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Impact of Resource Control in Irregular Networks on their Transmission Properties

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Abstract: The paper shows the analysis of the influence of the introduction of network resources control on the transmission properties of the networks described with irregular graphs. The method developed and used by the authors in reference to regular graphs was applied. It consists in distributing the transmission resources according to specified unevenness coefficients of usage of individual edges. The way of determining these coefficients was described as well as the applied rule of distribution of the resources in case of equivalent and various density of the traffic generated by the network users. The improvement of the transmission properties of the analysed networks, understood to be the lowering of the probability of rejecting a service call resulting from the introduction of network resources control, was proved by the results of simulation research of simple and more complex network structures.

Keywords: telecommunication network, graph, simulation, probability
Categories: C.2.0, C.2.1

1 Introduction

Due to a rapid increase in the Internet traffic [Coffman, 02, Cisco, 10] it is necessary to build new and extend the existing telecommunication networks. To ensure appropriate quality of the transmission, it is necessary to increase its speed and to reduce of the delays associated with data transmission. To face up to the increasing requirements, new generations of equipment are introduced that enable faster transmission of information [Ramaswami, 10]. An example of such activities can be the use of fully optical networks with high working stability miniature laser diodes, lasers with the light waves length adjustment, new broadband optical amplifiers, multiplexers with a dense and ultra dense wave length distribution DWDM, nondepressing, long-distance optical fibres and fully optical switches OXC (Optical Cross Connect) [Maier, 08]. It was concluded that the bandwidth of networks is influenced not only by the equipment used, but also by communication protocols [Radoslavov, 00], network systems topology [Hegde, 13] and the management of transmission resources [Pedersen, 08] that enables the adjustment of the resources to the changes of conditions and requirements [Dubalski, 10].

One of the fundamental matters to consider in the construction and analysis of the ICT terminals is the choice of the topology of the connections between parts of the network, which is a considerable factor in the system's effectiveness [Kotsis, 92, Xu, 01, Pavan, 10].

The ICT network structure can be described with graphs [Deswal, 12, Likaj, 13] where the commutation modules or specialised computers constitute the vertices and mostly bidirectional, independent transmission channels are the edges.

The thesis [Bujnowski, 18, Narayanan, 01] presents the matter of the research of transmission properties of net-work described with regular graphs, especially Reference Graphs which by definition have an equal degree.

During the simulations, which aimed to test the transmission properties of the networks described with these graphs, it was noted that despite the equal diameters and the average path length their transmission properties understood to be the probability of rejecting a service call are different. While looking for the source of these differences it was concluded that there is an unequal usage of individual graph edges describing the tested networks. Based on the analysis a conclusion was drawn that the result is influenced by the number of usage of particular edges in parallel paths of minimum length [Drzycimski, 18]. A minimal path is a path with the lowest number of constituent edges connecting any two nodes. The term 'parallel paths' means paths of the same length and consist of a specified number of various edges connecting the same graph nodes.

A factor was defined called the unevenness coefficient w_{spi}, which was determined by the following formula:

$$w_{spi} = \sum_{i=1}^{D(G)} u_{io} \qquad (1)$$

where $D(G)$ means the diameter of the graph and u_{io} values are calculated from the formula:

$$u_{io} = \frac{u_k}{k} \qquad (2)$$

u_k means the number of utterances of a particular edge in the sets of parallel paths of specified length and of power k.

The determined values of w_{spi} coefficients were used to control network resources. The term 'transmission resources' means e.g. a number of timeslots or bandwidth used to transfer the usage information between network nodes.

The rule applied was that the whole set of resources is divided among the edges in accordance with the values of w_{spi} coefficients defined by the calculations.

The resources are divided according to the following rule:

$$RES_i = RES_g \cdot F_i \; where \; F_i = \frac{w_{spi}}{\sum_{i=0}^{N-1} w_{spi}} \tag{3}$$

where RES_i is the resources used by the i-th edge, RES_g is the total network resources, and F_i is a coefficient for the resources distribution.

On the basis of the simulations it was determined that the introduction of the modification of network resources modelled by regular graphs using the calculated values of w_{spi} coefficients improves their transmission properties [Bujnowski, 18].

However, it should be assumed that network topologies rarely have a form of a regular graph and especially of a Reference Graph. Normally, the connection structure is irregular. The presented article is a summary of works aimed at verifying the possibility of improving the transmission properties of networks described with irregular graphs by introducing the control of their resources.

2 The analysis of the influence of use of individual links on transmission properties of networks

In order to study the transmission properties of the analysed network topologies described with irregular graphs, a modified software tool was used to carry out a simulation tests of irregular graphs. Its operating principle is thoroughly described in article [Drzycimski, 18].

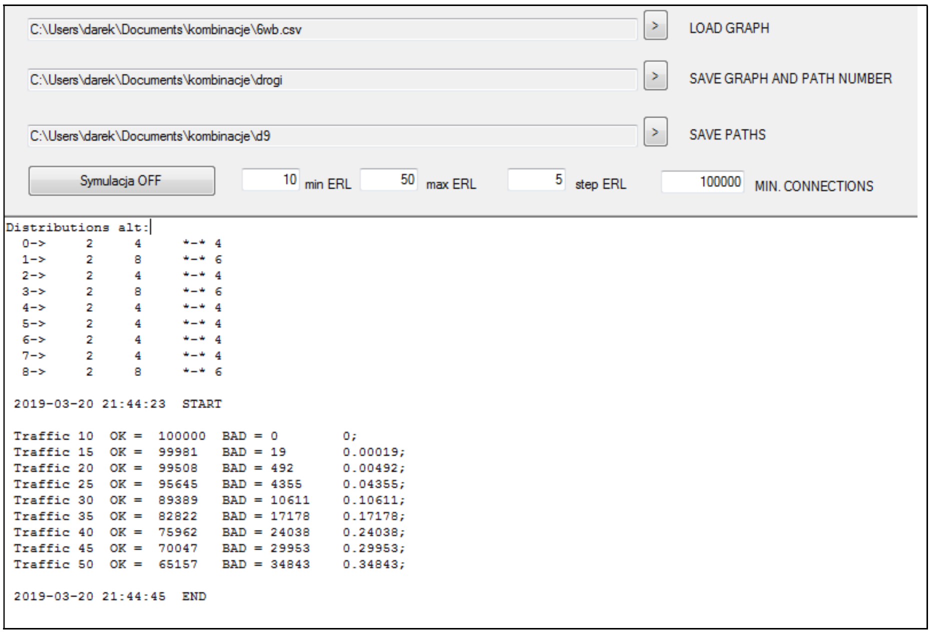

Figure 1: A screenshot of the simulator

Figure 1 shows the screen of the simulator used to perform the tests. Before the study, the following files are loaded:

- LOAD GRAPH— a file showing the connections between graph vertices along with a number of network resource units assigned to each edge, traffic generated in a specified node, and the transmission type is highlighted (one-way or two-way);
- SAVE EDGE NUMBER AND PATH NUMBER— a file to which the numbers of the edges connecting the graph's vertices will be saved.
- SAVE PATH— a file in which the distributions of use of individual edges in alternative paths of minimum length and the results of calculations of w_{spi} coefficients will be stored.

It is necessary to determine the range of the variability of the generated traffic in each node (min ERL ÷ max ERL), the difference between subsequent values of intensity step ERL and the minimum number of performed simulations (min CONNECTIONS).

After the test, the screen shows the distribution of usage of each edge in minimum length paths, a set of calculated unevenness indicators typical for each of them, the number of processed and rejected calls and the number of probability values calculated based on the number of calls in the function of changing the intensity of the generated traffic (see Fig. 1).

In order to explain the further methods, an example was used. A virtual network described by an irregular graph whose scheme is shown in Fig. 2 can serve as an example.

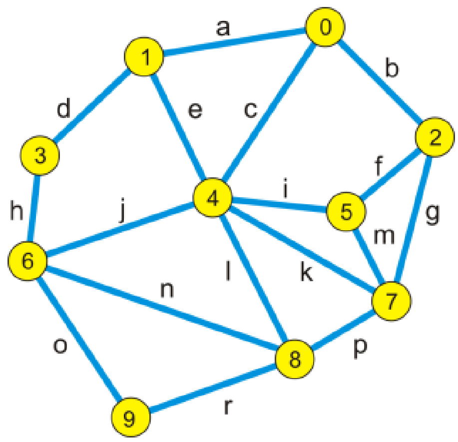

Figure 2: An example of a network described by an irregular graph

As mentioned before, the ICT system (its configuration, to be specific) can be presented with a graph and the graph can be presented with an adjacency matrix [Dubalski, 10].

While giving names to the graph edges presented in Fig. 2 the adjacency matrix M_S was transformed into an auxiliary matrix M_{ST}.

$$M_S = \begin{bmatrix} 0&1&1&0&1&0&0&0&0&0 \\ 1&0&0&1&1&0&0&0&0&0 \\ 1&0&0&0&0&1&0&1&0&0 \\ 0&1&0&0&0&0&1&0&0&0 \\ 1&1&0&0&0&1&1&1&1&0 \\ 0&0&1&0&1&0&0&1&0&0 \\ 0&0&0&1&1&0&0&0&1&1 \\ 0&0&1&0&1&1&0&0&1&0 \\ 0&0&0&0&1&0&1&1&0&1 \\ 0&0&0&0&0&0&1&0&1&0 \end{bmatrix} \rightarrow M_{ST} = \begin{bmatrix} 0&a&b&0&c&0&0&0&0&0 \\ a&0&0&d&e&0&0&0&0&0 \\ b&0&0&0&0&f&0&g&0&0 \\ 0&d&0&0&0&0&h&0&0&0 \\ c&e&0&0&0&i&j&k&l&0 \\ 0&0&f&0&i&0&0&m&0&0 \\ 0&0&0&h&j&0&0&0&n&o \\ 0&0&g&0&k&m&0&0&p&0 \\ 0&0&0&0&l&0&n&p&0&r \\ 0&0&0&0&0&0&o&0&r&0 \end{bmatrix}$$

Using the above-mentioned option of the simulator, Table 1 present the numbers of uses of the individual graph edges in the paths of minimum length.

Edge	$\sum u_i$	u_{il}			Edge	$\sum u_i$	u_{il}		
		1	2	3			1	2	3
a	8	2	4	2	*j*	30	2	12	16
b	14	2	8	4	*k*	16	2	8	6
c	18	2	10	6	*l*	16	2	8	6
d	16	2	6	8	*m*	6	2	2	2
e	20	2	10	8	*n*	10	2	4	4
f	8	2	4	2	*o*	14	2	4	8
g	14	2	6	6	*p*	18	2	8	8
h	18	2	8	8	*r*	16	2	4	10
i	22	2	10	10					

Table 1: The number of usage of individual graph edges in the function of length of minimum paths

Symbols: $\sum u_i$ — a total number of uses of the selected edge, u_{il} — number of uses of a given edge in a set of paths of length l.

Table 1 shows that the average of the analysed graph is 3. By multiplying the transformed matrix by itself three times, the path configurations made of one, two and three edges was determined.

After choosing the minimum length paths and eliminating the paths connecting a given node itself, a connection configuration shown in Table 2 was obtained.

Nodes	0	1	2	3	4	5	6	7	8	9
0	-	a	**b**	ad	c	**b**f, ci	cj	**b**g, ck	cl	cjo, clr
1	a	-	a**b**	d	e	ei	dh, ej	ek	el	dho, ejo, elr
2	**b**	a**b**	-	**b**ad	**b**c, fi, gk	f	fij, gkj, gpn, **b**cj	g	gp	gpr
3	ad	d	**b**ad	-	de, hj	dei, hji	h	dek, hjk, hnp	hn	ho
4	c	e	**b**c,fi, gk	de, hj	-	i	j	k	l	jo,lr
5	**b**f, ci	ei	f	dei, hji	i	-	ij	m	il, mp	ijo, ilr, mpr
6	cj	dh, ej	fij, gkj, gpn, **b**cj	h	j	ij	-	jk,np	n	o
7	**b**g, ck	ek	g	dek, hjk, hnp	k	m	jk,np	-	p	pr
8	cl	el	gp	hn	l	il, mp	n	p	-	r
9	cjo, clr	dho, ejo, elr	gpr	ho	jo,lr	ijo, ilr, mpr	o	pr	r	-

Table 2: Minimum paths configurations

The analysis of the obtained path set was performed (Table 2) and on its basis the number of occurrence of each edge in the sets of parallel (alternative) paths of specified length was calculated.

For example: the *b* edge appears six times in two-way single paths connecting the nodes 0 and 2, 1 and 2, 2 and 3, four times in two parallel paths 0–5, 0–7 formed by two parallel paths, twice in each set of paths consisting of three and four edges connecting nodes 2 and 4, 2 and 6.

Edge	N_{ar}				Edge	N_{ar}			
	1	2	3	4		1	2	3	4
a	8	0	0	0	*j*	6	12	6	6
b	6	4	2	2	*k*	4	6	6	2
c	6	8	2	2	*l*	6	6	4	0
d	6	6	4	0	*m*	2	2	2	0
e	8	6	6	0	*n*	4	2	2	2
f	2	2	2	2	*o*	4	4	4	0
g	6	2	2	4	*p*	8	4	4	2
h	6	6	6	0	*r*	6	4	6	0
i	6	8	6	2					

Table 3: The distribution of use of individual edges in alternative paths of the analysed graph

After having summed up all the results, distributions N_{ar} of each edge appearances in the shortest alternative paths of specified length were obtained (Table 3).

Using the results in Table 3 and using the formulas (1) and (2), the values of unevenness coefficients w_{spi} were determined. Their value is presented in Table 4.

Edge	w_{spi}	Edge	w_{spi}
a	8.000	*j*	15.500
b	9.167	*k*	8.500
c	11.167	*l*	10.333
d	10.333	*m*	3.667
e	13.000	*n*	6.167
f	4.167	*o*	8.000
g	8.667	*p*	11.833
h	11.000	*r*	10.000
i	12.500	$\sum \boldsymbol{w_{spi}}$	162.000

Table 4: Calculated coefficient w_{spi} *values*

In order to check the correctness of simulator operation, a comparison was made regarding the calculated coefficients of network resource distribution for individual edges obtained by using Fs with the results of theoretical calculations Ft.

The calculations of the values mentioned above were done with the formulas:

$$F_t = \frac{w_{spi}}{\sum_{i=0}^{N-1} w_{spi}} \tag{4}$$

$$F_s = \frac{L_{ui}}{\sum_{i=0}^{N-1} L_{ui}} \tag{5}$$

while for calculation of F_s the simulation result shown in Table 5 were used (L_{ui} number of the use of *i-th* edge).

Edge	L_{ui}	Edge	L_{ui}
a	389517	*j*	712267
b	446510	*k*	409612
c	534907	*l*	506540
d	511505	*m*	180695
e	622773	*n*	307583
f	202852	*o*	382326
g	423742	*p*	580521
h	535223	*r*	492877
i	594252	$\sum L_{ui}$	7833702

Table 5: The distribution of the use of edges resulting from the simulation

Table 6 shows the results of comparison.

Edge	F_s	F_t	Edge	F_s	F_t
a	0.050	0.049	*j*	0.091	0.096
b	0.057	0.057	*k*	0.052	0.052
c	0.068	0.069	*l*	0.065	0.064
d	0.065	0.064	*m*	0.023	0.023
e	0.079	0.080	*n*	0.039	0.038
f	0.026	0.026	*o*	0.049	0.049
g	0.054	0.053	*p*	0.074	0.073
h	0.068	0.068	*r*	0.063	0.062
i	0.076	0.077			

Table 6: The comparison of coefficients of the distribution of the resources obtained theoretically and thanks to the simulation

The presented results confirm the validity of the determination of coefficients obtained through the use of a simulator.

The coefficients were used in calculating the way of distributing the network resources among individual edges according to the formula (3).

Table 7 shows the values of distribution coefficients for the studied example of a network described with an irregular graph. It was assumed that the resources RES used by each of fourteen edges are equal to 32 conventional units which means that the global network resources are equal to 17 · 32 = 544 units.

Edge	*a*	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*
F_i	0.050	0.057	0.068	0.065	0.079	0.026	0.054	0.068	0.076
RES_i	27	31	37	36	43	14	29	37	41
Edge	*j*	*k*	*l*	*m*	*n*	*o*	*p*	*r*	
F_i	0.091	0.052	0.065	0.023	0.039	0.049	0.074	0.063	
RES_i	49	28	35	14	21	28	40	34	

Table 7: Calculated values of transmission resources distribution coefficients

Since the number of resources given to each edge must be an integer, the obtained values have been rounded out so that the sum of all units does not exceed the assumed total network resources.

Figure 3 shows the effects of introducing the proposed modification on the transmission properties of the analysed network.

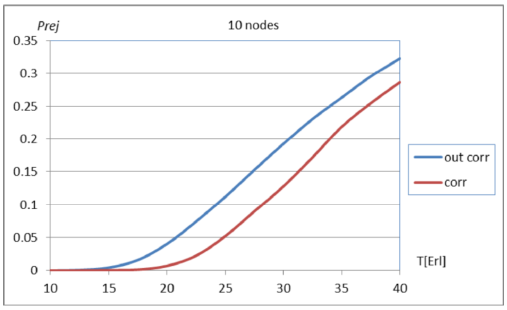

Figure 3: A comparison chart of the probability of rejecting a service call. outcorr — without resources control, corr — with resources control Network resources for a single edge — 32 units

The chart shows that introducing the control of transmission resources of the simple network causes a significant improvement of transmission properties of this network.

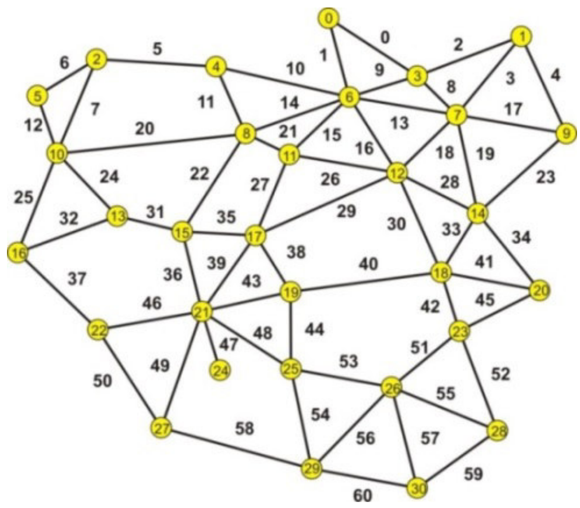

Figure 4: The analysed connection network

The benefits of the introduction of the control of network resources were verified on the basis of more complex network shown in Fig. 4. The network comprises of 31 nodes connected with 61 links.

Using the described method, the charts (Fig. 5) present the results of the relationship of the probability of rejecting the call in the function of generated traffic.

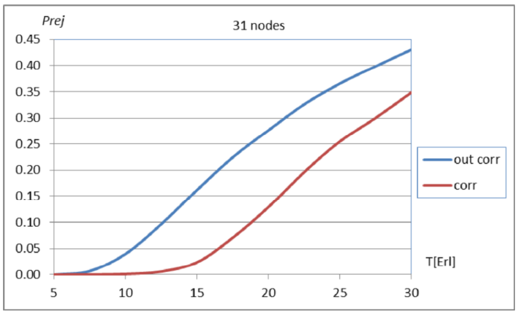

Figure 5: The results of the research of the network shown in Figure 4

The chart shows that the introduction of the control brought more significant effects.

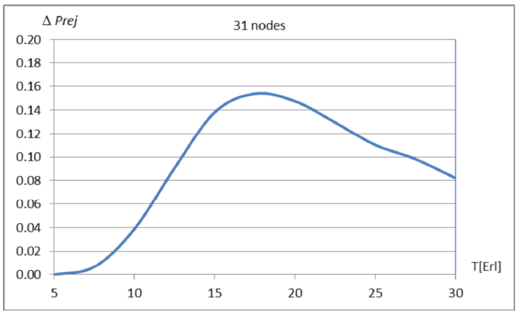

Figure 6: The differences of the probability of rejecting a service call in the function of the intensity of the generated traffic

The specified differences in the obtained probability of rejecting call for realisation are presented in the subsequent charts (Fig. 6).

Additional tests have been performed that aimed at checking if the introduction of network resources control has an impact on the network's transmission capabilities in case of a link failure. For this purpose, edge 30 was selected whose percentage of global resources utilisation is the largest (3.54%).

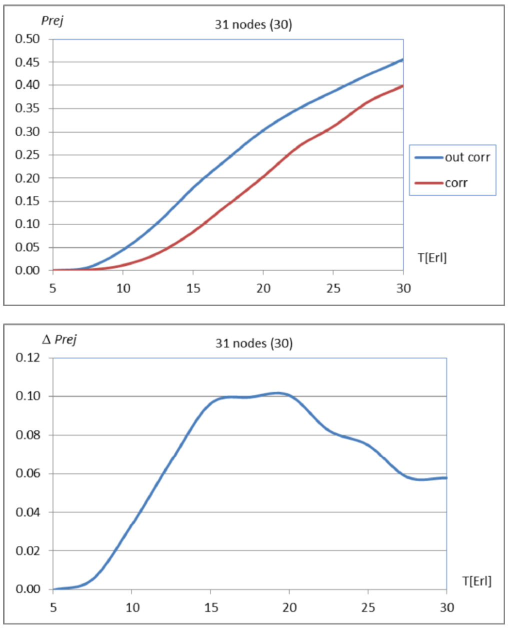

Figure 7: The comparison of changes in the probability of rejecting a call in case of link 30 failure

The charts (Fig. 7) also compare the changes in the probability of rejecting a call in the function of changes of the intensity of traffic in case of the failure of the link mentioned above. It is evident that despite the failure, the network using the potential of the resources still has better transmission properties.

Similar tests were conducted with the assumption that three busiest links (30, 36, 42) failed. In total they used over 10% of network resources.

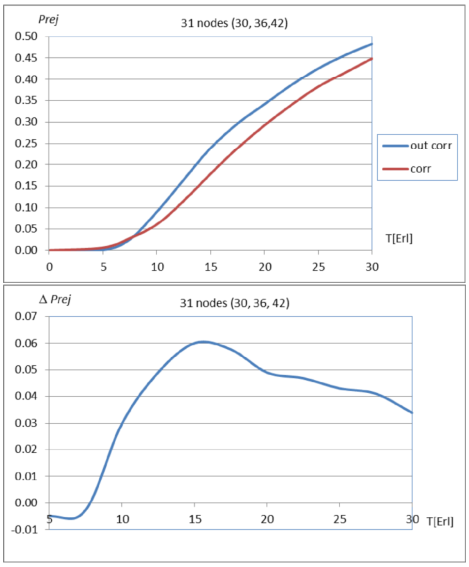

Figure 8: The results of simulations including the failure of three links

The results presented in the charts (Fig. 8) confirm that in this case the introduction of the control of resources also improves the transmission properties of a network. Research was done for the case in which a node is damaged. It was assumed that the node in question would be node 17 located in the centre of the network.

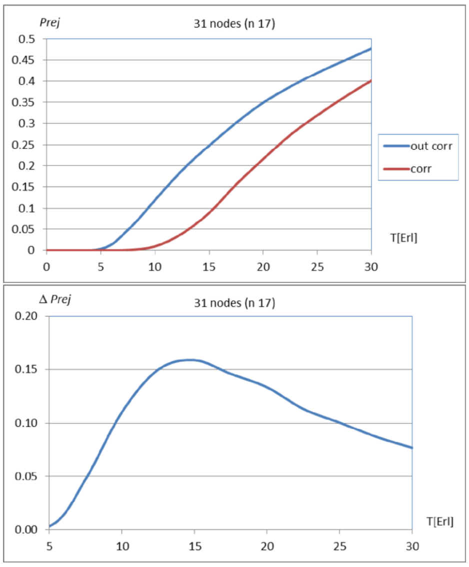

Figure 9: The simulation results with node 17 failure

The test results (Fig. 9) confirm that the network with the control of resources is more resistant to the effects of the node failure.

On the grounds of the analysis of the results, the following conclusion was reached:

The introduction of network resources management according to the proposed method causes the improvement of its transmission property and the increase of its resistance to failure without the need to change the network's configuration (e.g. by introducing additional connections).

3 Uneven traffic intensity generated in network nodes

In the above research on the control of network resources causing the improvement of the network's transmission properties it was assumed that the traffic generated in each node has equal density which is very often differs from the actual state of networks. This part of the thesis presents the method for solving this particular issue.

In order to explain it, an example of the network shown in Fig. 2 was used.

As mentioned earlier, the traffic generated in actual networks' nodes is usually of various density. To include the influence of this case, a matrix visualising total traffic density caused by users connected with particular nodes was used.

It was assumed that the generated traffic is twice larger in the zero node is, three times larger in the sixth node and four time larger in the fifth node in comparison to the remaining nodes. The matrix called the traffic matrix $\boldsymbol{M_r}$ would have the following form:

$$M_r = \begin{bmatrix} 0&1&1&1&1&4&3&1&1&1\\ 2&0&1&1&1&4&3&1&1&1\\ 2&1&0&1&1&4&3&1&1&1\\ 2&1&1&0&1&4&3&1&1&1\\ 2&1&1&1&0&4&3&1&1&1\\ 2&1&1&1&1&0&3&1&1&1\\ 2&1&1&1&1&4&0&1&1&1\\ 2&1&1&1&1&4&3&0&1&1\\ 2&1&1&1&1&4&3&1&0&1\\ 2&1&1&1&1&4&3&1&1&0 \end{bmatrix}$$

By multiplying this matrix by the matrix of minimum length paths, a set of use of individual graph edges was obtained. The results of this operation are shown in Table 8.

Nodes	0	1	2	3	4	5	6	7	8	9
0	-	2*a*	2*b*	2*ad*	2*c*	2*bf*, 2*ci*	2*cj*	2*bg*, 2*ck*	2*cl*	2*cjo*, 2*clr*
1	*a*	-	*ab*	*d*	*e*	*ei*	*dh, ej*	*ek*	*el*	*dho, ejo, elr*
2	*b*	*ab*	-	*bad*	*bc, fi, gk*	*f*	*fij, gkj, gpn, bcj*	*g*	*gp*	*gpr*
3	*ad*	*d*	*bad*	-	*de, hj*	*dei, hji*	*h*	*dek, hjk, hnp*	*hn*	*ho*
4	*c*	*e*	*bc,fi,gk*	*de, hj*	-	*i*	*j*	*k*	*l*	*jo,lr*
5	4*bf*, 4*ci*	4*ei*	4*f*	4*dei*, 4*hji*	4*i*	-	4*ij*	4*m*	4*il*, 4*mp*	4*ijo*, 4*ilr*, 4*mpr*
6	3*cj*	3*dh*, 3*ej*	3*fij*, 3*gkj*, 3*gpn*, 3*bcj*	3*h*	3*j*	3*ij*	-	3*jk*,3*np*	3*n*	3*o*
7	*bg, ck*	*ek*	*g*	*dek, hjk, hnp*	*k*	*m*	*jk,np*	-	*p*	*pr*
8	*cl*	*el*	*gp*	*hn*	*l*	*il, mp*	*n*	*p*	-	*r*
9	*cjo, clr*	*dho, ejo, elr*	*gpr*	*ho*	*jo,lr*	*ijo, ilr, mpr*	*o*	*pr*	*r*	-

Table 8: The set of use of minimum length paths including the differences in the traffic generated in individual nodes

Consequently, on the basis of the results the number of occurrences of particular nodes was calculated along with the unevenness coefficients from the formulas (1) and (2). The results are presented in Tables 9 and 10.

Edge	N_{ar}				Edge	N_{ar}			
	1	2	3	4		1	2	3	4
a	8	0	0	0	*j*	6	12	6	6
b	6	4	2	2	*k*	4	4	6	2
c	6	8	2	2	*l*	6	6	4	0
d	6	6	4	0	*m*	2	2	2	0
e	8	6	6	0	*n*	4	2	2	2
f	2	2	2	2	*o*	4	4	6	0
g	6	2	2	4	*p*	8	4	4	2
h	6	6	6	0	*r*	6	4	6	0
i	6	8	6	2					

Table 9: The distribution of use of individual edges in sets of alternative paths of the analysed graph

Edge	w_{spi}	Edge	w_{spi}	Edge	w_{spi}	Edge	w_{spi}	Edge	w_{spi}	Edge	w_{spi}
a	8.000	*d*	10.333	*g*	8.667	*j*	15.500	*m*	3.667	*p*	11.833
b	9.167	*e*	13.000	*h*	11.000	*k*	8.500	*n*	6.167	*r*	10.000
c	11.167	*f*	4.167	*i*	12.500	*l*	10.333	*o*	8.000	$\sum w_{spi}$	162.00

Table 10: Calculated values of the unevenness coefficients

Using the formula (3) the distribution of network resources was calculated for individual edges of the graph describing the network with the assumption that the general resources of this network are RES_i = 544 conventional units (Table 11).

Edge	*a*	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*
F_i	0.049	0.057	0.069	0.064	0.080	0.026	0.053	0.068	0.077
RES_i	26.9	30.8	37.5	34.7	43.7	14.0	29.1	36.9	42.0
RES_i'	27	31	37	35	44	14	29	37	42
Edge	*j*	*k*	*l*	*m*	*n*	*o*	*p*	*r*	
F_i	0.096	0.052	0.064	0.023	0.038	0.049	0.073	0.062	
RES_i	52.0	28.5	34.7	12.3	20.7	26.9	39.7	33.6	
RES_i'	52	28	35	12	21	27	40	33	

Table 11: The results of the calculations of the distribution of network resources

RES_i' means the value of resources after rounding to integers.

Using the calculated values of the resources distribution the simulation research was done for the analysed network. Figure 10 shows the results of this research in the case of using equal transmission resources for each edge and with the adjustment of their use. As it is visible from the included chart, the introduction of network resources control improved the transmission properties for the whole network.

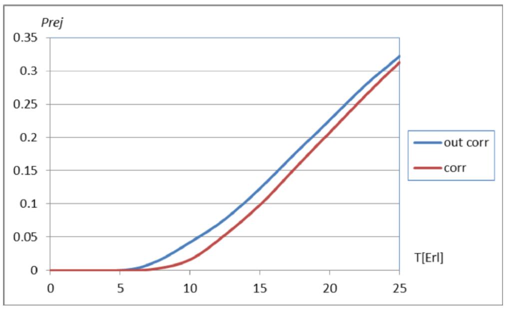

Figure 10: Simulation results

To check the influence of the discussed method in more complex and irregular connection topology, a simulation test of the network shown in Figure 4 was performed.

It was assumed that the intensity of the traffic generated up to node 6 is five times larger, in node 17 — four times larger, in nodes 18 and 21 — three times larger and in node 26 — two times larger than in the remaining nodes. The general number of network resources is 3904 conventional units — 64 for each edge on average. The total value of the wsp_i coefficients is 2878.

The results of the calculations are presented in Table 12.

Edge	wsp_i	RES_i	Edge	wsp_i	RES_i	Edge	wsp_i	RES_i
0	7.50	10	21	31.94	43	42	97.00	132
1	52.50	71	22	78.56	107	43	48.33	66
2	14.80	20	23	36.48	49	44	36.98	50
3	37.55	51	24	27.29	37	45	29.92	41
4	10.98	15	25	64.34	87	46	62.64	85
5	48.44	66	26	30.11	41	47	60.00	81
6	13.80	19	27	41.62	56	48	82.79	112
7	28.02	38	28	37.88	51	49	50.73	69
8	43.54	59	29	93.45	127	50	40.57	55
9	23.42	32	30	100.85	137	51	57.92	79
10	64.67	88	31	57.02	77	52	44.34	60
11	29.10	39	32	10.00	14	53	54.55	74
12	46.20	63	33	45.48	62	54	29.22	40
13	54.40	74	34	40.74	55	55	21.48	29
14	88.11	119	35	38.09	52	56	26.11	35
15	26.45	36	36	94.89	129	57	20.62	28
16	91.33	124	37	70.67	96	58	55.30	75
17	27.17	37	38	36.50	49	59	17.55	24
18	56.08	76	39	83.19	113	60	29.56	40
19	40.20	54	40	72.48	98			
20	91.33	124	41	25.18	34			

Table 12: The values of the unevenness coefficients and the way of distribution of the network resources

Figure 11 shows the comparison of the probability of the call rejection in the traffic density function.

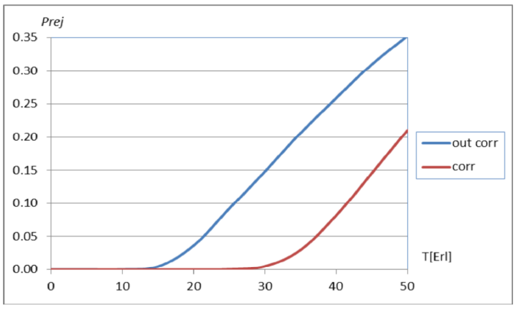

Figure 11: Simulation results

The simulation was done also for the case of a simultaneous failure of links 30, 36 and 42 and a damage of node 17. The results are presented in Figure 12.

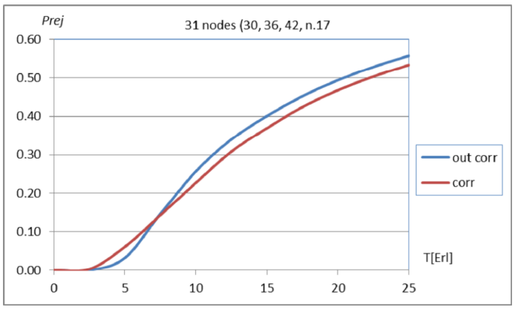

Figure 12: Simulation results

The introduction of network resources management according to the proposed method causes the improvement of the network's transmission property understood to be the lowering of the probability of rejecting a service call even with uneven traffic density generated in particular network nodes

4 Conclusions

The article discussed the matter of the research of transmission properties of network described with irregular graphs, whereby the parameter adopted as the measure of the properties was the probability of rejecting the call processing. To enable the testing of the analysed structures, a modified simulation application designed by the authors was used.

The main purpose of the research was to check the validity of the hypothesis regarding the possibility to improve the industrial properties of networks described by irregular graphs due to the introduction of control measures of the usage of transmission resources of these networks.

The way of determining the coefficients used for this task was presented. The coefficients were used to specify the way of distributing the global network resources among individual internodal links.

Exemplary results of research regarding simple and more complex network structures were presented, both with equivalent and various density of traffic generated by the users connected to the nodes and also in case of link or node failure.

In relation to previous works of the authors regarding the analysis of networks described by regular graphs, the results obtained from the tests in this thesis showed that the number of parallel paths consisting of specific edges significantly influences the network's transmission properties. The results also prove right the hypothesis that the introduction of the management of network resources improves the transmission properties of the network and makes it less vulnerable to link and node failures, without the need for changes in configuration.

In conclusion, the presented method can be used for more effective transmission of in-formation in actual telecommunication networks.

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