Analysis of the Impact of Priority Traffic Control Mechanisms on Network Quality of Service

Evgenia A. Abramova

The St. Petersburg National Research University of Information Technologies, Mechanics and Optics (University ITMO), 49 Kronverksky Av, St. Petersburg, 197101, Russia

Abstract

There are many ways of managing traffic in Info Communication networks. The priority ones are the most relevant for consideration to ensure the proper quality for services that have requirements for minimum delays or channel bandwidth. However, choosing the most appropriate way to manage traffic is a task that requires a comprehensive analytical approach. Within the universal package network, the telephony service is one of many services provided. In the corporate sector, there has been a noticeable increase in interest in IP telephony services in recent years, stimulated by some obvious advantages in the form of flexibility and openness of IP systems, the possibility of using various communication solutions (data, video, voice) within a single platform, as well as extensive use of wireless technologies. The purpose of the article is to study the effectiveness of traffic prioritization for Quality of Service (QoS) management in computer networks. Within the scope of the article, simulation modeling is carried out in AnyLogic, the behavior of packet delays of different classes is studied when using various service disciplines. The objects of the study are heterogeneous traffic and its prioritization disciplines with dynamic priorities, as well as Info - Communication systems and communication channels. The subject of the study is the disciplines of traffic maintenance with dynamic priorities within the framework of Info - Communication systems.

Keywords [1]

QoS, traffic, FIFO, WFO, low priority, throughput.

1. Introduction

Today, the era of Big Data has come in the field of Info -Communications. The Internet affects almost all spheres of modern life. Every minute, a huge amount of structured and unstructured data is transmitted over global networks. There is also a stable annual growth in the number of Internet users.

The main problem of the Big Data era is to optimize resources and increase the efficiency of data transmission. It should be noted that traffic cannot be considered as a single whole, for various network services, certain types of network traffic should be selected that meet the efficiency criteria for the maximum number of simultaneously working users. At the same time, practical limitations in the form of the width of communication channels and the limited power of network equipment are taken into account [1].

The work is intended to evaluate the effectiveness of traffic management mechanisms on the global Internet. This goal is achieved by solving the following tasks:

- Determining service quality indicators
- Study of traffic varieties and their heterogeneity
- Analytical review of service disciplines

Proceedings of VI International Scientific and Practical Conference Distance Learning Technologies (DLT–2021), September 20-22, 2021, Yalta, Crimea
EMAIL: vectra4444@mail.ru
ORCID: 0000- 0002-5637-7427

- Comparative analysis of existing traffic management mechanisms

In the article, the concept of quality of Service is considered, which implies the solution of two main tasks:

1. Creating and maintaining the order of receipt of packages
2. Minimizing delays and ensuring positive dynamics of packages transmission

2. Setting the Research Task

The use of data package switching technology can not guarantee high throughput in information and communication networks. The reason for this is the lack of guarantees for the delivery of the package. In some applications, the order and delivery intervals do not affect the performance and quality of user interaction. At the same time, for others, these parameters are fundamental. High traffic service requirements are not met by the TCP and UDP transport layer protocols because TCP allows some possible delays in delivery, although it guarantees the correct delivery of packets, and UDP can reduce delays, but does not provide high-quality traffic service and mechanisms for implementing such. At the same time, it is necessary to guarantee the delivery of such information like audio, video, and multimedia in real-time with the minimum possible delay [2]. The primary tasks of the Quality of Service (QoS) mechanism are:

- Creating and maintaining the order of receipt of packages
- Minimizing delays and ensuring positive dynamics of packet transmission
- Maintaining a high quality of service in the field of IP telephony

The quality of service is defined as "the total effect of the operating parameters of the service, which determines the degree of user satisfaction with this service". (ITU-T Recommendation E. 800) To be able to quantify the quality of service in the network, it is necessary to introduce some numerical parameters. The following parameters are used to evaluate QoS:

- Average packet Delivery Delay (IPPacket Transfer Delay). IPTD is defined as the sum of the delivery times of all packets between the source and the recipient, divided by the number of packets [3].
- Delay variation, jitter (IP Packet Delay Variation). IPDV determines the variability of the delay in the delivery of consecutive packets.
- Packet Loss Ratio (IP PacketLoss Ratio). The IPLR parameter determines the percentage of packets lost during transmission out of the total of all sent packets.
- Packet Error Rate (IP PacketError Ratio). IPER determines the percentage of received packets that have changed during transmission [4].

3. Maintenance Disciplines

FirstInFirstOut is one of the simplest maintenance disciplines, the essence of which is to process packets in the same order in which they are initially queued. The use of this discipline in the case of processing large traffic flows simultaneously leads to the dominance of several of them, which negatively affects the efficiency of using network resources.

Priority Queueing is a maintenance discipline that involves using a combination of several queues that are processed using the Taildrop or RandomEarlyDetection buffering disciplines and using the FirstInFirstOut service discipline within themselves [5]. The distribution of packets to these queues occurs according to the class of these packets. Then the packets are selected sequentially from these queues, starting with the queue corresponding to the highest priority. The disadvantage of this discipline is the fact that packets with low priorities can be processed with significant delays, in some cases, there may be losses of communication sessions organized using packets with low priorities.

WeightedFairQueueing is a maintenance discipline in which a separate queue using the FirstInFirstOut discipline is allocated for each traffic class, as well as the allocation of a certain share of the channel bandwidth for each of these queues [6,7]. The order of servicing these queues, as well as the capacity of the allocated share of the channel bandwidth, are determined by the packet priorities.

4. The Setting of the Experiment

Let us set the following parameters for the study:
Throughput capacity: N = 6 Mbps.
Buffer size: S = 10 Kb.
Priorities WFQ: W1 : W2 =7:1, W1 = 0.875 W2 = 0.125

Table 1
Parameters for Skype messenger and streaming service Twitch

Parameters	Skype	Twitch
Delay, ms	100	1000
Jitter, ms	50	-
Loss of packets, part	0.001	0.001

The capture of VoIP traffic is carried out as follows: the detection of opened Skype program ports, detection of the port and address that has the greatest activity during the call, the capture of the traffic with the filter (Fig. 1).

254	7.922	157.56.198.40	192.168.1.26	UDP	79 2002 → 62789 Len=37
255	7.942	157.56.198.40	192.168.1.26	UDP	117 2002 → 62789 Len=75
256	7.962	157.56.198.40	192.168.1.26	UDP	175 2002 → 62789 Len=133
257	7.983	157.56.198.40	192.168.1.26	UDP	176 2002 → 62789 Len=134

Figure 1: Screenshot of Skype traffic

VOD traffic is captured as follows: determining the address through which video traffic goes using the browser's debugging console; capturing traffic with a filter (Fig. 2).

1	0.000000	52.223.193.247	192.168.1.26	TLSv1.2	841 Application Data
2	1.301596	52.223.193.247	192.168.1.26	TLSv1.2	841 Application Data
3	1.348996	52.223.193.247	192.168.1.26	SSL	1506
4	1.349704	52.223.193.247	192.168.1.26	TLSv1.2	1506 Ignored Unknown Record

Figure 2: Screenshot of Twitch traffic

If we consider the packet length distribution functions for UDP and TCP traffic, we can see that UDP packets (Fig. 3) have a fixed maximum size, unlike TCP packets (Fig. 4). In case of loss of a TCP packet, it will be requested again, and the information will not be lost, unlike UDP - in case of loss of a packet, it is lost forever[8]. Therefore, it is necessary to transmit smaller UDP packets in order not to lose large parts of data. As for the distribution function of inter-packet intervals, they are similar in TCP and UDP and are close to the exponential distribution function.

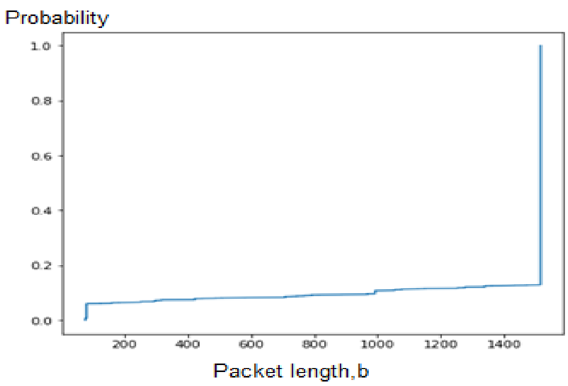

Figure 3: Packet length distribution function for UDP traffic

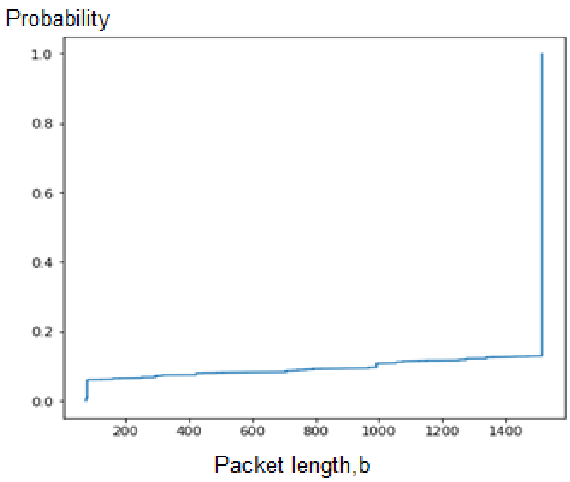

Figure 4: Packet length distribution function for TCP traffic

4.1. Study of FIFO Discipline

FIFO - an elementary queue without prioritization: each traffic class receives the same amount of service, taking into account the delay when issuing in the communication channel. Experiments with throughput values did not lead to obtaining characteristics that meet the specified requirements （Fig. 5, Table 2). This result is associated with a large packet size and a small-time interval between packets: the specified buffer size and bandwidth are not enough for the selected type of traffic. When trying to increase the initial parameters, the following results were obtained (Fig. 6, Table 3)

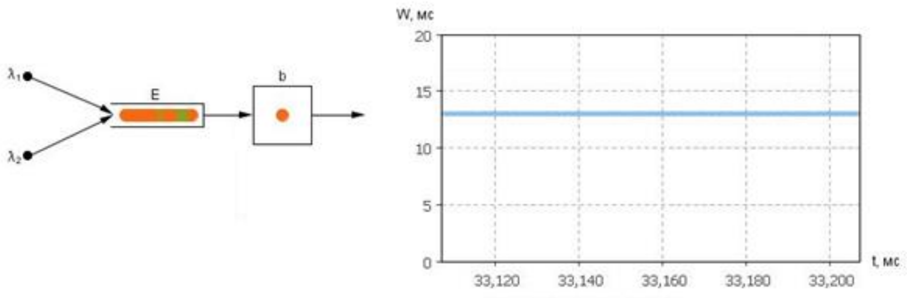

Figure 5: The average waiting time in the model with a capacity of 10 Kbytes and a bandwidth of 6 Kbit/s

Table 2
Parameters of the FIFO model with a capacity of 10 Kbytes and a bandwidth of 6 Kbit/s

Parameters	Values
Loading, p	1 +- 2.64E-5
Chance of loss, π	0.647 +-4.434E-5
Average waiting time, W, ms	12.986 +- 0.001
Average stay time U, ms	13.365 +- 0.002
Current packet queue length	34
Average I packet queue length,	34.346 +-0.025

Picture 6 shows that now the average stay time and the probability of losses are within the normal range. As a result of the iterative increase of throughput, the model met the QoS criteria better and better: the delay and the probability of loss decreased.

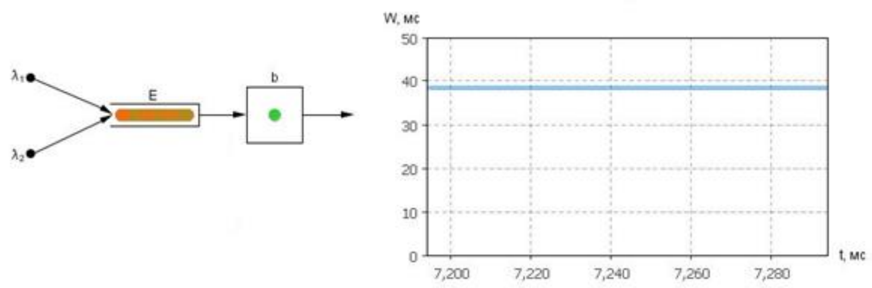

Figure 6: The average waiting time of the model with a capacity of 10000 Kbytes and a bandwidth of 20.5 Mbit/s

Table 3
Parameters of the model with the capacity of 10000 Kbytes and a bandwidth of 20.5 Mbit/s

Parameters	Values
Loading, p	1 +- 1.279E-4
Chance of loss, π	0.179 +-2.314E-4
Average waiting time, W, ms	38.407 +- 0.028
Average stay time U, ms	38.57 +- 0.028
Current packet queue length	238
Average I packet queue length	235.75 +-0.423

4.2. Study of PQ Discipline

Priority is set for different traffic classes: low-priority class traffic is transmitted only when there are no high-priority class packets in the queue. Thus, the best quality of service is provided for the high-priority class, but the low-priority class is blocked during overloads. It can be seen from the schemes (Fig. 7,8,9) and tables (Table 4,5) that the change in the bandwidth strongly affects low-priority traffic. As in the previous case, with variations of the bandwidth, it is not possible to achieve the required qualities.

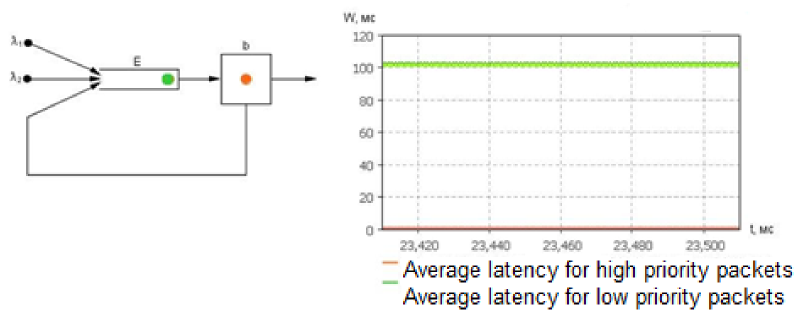

Figure 7: AnyLogic model scheme with the capacity of 10 Kbytes and a bandwidth of 6 Kbytes/s

Table 4
Table of parameters of the model with a capacity of 10 Kbytes and a bandwidth of 6 Kbytes/s

Parameters	Values
Loading, p	1 +- 3.767E-5
Chance of loss, π	0.66 +-9.465E-5
Average waiting time, W, ms	0.215 +- 0.02
	101.541 +- 0.277
Average stay time U, ms	0.592 +- 0.002
	103.331 +- 0.588
Current packet queue length	24
Average I packet queue length	24.783 +-0.036

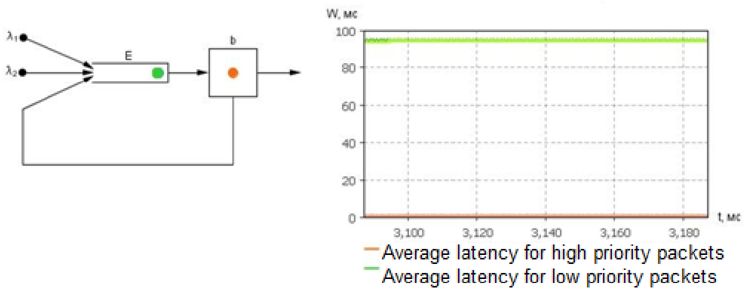

Figure 8: AnyLogic model scheme with the capacity of 10 Kbytes and a bandwidth of 20.5 Mbit/s

Table 5
Table of parameters of the model with a capacity of 10 Kbytes and a bandwidth of 20.5 Mbit/s

Parameters	Values
Loading, p	1 +- 3.754E-4
Chance of loss, π	0.185 +-5.26E-4
Average waiting time, W, ms	0.005 +- 2.961E-4
	94.088 +- 0.184
Average stay time U, ms	0.137 +- 8.892E-4
	94.803 +- 0.325
Current packet queue length	143
Average I packet queue length	144.801 +-0.564

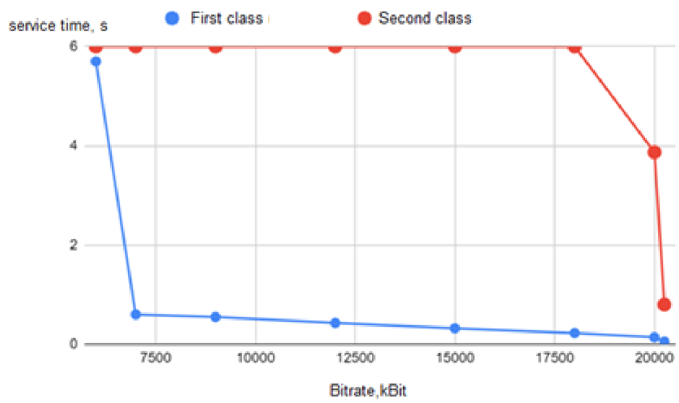

Figure 9: The scheme of the dependence of the service time on the bandwidth for PQ

4.3. Study of the WFQ Discipline

Weight is set for each traffic. For each cycle of the WFQ operation, packets are transmitted from the queue of one class, the total size of which is equal to the weight of the class. Setting the weight guarantees that a class with a higher weight will receive a higher quality of service, and that in conditions of high load, the class will receive a channel in a finite time[9,10].

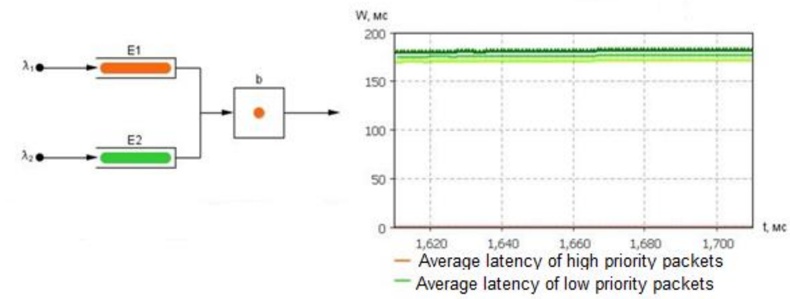

Figure 10: AnyLogic model scheme with a capacity of 600 Kbytes and a bandwidth of 600 Kbytes/s

When the weights were varied, the results improved slightly (Pic. 10.11). As in the previous case, with the variation of the bandwidth, it is not possible to achieve the required qualities. The lowest bandwidth value was achieved at 23000 bps (Table 6,7). When varying the weights at this throughput and some values below, it was not possible to achieve significantly better results.

Table 6
Table of parameters of the model with a capacity of 600 Kbytes and a bandwidth of 600 Kbytes/s

Parameters	Values
Loading, p	1 +- 4.709E-4
Chance of loss, π	0.499 +- 0.003
	0.891 +- 0.004
Average waiting time, W, ms	0 +- 0
	177.249 +- 5.031
Average stay time U, ms	0 +- 0
	180.58 +- 5.079
Current packet queue length	354
	228
Average I packet queue length	343.702 +- 2.415
	184.463 +- 1.867

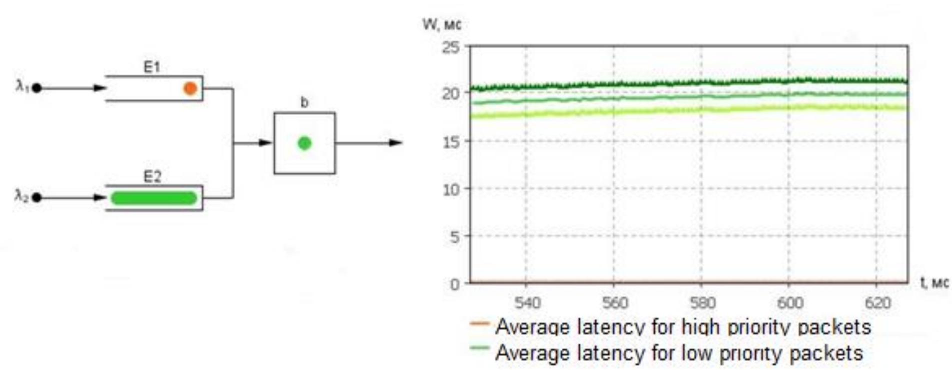

Figure 11: AnyLogic model scheme with a capacity of Kbytes and a bandwidth of Mbit/s

Table 7
Table of parameters of the model with a capacity of 600 Kbytes and a bandwidth of 600 Kbytes/s

Parameters	Values
Loading, p	1 +- 0.001
Chance of loss, π	0 +- 0
	0.451 +- 0.007
Average waiting time, W, ms	0 +- 0
	19.785 +- 1.373
Average stay time U, ms	0 +- 0
	21.048 +- 1.455
Current packet queue length	1
	151
Average I packet queue length	2.194 +- 0.109
	136.205 +- 2.574

The WFQ discipline gives zero latency for high-priority packets, unlike PQ. In both cases, changing the bandwidth greatly affects low-priority traffic. (Fig. 12,13)

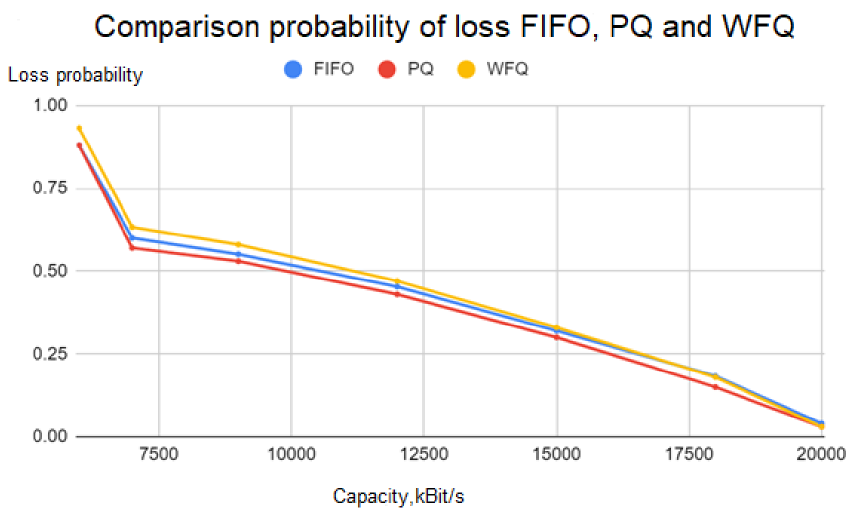

Figure 12: Scheme of changes in the probability of bandwidth losses for FIFO, PQ, and WFQ

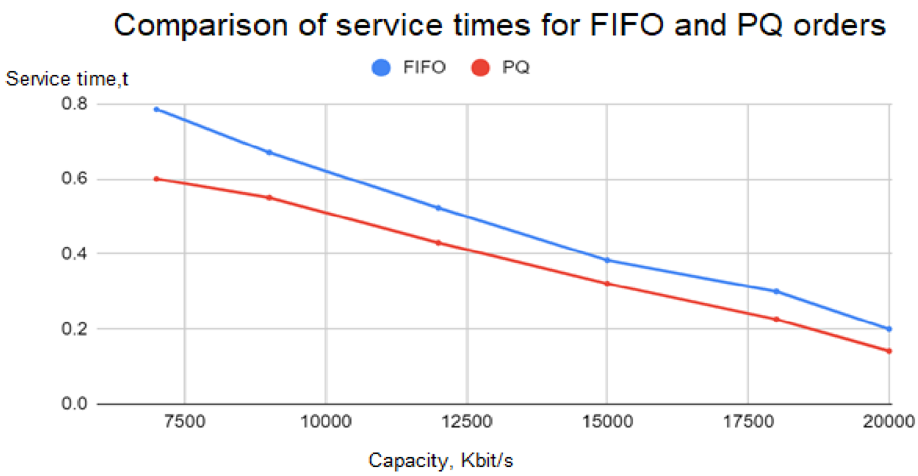

Figure 13: Scheme of change of service time due to the bandwidth for FIFO and PQ

5. Conclusion

As a result of the work, the following results were obtained:

1. When the bandwidth of the channel increases, the characteristics decrease to a certain threshold, after which the bandwidth increase has no effect
2. The FIFO Service Discipline does not provide traffic management mechanisms.
3. The PQ Service Discipline provides an elementary control mechanism that cannot handle overload cases.
4. The WFQ Service Discipline provides a traffic management mechanism by assigning weights to the classes into which traffic is divided; it is more flexible than the previous two, and it copes with congestion better than PQ.
5. The initial configuration (6 Mbit/s bandwidth and 600 Kbyte/s buffer) is unacceptable when applying any Service Discipline in the case of simultaneous use of Skype and Twitch.
6. If it is necessary to separate the quality of service and the minimum bandwidth, WFQ will be a suitable option, otherwise, FIFO will do.

6. References

[1] V.A. Bogatyrev, A.V. Bogatyrev, S.V. Bogatyrev, Redundant Servicing of a Flow of Heterogeneous Requests Critical to the Total Waiting Time During the Multi-path Passage of a Sequence of Info-Communication Nodes. Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). 2020. Vol. 12563. pp. 100-112. DOI 10.1007/978-3-030-66471-89.

[2] V.A. Bogatyrev, S.V. Bogatyrev, A.N. Derkach, Timeliness of the Reserved Maintenance by Duplicated Computers of Heterogeneous Delay-Critical Stream. CEUR Workshop Proceedings. 2019. Vol. 2522. pp. 26-36.

[3] V.A. Bogatyrev, S.V. Bogatyrev, A.V. Bogatyrev, Redundant multi-path service of a flow heterogeneous in delay criticality with defined node passage paths. Journal of Physics: Conference Series, Volume 1864, 13th Multiconference on Control Problems (MCCP 2020) 6-8 October 2020, Saint Petersburg, Russia 2021 J. Phys.: Conf. Ser. 1864 012094 - 2021, Vol. 1864, 012094, No. 1, pp. 012094. DOI 10.1088/1742-6596/1864/1/012094.

[4] M. Rouached, W. Fdhila, and C. Godart, Web services compositions modeling and choreographies analysis, International Journal of Web Services Research, vol. 7, no. 2, pp. 87–110, 2020.DOI: 10.4018/jwsr.2010040105

[5] L. Li, S. Li, and S. Zhao, QoS-Aware scheduling of services-oriented internet of things, IEEE Transactions on Industrial Informatics, vol. 10, no. 2, pp. 1497–1507, 2014.DOI: 10.1109/TII.2014.2306782

[6] W. Sugeng, J.E. Istiyanto, K. Mustofa, and A. Ashari, "The Impact of QoS Changes towards Network Performance", International Journal Computer Networks and Communications Security, vol. 3, no. 3, pp. 48-53, February 2015. DOI: 10.34128/jsi.v5i2.191

[7] D. Mistry, P. Modi, K. Deokule, A. Patel, H. Patki, and O. Abuzaghleh, "Network traffic measurement and analysis", 2016 IEEE Long Island Systems, Applications and Technology Conference (LISAT), Farmingdale, NY, pp. 1-7, 2016. DOI: 10.1109/LISAT.2016.7494141

[8] R. S. Matos, P. R. M. Maciel, and R. M. A. Silva, QoS-driven optimization of composite web services: An approach based on GRASP and analytical models, International Journal of Web and Grid Services, vol. 9, no. 3, pp. 304–321, 2013.

[9] Ga-Won Lee, Sung-Young Lee, and Eui-Nam Huh "Congestion Prediction Modeling for Quality of Service Improvement in Wireless Sensor Networks", Sensors, 14, 7857-7880, 2014 DOI: 10.3390/s140507857

[10] E.A Abramova, I.V. Kalinin, D.A. Mezentsev, L.A. Muravyeva-Vitkovskaya, Models and research methods of heterogeneous traffic control processes in information and communication systems // 20th International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM-2020 - 2020, No. 2.1, pp. 223-230.