THE APPROACH TO CONSTRUCTION OF SIMULATION MODEL FOR URBAN TRAFFIC FLOWS ROUTING ON THE BASIS OF THE COMPUTER NETWORKS DYNAMIC ROUTING PROTOCOL OSPF

Alexander Berezhnoy, Konstantin Chudinov

Transport and Telecommunication Institute
Lomonosova str. 1, Riga, LV-1019, Latvia
Ph.: +371 29110030, +371 26481880. E-mail: avb@tsi.lv

In the given research the alternative approach to the decision of a problem of traffic flows management in the city scale is offered. Using a similarity method the comparative analysis of major control principles in the areas of transport systems and computer networks is realized. It is proposed to apply the computer networks dynamic routing protocols for arranging the information management and control of vehicular traffic. General requirements to development of simulation model for solving the given problem are formulated, base structural elements are developed and the model for the arbitrary topology of street road network is constructed. The analysis of simulation results is carried out.

Keywords: *traffic management and control, street road network, computer networks, dynamic routing protocols, simulation modelling*

1. Introduction

For the long period of time the trend of vehicles park constant growth within the world scale is observed. The huge number of automobiles in the urban streets often results in substantial decline of productivity of urban transport system or in total blocking the traffic.

The partial solution of a road congestions problem is rooted in application of intelligent transport systems for traffic management and control. In a context of modern technical control means usage it is regarded to be especially valuable revealing of analogies, search for approaches and the examples-analogues successfully realized in the related subject domains. The similar analogy investigated within the framework of given article is an application of dynamic routing protocols for solving the tasks of urban traffic management.

2. Application of Computer Networks Management Methods for Construction of Models of Vehicular Traffic Flows Management

The driver makes a choice of a driving route, which can be described as a set of rules for defining the best path on the basis of the chosen criteria in transport system. The given formalized set of rules is known as routing protocol in the sphere of computer networks. OSPF (Open Shortest Path First) protocol has been taken as the dynamic routing protocol for construction of information routing service of urban vehicular traffic management.

The OSPF routing protocol is a protocol, which is based on link state and is using an SPF (Shortest Path First) algorithm for finding out of the shortest way in the graph [1]. OSPF is applied for the purposes of intra-domain routing in computer network systems of any complexity degree. The OSPF protocol algorithm provides the operation of the several general functions inherent by any dynamic routing protocol:

- construction of routing tables;
- selection of the shortest path;
- datagram's moving on the chosen route.

Carrying out of the full nature experiment in the urban environment is not obviously possible, generally due to the issues of increased risk for drivers safety as well as due to rather high complexity and high cost of the given project implementation. The only alternative is considered to be modelling of examined system. Construction of the adequate analytical model, allowing to investigate all possible variants of management for the various initial values of system parameters and in various conditions is practically impossible, mainly, owing to complexity of its realization. Therefore, one of the possibilities for obtaining the decision of the given problem is applying the simulation techniques.

As simulation modelling environment in the given research software AnyLogic 5, being the universal tool for modelling of discrete, continuous and hybrid systems has been chosen.

2.1. The comparative analysis of routing in computer network and transport fields

Using a similarity method for finding of conformity amongst road-transport system and computer networks in the routing area allows receiving the results of comparison submitted in Table 1.

Table 1. The comparative analysis of routing for computer and transport areas

Computer network	Street-road network (SRN)
The topology of computer network consists of nodes (Routers) and connections (Links).	Road network topology consists of nodes (Crossroads) and links (Streets).
Link. Realizes connections between routers interfaces.	Road section: highway, road, street. Ensures the connections between crossroads.
Router. Has a limited number of interfaces through which sending and receiving of datagrams takes place.	Crossroads. It is characterized by a certain number of streets connected to it at which the vehicles are driving.
Metrics. Shows the current link state. Metrics is used while creating the routing tables.	Route choice criteria.
Routing table. Datagram routing in computer network is performed on its basis.	Map of the SRN. Allows the driver to determine its driving route.
Media access method. Set of rules under which the message transfer by the data link is carried out.	Road driving rules. Define the rules of vehicular traffic motion at the SRN.
Packet (datagram). Messages that are transferred by the routers. Possesses such a trait like size.	Vehicle. Moves by the road sections from the crossroads to crossroads. Is characterized by its size.
ToS (Type of Service). There are defined 8 priority levels and 3 standard types of service for the IP-datagrams in the computer networks: requirement to the time delay, requirement to the throughput and requirement to reliability.	The requirements described by the Type of Service field in the computer networks may be entirely applied to the SRN.
Queuing system. The router may be considered as the service device having few queues. The requests are coming to its inputs. The requests may be of different types, may have various priorities and be served under various rules.	Similar to the computer network, the SRN may be regarded as a network containing the queuing systems, where the crossroads acts as a service device having few queues. The requests (vehicles) of different types with different priorities (public transport, operative transport, etc.) are coming to the inputs of the device.

2.2. The transferability of topologies

The topology from several city crossroads and the binding streets is shown on Figure 1. Using a similarity method it becomes possible to carry out the equivalent replacement of the SRN by the computer network topology.

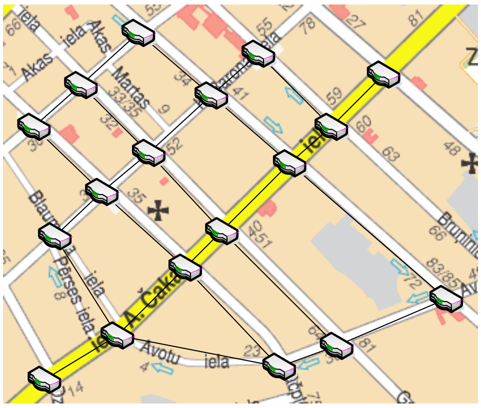

Figure 1. The topology of street-road network

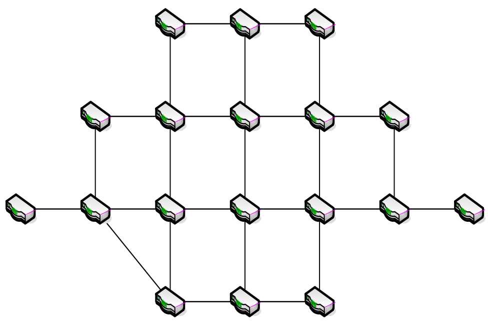

Figure 2. The computer network topology projected to the SRN

In the environment of simulation modelling AnyLogic, by means of using the constructor, from the developed set of blocks, it is possible to create a model, which will correspond to topology of the given computer network.

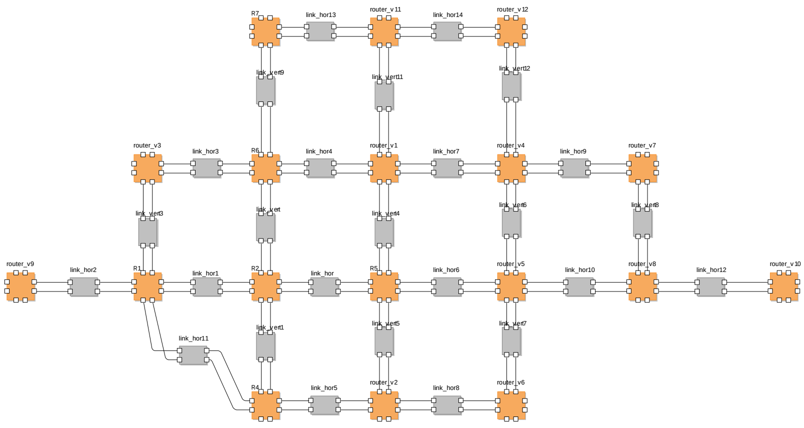

Figure 3. Block network topology on the basis of SRN

2.3. Construction of the conceptual model

For realization of model functioning the following structural blocks are used [3]:

1. The generator – carries out generation of datagrams under the set law of distribution.
2. The router – carries out construction the graph of conditions on the basis of which tables of routing are created, as well as routing process is performed.
3. Link – the block carrying out the connection between routers. It consists of the queues and blocks of time delays.

The model is constructed basically of two block types – routers and links. During construction of model the following restrictions and assumptions have been introduced:

- Each interface of a router consists of two ports. It is realized for simplification of an one-way traffic implementation.
- The most significant assumption in model at a stage of carrying out of investigation is the absence of rules of travel turns at crossroads.

2.4. Simulation model structure

At the first step there has been constructed a model, reproducing processes of routing in a computer network. For realization of OSPF protocol [1] functioning model there is enough to use three main blocks: Source, Router and Link.

Source is the block carrying out packages generation under the given law of distribution.

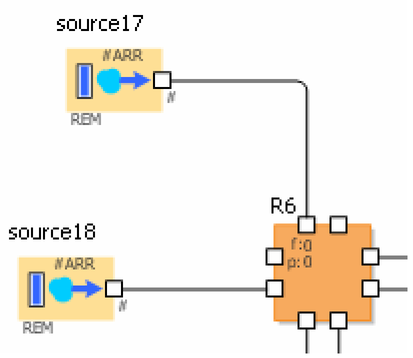

Figure 4. Generator connection to the routing block

Link represents the media of data transmission. It contains values of metrics and is responsible for its dynamic change. The internal circuit of realization of block Link is shown in Figure 5.

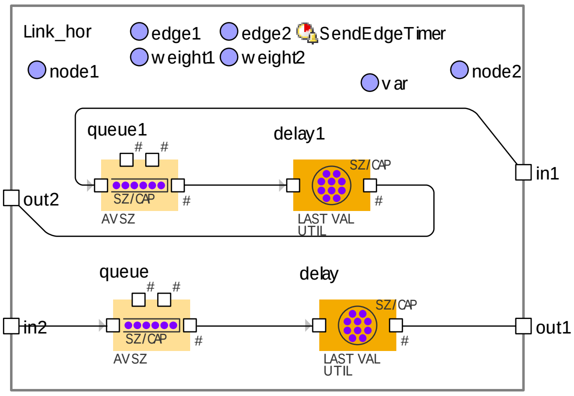

Figure 5. Internal structure for the block Link

The given block contains two queues (each for every input port), two blocks responsible for a package delivery delay, variables having the information on Link metrics, and also containing the information on units, which are connected with the given block.

Router is a block that is responsible for reaching the primary goal of the given model – construction of routing tables on the basis of which routing of packages is performed. Each of routers has 4 interfaces. Interfaces contain two ports: in and out. Router block is also equipped with 4 timers:

1. SendHelloTimer – the timer sending Hello messages.
2. SendEdgeVectorTimer – the timer sending the messages, containing base of Links constructed on the basis of Hello messages.
3. MakeNodeVectorTimer – the timer forming base of knowledge for units on the basis of received messages.
4. MakeRouteTableTimer – forms the table of routing taking into account a vector of units and vector of Links by means of applying the Dijkstra algorithm.

The internal router structure is presented in Figure 6. The packages routing task is realized with the outputCheck block.

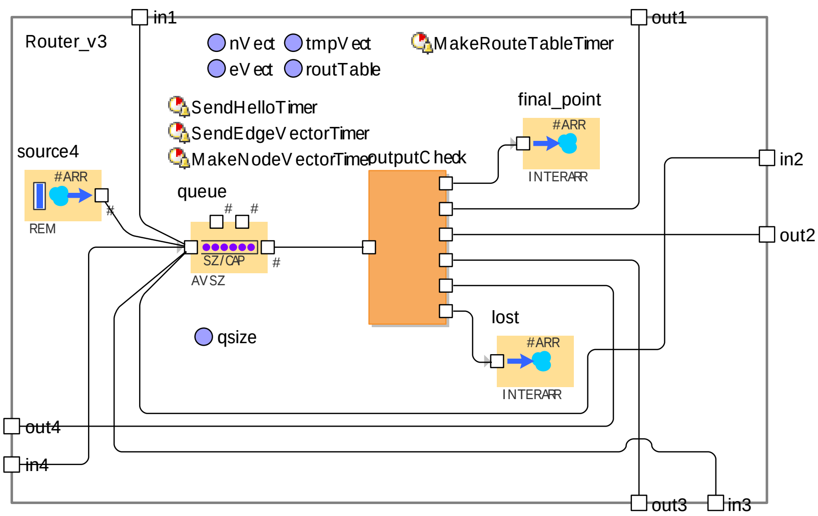

Figure 6. Router block internal structure

All entering messages get in the block "queue", whence they are moved to the block "outputCheck", which carries out frame switching. In case if the package comes to a destination it reaches the Final_point block. If the given router is not a destination point for the message, the datagram is redirected in accordance with routing table to the required location. In case the package has been lost or there was a distortion of the message, the message goes to the Lost block. The internal structure of the outputCheck block is resulted below (see Figure 7).

The outputCheck block consists of 5 decision-making units. Each of them is responsible for the separate port. The queues are established in front of each of target output port.

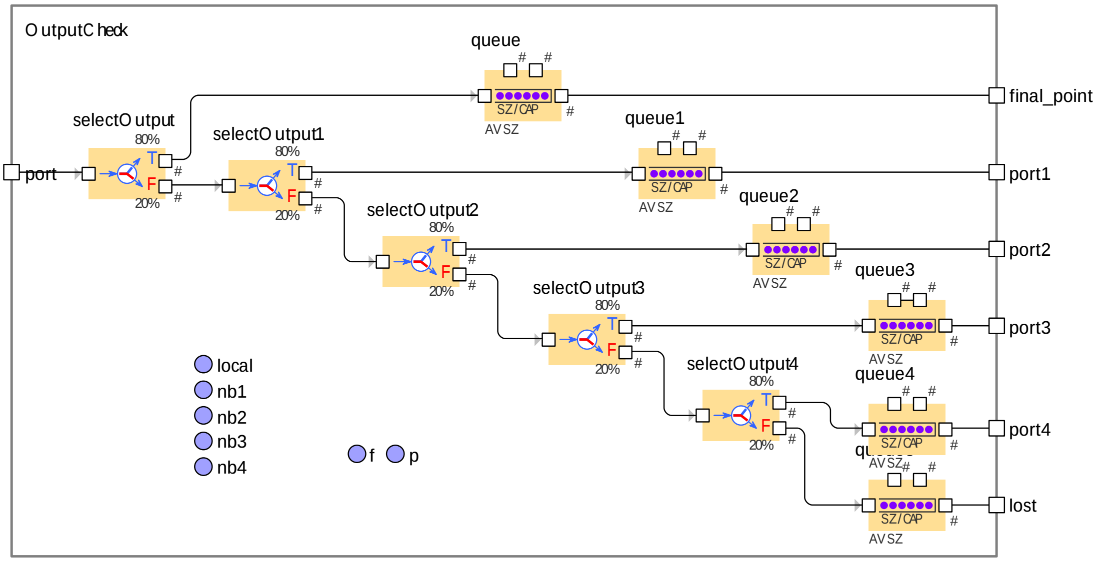

Figure 7. outputCheck block internal structure

Datagram (package), which is transferred over the network, has the following structure [2]:

Destination point	*Source point*	*Next hop*	*ToS*	*Message size*

1. Destination - a final point of travel.
2. Source - a point of departure.
3. Next hop - unit in which it is necessary to transfer the message. It is calculated under the table of routing.
4. ToS - type of service.

Below in Figure 8 the example of the computer network topology constructed by means of using created blocks described above is shown. The block approach to construction of model allows expanding and scaling model of a researched network easily.

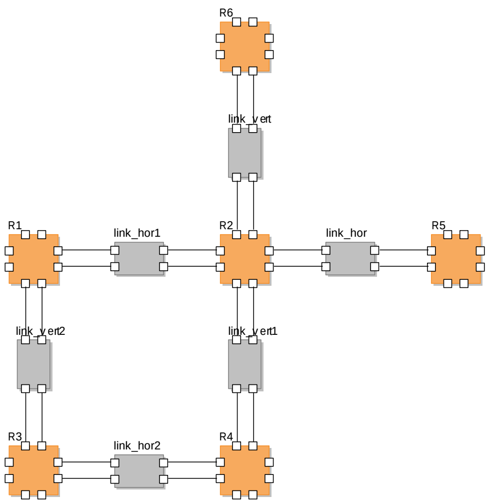

Figure 8. Computer network topology block realization

3. Simulation Experiments

In order to perform model verification the simulation experiments for the constructed model have been realized.

In the given model the following parameters are considered:

1. Input parameters
   - topology of a network;
   - initial values of metrics;
2. Output parameters
   - set of all possible routes;
   - the best route according to the given metrics;
3. Managing parameters
   - the metrics (metrics can be both static, and dynamic);
   - ToS (type of service).

3.1. Experiments planning

The purpose for carrying out of experiments is to define the threshold value of vehicular traffic flux value at which achievement the dependence between traffic flux and average travel time for passing of the given route by the package/automobile becomes non-linear, and also to reveal the character of the given dependence.

In order to reach the pointed objective the mathematical apparatus of the regression analysis is applied. It is stated that the value of an average error should not exceed 0,2.

As changeable parameters of model are selected the intensity of packages generation in traffic generators located at the boundary area of transport system on the entrances to SRN.

The initial number of runs is taken equal to 20. The number of runs increases till the moment while half of a confidential interval width does not exceed 10 % of an estimated (selective) average.

3.2. Carrying out of experiments, processing and analysis of obtained data

The experiments are carried out for the model with the topology presented on Figure 9.

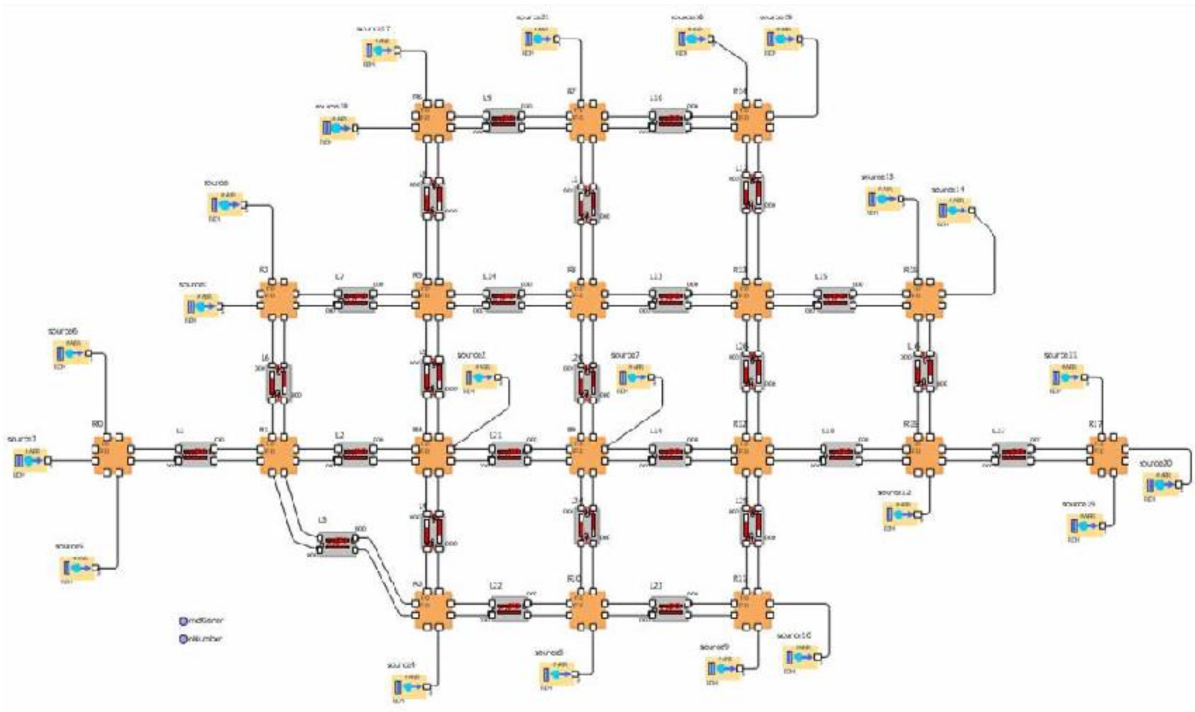

Figure 9. The topology of considered network

The collected experimental data have been used in order to carry out a regression analysis with the purpose of determination of vehicular traffic flux boundary value. As a result of processing specified representative samples, the average travel time values required for passing through system for each traffic flux value have been received.

Table 2. Simulation output results

	Traffic flux	Average waiting time		Traffic flux	Average waiting time
1	0,5	0,87111	13	3,5	3,22893
2	0,75	0,90534	14	3,75	3,88639
3	1	0,95805	15	4	5,12421
4	1,25	1,01852	16	4,25	6,85405
5	1,5	1,07001	17	4,5	8,83943
6	1,75	1,16986	18	4,75	11,7321
7	2	1,27306	19	5	18,5239
8	2,25	1,43874	20	5,25	25,506
9	2,5	1,60943	21	5,5	36,3328
10	2,75	1,81315	22	5,75	45,8509
11	3	2,05501	23	6	52,6718
12	3,25	2,33917	24	6,25	60,837

On the basis of the received data the dispersion diagram and regression models are constructed.

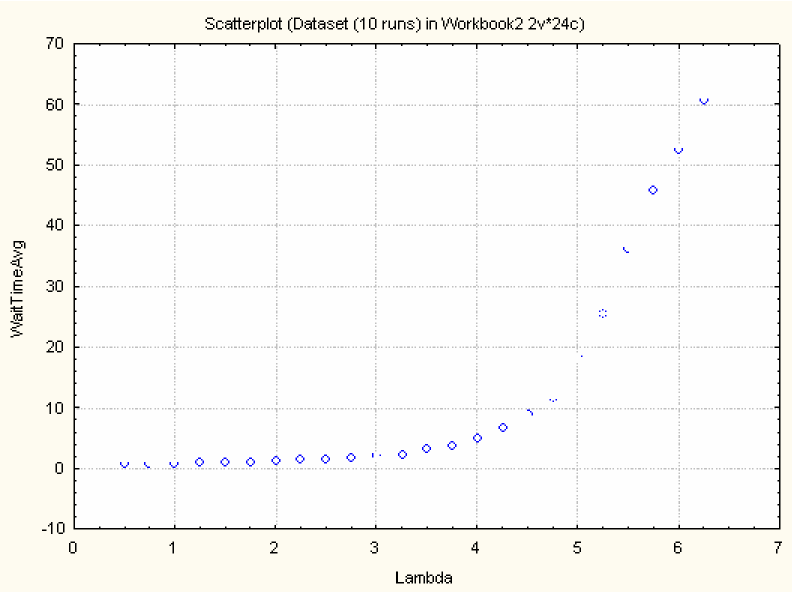

Figure 10. Dispersion diagram representing the behaviour of average waiting time in queue

Table 2. Table of regression model results

λ	N	R	F	LPA	SEE
3,25	12	0,91567236	108,59	0; 4,964603	0,14704
3,5	13	0,83077334	54,002	0; 4,844336	0,29692
3,75	14	0,80767761	50,395	0; 4,747225	0,41861
4	15	0,7717401	43,953	0; 4,667193	0,62084
4,25	16	0,73625126	39,081	0; 4,60011	0,91868
4,5	17	0,71904016	38,388	0; 4,543077	1,2689
4,75	18	0,70073731	37,465	0; 4,493998	1,7539
5	19	0,6336033	29,398	0; 4,451322	2,8963
5,25	20	0,60820379	27,942	0; 4,413873	4,254
5,5	21	0,58665287	26,966	0; 4,38075	6,1979
5,75	22	0,59406229	29,269	0; 4,351244	8,1139
6	23	0,62052336	34,339	0; 4,324794	9,626
6,25	24	0,6476663	40,441	0; 4,30095	11,02

Using of Fisher's criterion values it is possible to assert that all models can be regarded as statistically significant. However, as according to the set entry condition the level of regression error cannot exceed 0.2 the best is considered to be the model number 12. It corresponds to the traffic flux value equal to 3,25 and looks like as follows:

$$WaitTimeAvg = 0,41 + 0,51 * Lambda .$$

Conclusions

In present article the alternative approach to the decision of a problem of traffic flows management in the city scale is considered. Using a similarity method the comparative analysis of terminology and major control principles in the areas of transport systems and computer networks is carried out. Taking into account a modern level of technical development of intelligent transport systems, it is offered to get the benefit of using the computer networks dynamic routing protocols for arranging the information management and control of traffic.

As the major tool of investigation for solving of given problem the simulation modelling is chosen. General requirements to simulation model are formulated in the research, base structural elements are developed and the model for the arbitrary topology of SRN is constructed using the AnyLogic environment. During construction of model some essential restrictions and assumptions are introduced.

For verification of the constructed model numerical experiments are carried out. As a result of performing the regression analysis of the collected experimental data a threshold value of the traffic flux characteristic at which excess function of an average waiting time of vehicles in queue loses a linear form and sharply grows is obtained. The given threshold point is interpreted as boundary of controllability of investigated transport system.

References

1. Olifer, V.G., Olifer, N.A. *Computer Networks. Principles, Technologies, Protocols: A study aid for higher schools,* 3rd edition. St. Petersburg: Piter, 2006. (In Russian)
2. Tanenbaum, E. *Computer Networks*, 4th edition. St. Petersburg: Piter, 2006. (In Russian)
3. Karpov, J. *Imitating Simulation of the Systems. Introduction to Simulation with AnyLogic 5*. St. Petersburg: BHV-Petersburg, 2005. (In Russian)