А.В. Рындин [A.V. Ryndin],

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# МЕТОД ПРИОРИТЕТНОЙ МУЛЬТИПОТОКОВОЙ ПЕРЕДАЧИ МНОГОМОДАЛЬНЫХ СООБЩЕНИЙ

# METHOD OF PRIORITY MULTIPATH MULTIMODAL MESSAGES TRANSMISSION

***Южный федеральный университет/ Southern Federal University***

***Аннотация***

*В статье представлен метод, позволяющий распределять протокольные блоки данных многомодальных сообщений на транспортном уровне модели OSI, учитывая их приоритет. Рассмотрена его реализация в имитационной среде AnyLogic, получены результаты имитационного моделирования с применением разработанного метода и без него.*

**Ключевые слова:** мультипотоковая передача данных, многомодальное сообщение, модальность, имитационное моделирование

***Abstract***

*The paper presents a method that allows to allocate protocol data units of multimodal messages at the transport layer of the OSI model, considering their priority. Its implementation in the AnyLogic simulation environment is developed, the results of simulation modeling are obtained with the developed method and without it.*

**Keywords:** multipath data transmission, multimodal message, modality, simulation modelling

## Introduction

With the widespread use of personal means of communication, such as tablets, smartphones, questions of their individualization arise. This means that the user device must adapt to the characteristics and needs of the user in order to provide maximum comfort. In such a scenario, the use of traditional user interfaces becomes inappropriate, they are replaced by multimodal interfaces - interfaces that provide a choice of modalities for transmitting various types of information and their sharing [1].

Modality should be understood as a physically recorded element of communication (human-machine and / or interpersonal), including both the information itself transmitted (message) and information about the individual himself (his state; attitude to the message, to the interlocutor, to communication, etc.) [2]

On the other hand, modern personal communication media of users are equipped with multiple communication interfaces and use wireless communication for data transmission. Although wireless network throughput is predicted to increase significantly in the coming years [3], the amount of transmitted traffic will also increase. This is due, on the one hand, to the growth of the Internet of Things (IoT) technology, on the other hand, the role of telecommunications in professional activities, training and public relations is significantly increasing. Thus, in the structure of information flows, the share of services that consume significant amounts of the data transmission resource increases [4]. Thus, the trend of data transmission over wireless communication channels is also relevant for multimodal information systems.

In addition, one should take into account the fact that the wireless user device does not have a permanent connection to any access point (base station) that would guarantee the required level of quality, since it has a large spatial dynamics. In this case, the user can move to areas with a critically weak network signal or no network signal at all, or to areas with a large number of users sharing the channel capacity.

**Investigation of the problem and its current state**

The analysis of the subject area showed that the issues of multimodal information transmission in communication networks have not yet been worked out: there are no recommendations and a unified approach to the transmission of various modalities. Moreover, the issue of using a multistream scheme for transmitting multimodal information has never been considered.

One of the solutions to these problems can be the development of models, as well as methods and algorithms for transmitting multimodal information by using a multistream data transmission scheme. In this case, protocol data units (PDUs) of modalities of the same transport stream of a multimodal message are distributed among several transport substreams, each of which has its own route.

Due to one of the main principles of the architecture of the worldwide network - the "End-To-End" principle [5], it is not desirable to interfere with the work of the flow within the network, this should be done at the ends of the connection. Therefore, the distribution of PDU between communication channels must be carried out on the terminal sides of the interaction.

In addition, we believe that modalities within a multimodal message have different priorities. The ranking of modalities by priority is relevant for various systems of multimodal interaction, for example, for systems of infocommunication interaction of officials of the public administration system with the determination of their psychophysical state [6], or for multimodal authentication systems [7].

To solve this problem, a method was developed for priority multistream transmission of multimodal information, which makes it possible to increase the efficiency of data transmission. In this case, efficiency is understood as a reduction in PDU losses of a multimodal message.

**Proposals and prospects for solving the problem**

In the study, we assume that the system of multi-stream information transfer has a client-server architecture (consists of a source and a receiver). On the source side, PDUs of multimodal messages are generated, and on the receiver side, service PDUs are generated, which allow to determine the data transfer statistics.

of multi-modal $N$data are: a $\mathrm{L} = \{L_1, L_2, \dots, L_N\}$,multi -modal message consisting of a PDU $K$of modalities of different priority levels with the $X = \{X_1, X_2, \dots, X_K\}$volume

The output parameters are the modalities PDUs distributed to the available transmission substreams.

***The initial phase of the method of priority multistream transmission of multimodal information***

At the initial moment of time, the data transmission system does not have information about the throughputs and transmission delays of available communication channels if the communication interface was not used before the start of the multimodal subsystem. One solution is to check the availability of the node using the ping command ( ICMP protocol ) in order to get the first value of the round trip ( Round - Trip Time , RTT ), however, in this case, the multistream protocol loses the ability to send data on new substreams. Another solution might be to use the Round algorithm Robin and automatically switch to the substream that shows the lowest RTT or the highest throughput. However, in the case of a large heterogeneity in the characteristics of substreams, the problem of blocking the head of the queue ( Head - of - line blocking ). The most obvious solution is redundant modality messaging. This is due to the lack of data on the indicators of the quality of service of communication channels. The transmission of the same data on all available communication channels increases the probability of data delivery, but does not guarantee optimal use of the channel resource. The recalculation of network service quality indicators occurs after receiving service PDUs on each of the communication channels.

After receiving the first service PDU, according to the priority multistream data transfer method, it is necessary to calculate the available bandwidth of the available communication channels as follows:

$$C_i(t_1 - t_0) = \frac{(X_i(t_1 - t_0) + A_i(t_1 - t_0)) * (1 - \omega_i(t_1 - t_0))}{t_1 - t_0}, \quad (1)$$

where $t_0$is the time of departure of the first group of PDUs along the subflow $i$, $t_1$is the time of receipt of the first group of PDUs, $X_i(t_1 - t_0)$is the amount of PDUs of a multimodal message sent in the stream $i$over time $t_1 - t_0$, $A_i(t_1 - t_0)$is the amount of PDUs of third-party applications sent in the stream $i$over time $t_1 - t_0$, $\omega_i(t_1 - t_0)$is the number of losses in the stream $i$over time $t_1 - t_0$.

Thus, the method of priority multistream transmission of multimodal information makes it possible to obtain the first portion of statistics. Further, according to the method, it is necessary to initiate the procedure for distributing PDUs of a multimodal message between the available communication channels without retransmitting the same packets to flows, but in accordance with the policy of distributing PDUs of a multimodal message to subflows.

**Distribution of PDUs of a multimodal message into substreams**

After the initial phase and the definition of the primary set of communication channels for sending data and their characteristics, the method of priority multistreaming of data determines the logic for distributing PDU modalities to the available communication interfaces. Each multimodal message has a lifetime $ttl$after which it will not be transmitted. This is due to the fact that these modalities are sensitive to delay and $ttl$will be irrelevant after the deadline in multimodal communication. To ensure the transmission of high-priority modalities, the developed method ranks PDUs of modalities of different priority within a multimodal message: $X = \{X_j\}, j = \overline{1, K}$. In this case, we assume that multimodal messages certainly have a higher priority than data from other applications.

The amount of data that can supposedly be transferred (resources) within the lifetime of a multimodal message for each of the substreams is calculated:

$$Y_i = ttl * C_i(\tau) \quad (2)$$

and the total amount of data that can be transmitted across all substreams within $ttl$:

$$Y = \sum_{i=1}^{L} Y_i \quad (3)$$

The obtained values of the volumes of resources are ranked from the largest to the smallest:$Y = \{Y_i\}, i = \overline{1, L}$

Next, within the framework of the method of priority multi-streaming of multi-modal messages, it is checked whether PDUs of a multi-modal message $X$can be transmitted within its lifetime on any sub-stream. If the condition is achievable, then the multimodal message is completely distributed to one of the substreams. Otherwise, the PBDs of each modality are distributed separately $X_j, j = \overline{1, K}$. In this case, if modality PDUs have already been allocated to one of the substreams, the free amount of resources in this substream is checked to allocate PDUs of the current modality.

If the PDUs of any modality cannot be allocated to any substream (the resources are all busy), then the PDUs of the modality are allocated to the next substream. If modality PDUs cannot be allocated to any substream, then they are distributed in parts, starting with high priority, to all substreams until all modality PDUs have been allocated or all available resources are occupied.

This approach can be illustrated by the following example (Fig. 1): a multimodal message consists of PDUs of three modalities of different priority $X = \{X_1, X_2, X_3\}$, the user device has two communication interfaces $L = \{L_1, L_2\}$. Assume that a multimodal message $X$cannot be transmitted in its entirety on one of the substreams. Then, according to the developed method, it must be fragmented into modalities $\{X_1, X_2, X_3\}$, which will be distributed among substreams depending on the amount of data that can be transmitted by them.

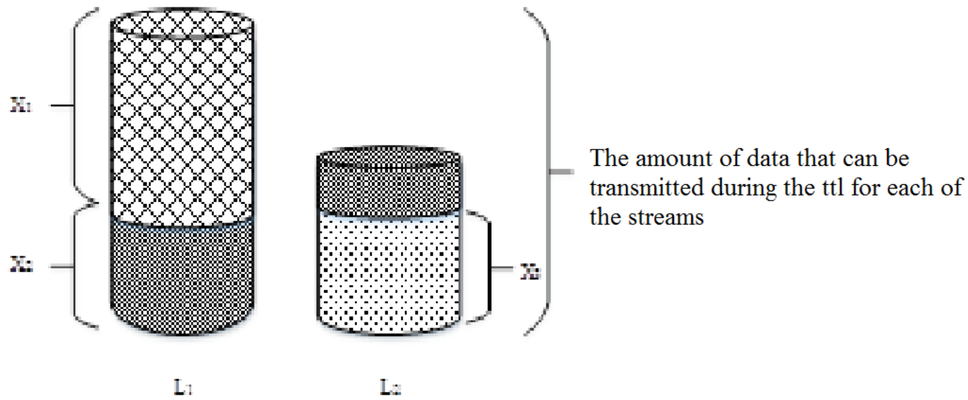


**Figure 1. The result of the distribution of PDU modalities according to the method of priority multi-stream transmission of multimodal messages**

Within the framework of the proposed method, it is assumed that service PDUs are transmitted from the receiver to the sender, based on the information of which it is possible to calculate the current throughput of all substreams, the number of losses on all substreams, delays and delay variation.

According to the proposed method, each time the sender receives a service PDU, it determines the loss factors $\omega'_i, i = \overline{1, L}$and the values of the current available network throughputs $C'_i, i = \overline{1, L}$for each flow L.

The loss factor $\omega_i, i = \overline{1, L}$is defined as the percentage of multimodal message PDU losses that were sent but not delivered to the receiver.

Throughput per time τfor each of the substreams is defined as [58]:

$$C_i(\tau) = \frac{(\beta_i(\tau) * (1 - \omega_i(\tau))}{\tau}, i = \overline{1, L} \qquad \text{(four)}$$

where $\beta_i(\tau)$is the number of bits sent to the stream in time $\tau$.

The average PDU delivery delay is the time interval required for the delivery of a message PDU from the source to the recipient, plus the delivery time of the service PDU. In other words , $t_1$the $t_2$delivery delay is determined from the $(t_2 - t_1)$relation Moreover $t_2 > t_1$, , ( $t_2$-$t_1 \leq ttl$), where $ttl$is the maximum allowable delay. Exceeding the maximum allowable delay will cause the message PDU to be lost.

At the same time, the issue of calculating the value of the time interval is relevant $\tau$, within which the available bandwidth is calculated. Since the data rate can change significantly over time, it is clear that the throughput is a time function depending on the previous values. However, $\tau$it should not be so large that old values do not have a significant effect on its value, and not so small that the throughput calculation is not skewed by short-term changes in the transfer rate. Taking into account all of the above, it can be concluded that the calculation of the average throughput of the sub-data streams can be calculated as a function of the moving average. However, its result will greatly depend on the input load, so it is obvious that it should be considered individually for each transmission system.

Approbation of the method of priority distribution of multimodal information on a data transmission network in the anylogic environment

To test the method of priority transmission of multimodal information, an algorithm was formulated for the priority transmission of multimodal messages in the AnyLogic 8.7.12 simulation environment, which implements the logic of the developed method (Fig. 2).

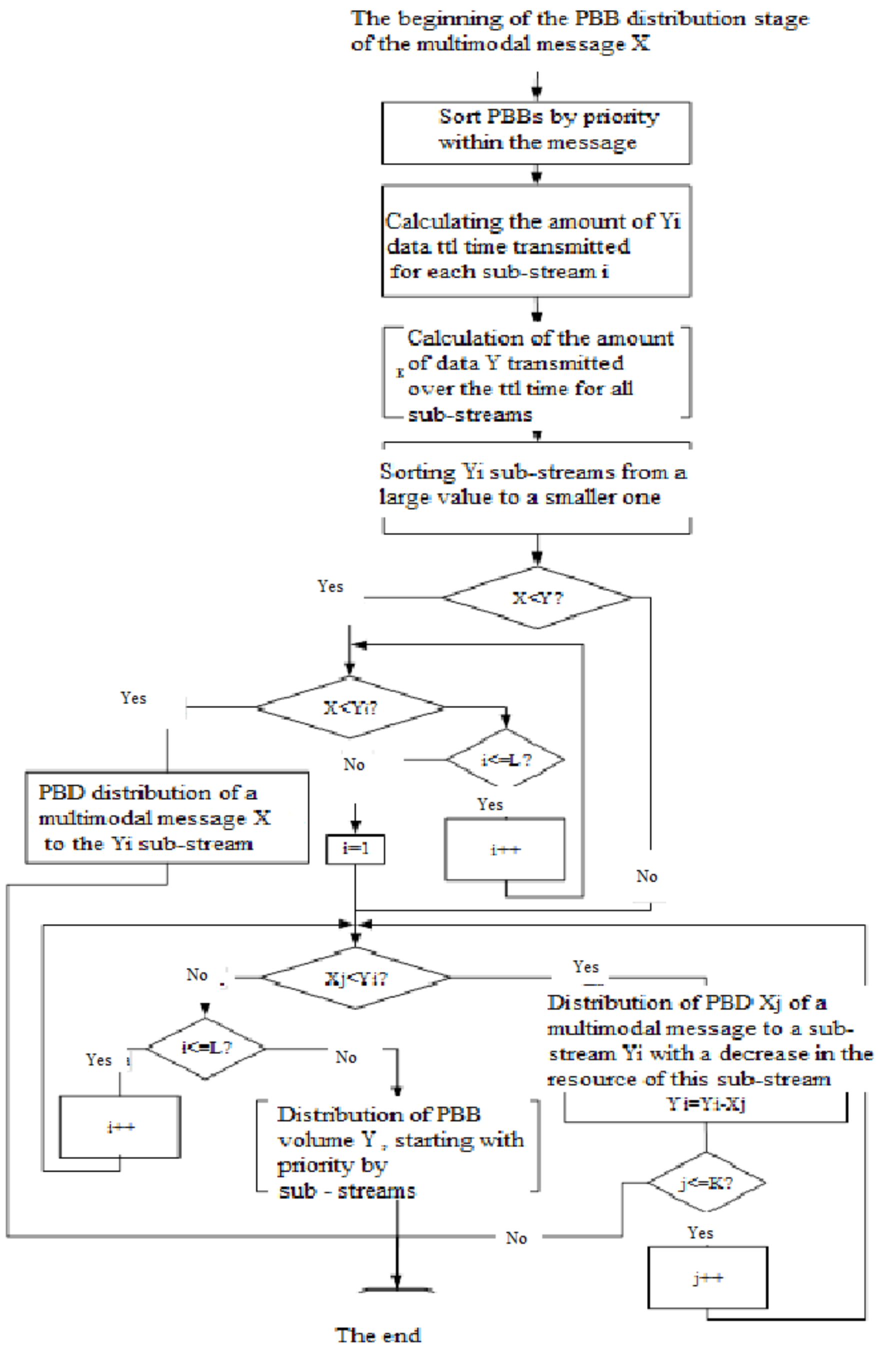


**Figure 2. Block diagram of the algorithm for priority multi-streaming transmission of multimodal information for the AnyLogic simulation environment**

The Source generates a PDU of a multimodal message of a different priority class according to the Poisson distribution law. Let's assume that the modalities are synchronized in time.

Algorithm execution starts from the Exit block . The logic of work is implemented through the Action Diagram. Defragmentation of a message into parts is implemented using the Split block . Timeout messages are implemented using the Enter 4 block.

As a result of the implementation of the algorithm in the simulation environment, additional restrictions are introduced. Since the value of the number of resources is given in the simulation, it is assumed that the value of the network bandwidth is known. In addition, it is obvious that during simulation there are no service PDUs, and all statistics on the operation of the algorithm are collected inside the model. Then it is obvious that when considering the reception-transmission delays, their end-to-end characteristics are taken.

The structure of the simulation model in the AnyLogic 8 University 8.7.12 environment with the implementation of the developed algorithm is shown in Figure 3.

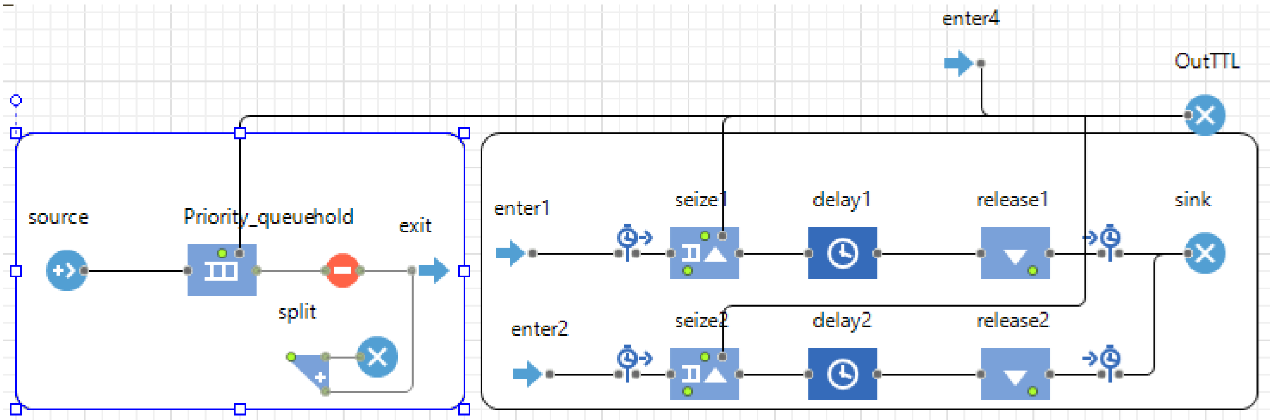

**Figure 3. Simulation model of multi-stream transmission of multi-modal information with the implementation of the algorithm for the priority distribution of multi-modal information on the data network in the AnyLogic environment**

To analyze the operation of the algorithm, a number of experiments were carried out with the following initial data. Let us assume that a stream of modalities is received at the input: a data stream with an optical resolution of 1280x720 pixels at 30 frames per second and a bit rate of 1536 Kbps [8], an audio stream in mono mode is 128 Kbps. Let's also assume that the upstream bandwidth of one of the available networks is 2048 Kbps, the other network is 3072 Kbps. For ease of modeling, assume that the packet size for all priority levels is the same. Then the formalized record of the initial data using the ECR equal to 128 Kbps will look like: n = 2, $u$ 1 = 12 ECR, $u$ 2 = 1 ECR. The total channel resource in this case is 40 ECR. The packet service time is inversely proportional to the amount of free network resources.

Each experiment lasted 1000 seconds with the random number generator initialized with a random seed to set the number of generated input messages. The results of the experiments are given in table. 1 (average values).

When modeling without using the method of priority multi-stream data transfer, modality PDUs are distributed first to the first sub-stream, if there are resources in it, then to the second substream.

**Table 1 - Message passing simulation results**

| Link | Number of received messages | Number of messages sent | Transmission delay, sec | Channel delay variation, sec | Channel Loss Factor | Timeout care factor |
|---|---|---|---|---|---|---|
| Without applying the algorithm | | | | | | |
| Substream 1 | 2960 | 2220 | 0,36 | 0,08 | 0,02 | 0,05 |
| Substream 2 | | 592 | 0,51 | 0,03 | 0,01 | |
| Using the algorithm | | | | | | |
| Substream 1 | 300 0 | 2400 | 0,181 | 0,01 | 0,01 | 0,02 |
| Substream 2 | | 540 | 0,266 | 0,02 | 0 | |

Based on the simulation results, the following conclusions can be drawn. It is obvious that the application of the developed method increases the efficiency of multimodal information transmission in the scenario of multistream data transmission. The number of lost messages in substreams decreased by 2 times. The number of messages sent by timeout has decreased by 3 times.

There has been a significant decrease in delay values and delay variation in both communication channels, which increases the likelihood of using interactive services.

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## ОБ АВТОРЕ / ABOUT THE AUTHOR

**Рындин Артём Валерьевич**, соискатель кафедры Синергетики и процессов управления имени профессора А.А. Колесникова ФГАОУ ВО «Южный федеральный университет», 347928, учебно-лабораторный корпус «И» ЮФУ, г. Таганрог, ул. Чехова, 2.

**Ryndin Artem Valerievich**, PhD student of Synergetics and Management Processes department named after A.A. Kolesnikov, Southern Federal University, 347928, educational and laboratory building “I”, Taganrog, Chekhov str., 2.

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