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ALGORITHMIC AND MATHEMATICAL SUPPORT FOR TOPOLOGY RESEARCH OF THE CORPORATIVE NETWORKS

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Abstract. In the paper a general structure of technical support tools is proposed to ensure the automation of corporative information systems (CIS) in higher education institutions (HEI). On an example of the Sumgayit State University faculty of Engineering (SSUFE) a local area network architecture of the automated corporative information system is analyzed to improve the quality of educational and scientific activities. An algorithm is developed and computer experiments carried out to justify the choice of technical means of the local network of SSUFE corporate information system. The productivity index is determined using average load factor of mutual information exchange. To ensure the high throughput of the corporate network, a mathematical model is developed for the selection and justification of the types of basic and supporting technical means. The overall performance of the corporate network is tested by the logical algorithm and computer experiments.

Keywords: higher education institution, corporate network system, automated workplace, network productivity, capacity, M/M/1 and P/M/1 models.

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1 Introduction

In order to ensure the automation of HEI, the issues of rapid mutual exchange of information within the enterprize, the small number of technical equipment of the local and global network, the choice of the optimal routes between network customers, in general, the selection of a suitable corporate network layout is required (Saigushev et al., 2018). Given that CIS applied in HEI is a complex system that combines large-scale educational, scientific, innovative and economic activities (Nama & Kurniawan, 2017), (Alguliyev et al., 2014; Vu et al., 2019). All the administrative and training units of FESSU as the object of research - the teaching process; research; commercialization of projects; results of commercialization; automated workplaces (AWP) should be applied in the dean office, design, production and commercialization departments of the innovation center according to each type of activity.

2 Analysis of the research object and the requirements for the establishing its corporative network at HEI

The analysis of the departments SSUFE shows that from the architectural point of view CIS should provide effective work process of the dean office (D_{cm}), departments (D_{pi}) of the Faculty, dean office (D_{cm}) innovation center production (IC); automated workplaces (AWP) and the commercial unit of the innovation center (CUIC). The corresponding communication lines connecting them, reliable connection, uninterrupted information exchange, security, technical, information and software tools are organized according to hierarchical levels:

1. System-wide and special software;
2. System services (www, e-mail, group work tools);
3. Database management system;
4. Electronic document management system;
5. Network operating systems;
6. Data transmission network;
7. Data storage and transmission center.

In the process of designing SSUFE corporative network hardware, network administrators and network integrators must meet a number of requirements that affect the quality of the corporate network:

- network expansion (simple integration of individual components);
- scalability (increasing the productivity of new nodes, communication lines, network equipment and nodes);
- productivity (providing the required productivity parameters of communication channels and network nodes);
- management (ensuring centralized management, planning and monitoring of the network);
- reliability (ensuring the uninterrupted operation of network nodes and communication channels, ensuring the completeness of the data, uninterrupted and safe delivery to the required customer);
- security (ensuring data protection).

3 Selection of topological scheme of HEI corporative network and research of basic parameters

One of the important issues in the development of technical support for the corporate network of SSUFE is to ensure its quality parameters. In this regard, by determining the amount of information transmitted by the network over time, the error-free capacity of the network can be determined as follows (Zhelvakov, 2012):

$$C = V_x max I_{xy} = V_x max H_y - H_{y/x}, \tag{1}$$

where $H_y - H_{y/x}$ is the difference between encoder entropy and channel entropy; I_{xy} is the informativeness of the transmission (bit / sec); V_x is the data transfer rate.

Formula (1) is true when there are no errors in the flow of information on the discrete channels of the corporate network of the HEI.

Given that the corporate network of an HEI consists of discrete channels and uses a double symmetric channel in the network, the probability of errors p_0 (0 and 1) during the information flow is high. Therefore, by performing certain transformations in expression (1), the network throughput is defined as follows (Zhelvakov, 2012)

$$C = V_x[1 + p_0 \log_2 p_0 + (1 - p_0)\log_2(1 - p_0)], \tag{2}$$

where p_0 is the probability of errors in the dual channel of the corporate network; V_x is the data transfer rate.

Graphically, the change in the probability of p_0 errors is shown in Figure 1.

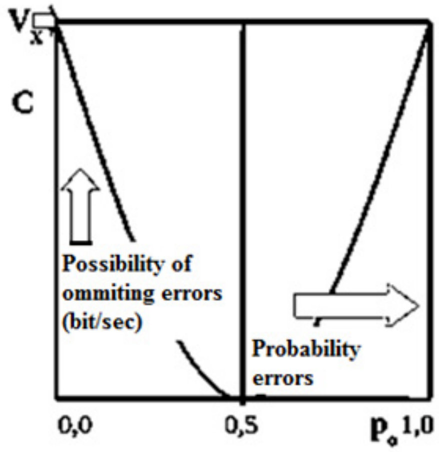

Figure 1: The probability field of p_0 errors

According to the M_i positions (Fig. 2), where the dean's office and departments of SSUFE are located on the 1st and 2nd floors of the 1st building, the architecture of the separate AWP_i of the faculty is formed. Construction of the corporate subnet of the Faculty of Engineering in accordance with the architecture of the number of interfaces and routes to interact with the corporate network and the throughput are determined. Coaxial cables are used to increase the bandwidth of the corporate network. This type of cable is compatible with all telephone systems, providing high performance. According to the standards, according to the capacity of the cables, the data transfer rate is not less than 100 Mbit/s, grade 5 is selected (Mamedov & Alieva, 2017).

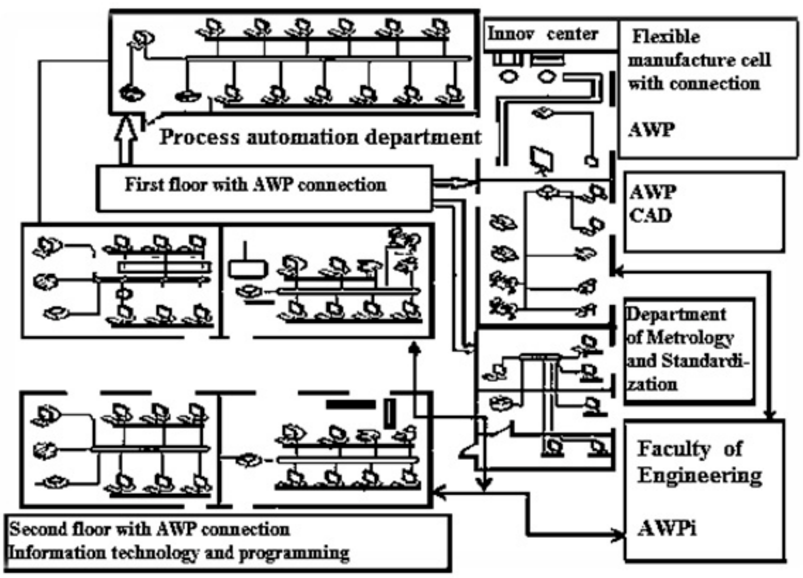

Figure 2: Topological scheme of SSUFE corporative network

SSUFE corporative network uses a high-throughput corporative operating system (COS) (Huseynov & Mammadov, 2012). The high performance of the COS can be increased to 64 processors on a multi-processor and cluster platform Unix. The presence of a centralized reference service of the COS in the Unix database ensures the efficient operation of a large number of users and the use of allocated resources.

To ensure the effective operation of SSUFE within the corporate network, topological schemes of the local corporate network of separate teaching, research and production areas (in the innovation center) are selected (Fig. 2). When connecting the departments of the Faculty of Engineering to the corporate network, taking into account the tasks and scope of equipment, laboratory stands, software used in the departments, the number of departmental contingents and the number of students studying in specialties, it was determined that more effective teaching and research,it is more expedient to establish a bus topology with a local computer network to organize research, to ensure the operation of an automated corporate information system. This is due to the fact that the transmission of information in the corporate network, built with this type of local topology, is delivered to all AWP_i via communication lines. All workstations have direct access to AWP_i in the network. The operation of the computer network does not depend on the situation of individual AWP_i. Based on the new bus technology, it is possible to connect and disconnect workstations through passive plug boxes. Because network processes and communication environments can be seamlessly connected to workstations, it is easy to view information, ie to separate information from the communication environment which increases the bandwidth of a corporate network with a selected bus topology.

To ensure the high throughput of the corporate network of the Faculty of Engineering, a switch is used in each department. Switch - Divides the loaded network into smaller, more efficient segments. In this way, the corporate network connection method allows you to process several data at once and connect segments of different types of networks. The switch's throughput allows all packets from the ports to be processed in one second.

One of the important research issues is to calculate the productivity of the corporate network in order to justify the choice of the bus topology scheme of the corporate network according to the location architecture in the first building of the SSU of the Faculty of Engineering. In this regard, the question is to determine the indicators that reflect the productivity of the corporate network of the Faculty of Engineering and evaluate the network based on the results obtained.

4 Mathematical modeling and experimental research of HEI corporate network traffic planning process

As can be seen from Prencipe (2016), one of the indicators of SSUFE corporate network performance is the stable maintenance of TCP protocol losses on the wall by 5÷15%. This is because if it is higher than this figure, ie the loss of about 40% of TCP protocols, it indicates that the network is practically faulty. With this in mind, it is to minimize traffic costs and minimize delays in the delivery of incoming requests. Thus, the following condition can be accepted (Huseynov & Mammadov, 2012):

$$f(t_{inquiry}) = F(t_{inquiry\_i}/2) + S/t_{inquiry\_i}\, min, \tag{3}$$

where $t_{inquiry\_i}$ is the time of inquiries from users of the decan's office of the Faculty of Engineering, departments and the Innovation Center. This parameter varies in the range of two-way delivery time (forward and reverse) - 0÷1200Ms. The set of query times defined by (3) can be assumed to be 100÷600Ms with a minimum of 0÷1200Ms

$$t_{inquiry\_i} = \frac{Pb}{K(1-\rho)}, \tag{4}$$

where P must be able to service the number of devices i requests; $\rho = \lambda b$ - is the system load, ie, taking the theoretical maximum value of the input speed λ_0, the corporate network node can process all requests; b is the average time of transfer of the information frame from the input buffer of the switch processor to the output channel.

The probability of i requests serving in a corporate network is defined as follows (Huseynov & Mammadov, 2012):

$$P = \frac{(K\rho)^k}{K!(1-\rho)} P_0, \tag{5}$$

where k is the number of collectors, the volume of which is infinite, ie queries are stored in memory. When the buffer runs out, the request is not lost; P_0 - the probability that there will be no queries in the corporate network:

$$P_0 = \left[\frac{(K\rho)^k}{K!}(1-\rho) + \sum_{i=0}^{K-1} \frac{(K\rho)^i}{i!} \right]^{-1}. \tag{6}$$

The indicator that reflects the average time of requests in the system is defined as follows:

$$T_{average\_query} = t_{inquiry\_i} + b. \tag{7}$$

The average length of queries in the system is determined as follows:

$$L_{average\_query} = t_{inquiry\_i}\lambda. \tag{8}$$

The average number of queries at the control node is defined as follows:

$$S_{average\_query} = \lambda T_{average\_query}. \tag{9}$$

The access speed of the request is limited to $100 Mbit/s -$ 148800 frames / s or $1000 Mbit/s -$ 1488000 frames / s and 70-90% of the number of users of the Faculty of Engineering. The output frames of the node are compatible with Ethernet. In this case, the output frame rate corresponds to the Ethernet standard:

- 100 Mbit / s - 148800 frames / sec or 1000 Mbit / s - 1488000 frames / sec.

To evaluate the productivity of the corporate network of the Faculty of Engineering, a comparison is made between the models of the public service system. Using the $M/M/1$ and $P/M/1$ models, the performance of the corporate network is checked by determining the average and maximum parameters of the queue length of incoming requests, the parameters of the average waiting time in the queue. According to the Poisson distribution frequency, time intervals between requests entering the network are exponentially distributed by the distribution function (Leguesdron et al., 1993).

$$F(x) = 1 - (e^{-\lambda x}). \tag{10}$$

Pareto distribution has a probability distribution function of the form

$$F(x) = 1 - (\lambda/x)^{\alpha} \ \ (x > k; \ \alpha > 0). \tag{11}$$

When there is a non-exponential external influence on the ACIS of the Faculty of Engineering, the task is to create an imitation model in the GPSS World environment to reflect the processes. Generated GPSS environment is used as input information. Waiting time, storage time, queue length, depending on the system load, is measured by the installed subsystem of GPSS (Kopei et al., 2019). For example,

$$\rho = \lambda/\mu, \tag{12}$$

where λ is the average intensity of the input information flow; μ is the average intensity of the query service process.

Pareto distribution slow extinguishing distribution parameters are determined by the minimum value of the random quantity and the average value of the random quantity, the variance. PARETO λ - distribution parameter which determines the minimum value that can take a random quantity x. α - determines the average value and variance of a random quantity. If the parameter α is rated from 1 to 2, then the random variable has a finite mean and an infinite variance.

According to Yu (2005), the α parameter from individual sources for Ethernet traffic is equal to 1.2. Internet traffic corresponds to the condition $1.16 \leq \alpha < 1.5$ with Pareto distribution. The λ parameter is selected so that it is equal to the load of the $M/M/1$ model.

Modeling of the $M/M/1$ system shows that the main characteristics of the $M/M/1$ are the average length of the queue, the maximum length of the queue, the average waiting time in the queue and the average storage time in this system (Lukov et al., 2005). In order to assess the difference between the $P/M/1$ and $M/M/1$ systems, the following logical expressions are checked:

If $\rho \leq 0.1$ then the difference between the values in the $P/M/1$ system and the $M/M/1$ system during system loading is not large;

If $0,1 \leq \rho \leq 0,3$ then, unlike the $P/M/1$ system, the performance of the $M/M/1$ system increases several times during system loading;

If $0.3 \leq \rho \leq 0.7$ then the difference between the $P/M/1$ and $M/M/1$ systems increases up to 10 times during system loading;

If $\rho > 0.7$, then the difference between the $P/M/1$ and $M/M/1$ systems increases many times during system loading.

According to the logical expression, the dependence of the average waiting and latency times of the system load from 0.1 to 0.7 for exponential and similar cases can be graphically described (Fig. 3).

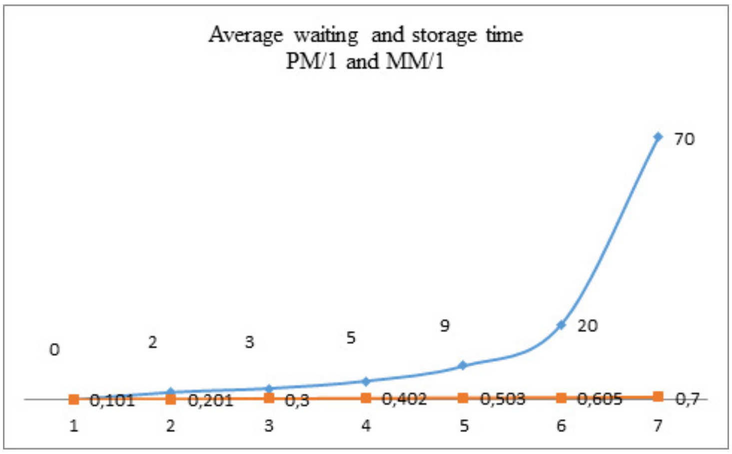

Figure 3: Graphical dependence of the average waiting and storage times of the system load from 0.1 to 0.7 for exponential and similar cases

When the corporate network is overloaded, ie when $\rho > 0.7$, the difference between the $P/M/1$ and $M/M/1$ systems increases up to 60 times, which increases the importance of the queue indicators. Based on the assessment, it can be noted that in the logical expression $\rho \leq 0,1$ and $0,1 \leq \rho \leq 0,3$ in the corporate network, the ρ indicator of the queue is the most efficiently accepted productivity.

For the $M/M/1$ model which consists of exponentially distributed time interval queries, the parameters of the dependence of the size of the buffer size q on the average load factor ρ must be analyzed (Nikolov et al., 2017). For this purpose, the average load coefficients are determined according to the required dimensions of the network buffer according to the bus distribution scheme between the dean's office and the departments of the corporate network of the Faculty of Engineering (Table 1). According to the bus distribution scheme between the deans and departments of the corporate network of the Faculty of Engineering, a graph of dependence between the service exponential distribution intervals and time exponential distribution intervals of $M/M/1$ was established (Fig. 4).

Table 1: Average loading ratios according to the required dimensions of the network buffer

ρ	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
H=0.5 (MM/1)	0.111	0.25	0.428	0.667	1	1.5	2.33	4	9
H=0.92	1.89E-06	0.00056	0.033	1.159	38.05	1547.9	110909	27068704	1.64E+11
H=0.9	2.58E-05	0.0024	0.06	1.016	16	296.6	8538.8	640000	5.9E+08
H=0.75	0.0137	0.078	0.262	0.740	2	5.625	18.148	80	810

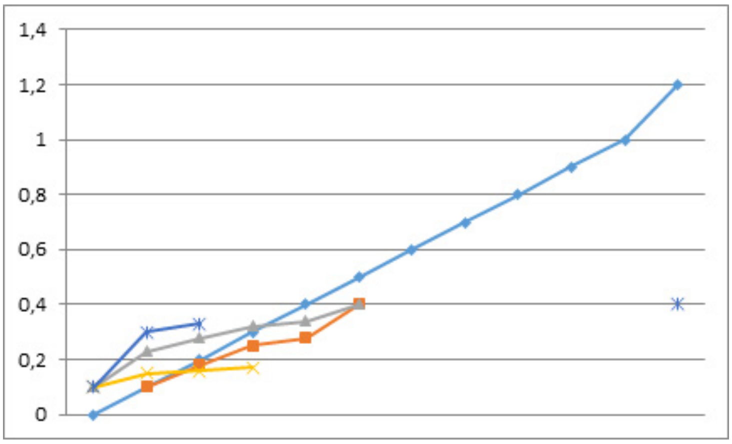

Figure 4: Dependence of system load on the size of buffers on the basis of the maintenance system of M/M/1

To ensure efficient productivity in the corporate network of the Faculty of Engineering, the load index can be up to 0.3 and the size of the buffer can be calculated as 0.5, which corresponds to the condition of about $0.1 \leq \rho \leq 0.3$. As can be seen from Figure 4, when the network load is $\rho = 0.3$ and the buffer size is $H = 0.5$, it is possible to observe the intersection of the graphs in the near field.

5 Conclusion

In the paper a topological scheme of the corporative network of SSUFE is proposed. A mathematical model is developed to to minimize the traffic costs of the SSUFE corporative network and minimize the delays in the delivery of incoming requests. To estimate the difference between the P/M/1 and M/M/1 systems, the average and maximum values of the queue of incoming requests, the parameters of the average waiting time and the overall performance of the corporate network are checked by logical algorithms and computer experiments.

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