletraffic systems with p-preemption using simulation due to the high theoretical complexity of the problem [8].

## REFERENCES

[1] Chan, K. Precedence Based Admission Control and Preemption in IP Networks. vol. 00, 2006, pp. 1-7, doi:10.1109/MILCOM.2006.302239

[2] Kaczmarek, S., K. Nowak. Performance Evaluation of Preemption Algorithms in MPLS Networks. Intl Journal of Electronics and Telecommunications, vol. 57, no. 2, 2011, pp. 169–175.

[3] Wen-Kang, J., C. Yaw-Chung. Deploying Circuit Emulation Services (CES) Over EPON Using Preemptive Priority Medium Access Controller. Journal of Network & Systems Management, Vol. 21 Issue 1, 2013, pp. 25-46.

[4] Mirza Golam Rashed, M., M. Kabir. A comparative study of different queuing techniques in voip, video conferencing and file transfer. Daffodil International University Journal of Science and Technology, Volume 5, Issue 1, 2010.

[5] Nguyen, H., T. Nguyen, D. Choi. How to Maximize User Satisfaction Degree in Multi-service IP Networks. First Asian Conference on Intelligent Information and Database Systems, ACIIDS 2009, Dong hoi, Quang binh, Vietnam, 2009.

[6] Castro, E., A. Kumar, M. Alencar, I. Fonseca. A Packet Distribution Traffic Model for Computer Networks. Conference: Proceedings of the International Telecommunications Symposium - ITS, 2010.

[7] Mirtchev, S., R. Goleva, D. Atamian. IP network link capacity evaluation at the packet level by Pareto/BM/1/k queue. Proceedings of the International Conference of Information Technologies, 2016.

[8] Fotakis, D., Algorithms and Complexity - 10th International Conference, CIAC 2017, Athens, Greece, May 24-26, 2017, Proceedings, Lecture Notes in Computer Science 10236, 2017.

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