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MODELING AND OPTIMIZATION OF TELECOMMUNICATION NETWORKS USING FLOW REDISTRIBUTION

Summary. This article describes a problem of telecommunication network modeling and optimization using flow redistribution. For these purposes a computer system was created. Structure of the application is described briefly. Optimization possibilities of the program are demonstrated on examples and analyzed.

Keywords: telecommunication network, graph, flow redistribution

MODELOWANIE I OPTYMIZACJA SIECI TELEKOMUNIKACYJNYCH Z WYKORZYSTANIEM PODZIAŁU PRZEPIŹYWÓW

Streszczenie. W artykule opisano problemy modelowania oraz optymalizacji sieci telekomunikacyjnych z wykorzystaniem metody podziału przepływów. W celu optymalizacji zostało stworzone oprogramowanie. Dokładnie opisano strukturę oprogramowania. Możliwości optymalizacji oprogramowania zostały pokazane na przykładach i przeanalizowane.

Słowa kluczowe: sieć telekomunikacyjna, graf, podział przepływów

1. Introduction

Nowadays telecommunication networks (TCN) belong to the most dynamically and rapidly developing ones. Telecommunication companies are trying to improve quality of their service and to implement modern technologies. That's why, without a doubt, optimization problem of such networks is actual and practically important. There is now a possibility of modeling TCN using computer and developing optimal strategy for a telecommunication

company using appropriate mathematical calculations. Obviously, an efficient mathematical model and a computer system for these purposes should be created. Development of algorithms for analysis and configuration of transportation flows for better reliability and, obviously, quality of service of the network, is an important problem. Designing routing algorithms using minimal packet delay criterion is also an important problem. Optimization problems of minimal signal passing time and maximal possible flow play very important role in raising TCN efficiency. Solving of these problems allows efficient redistribution of load in the network, managing flows at the moments of critical load (overloaded mode) and preserving enormous delays at some of the telecommunication nodes.

Telecommunication network consists from an aggregate of nodes and an aggregate of connections between nodes. Therefore, it could be treated as a graph in the mathematical model. Modeling using graph theory is widely described in scientific literature [1, 2, 5], our mathematical model of the TCN is given in [8].

A computer system that allows telecommunication networks modeling and solves some of the described problems was developed. The structure, users interface and target platforms of the program were described in details in [8]. In this article only a brief description is given. More attention is paid on testing and optimization possibilities of the program.

2. Computer system: brief characteristic

The computer system for telecommunication network modeling and optimization was developed using C# language in Microsoft Visual Studio 2008. It allows modeling telecommunication networks using graph theory and solves some of the described in the introduction optimization problems, i.e. calculation of minimal passing time and maximal flow in the network. For these calculation own algorithms were developed. They are based on classical Dijkstra [3], Floyd and Ford-Fulkerson [4] algorithms but take some specific features of the telecommunication network (i.e. delay on nodes, different working modes of every node) into account. All these features are described in details in [8].

Nowadays together with usual (desktop) computers the pocket PCs, communicators and smart phones are getting more and more widespread. So, mobile platforms during computer system development were also taken into account. Target platforms are desktop PCs and laptops from one side and PDAs, communicators and smart phones from the other. In case of desktop PCs and laptops the program runs under Windows 2000/XP/Vista, .NET Framework 2.0 or later must be installed. Mobile edition of the program runs under Windows Mobile 2003/5.0/6.0/6.1, .NET Compact Framework 2.0 or later is required. It's important to note that the mobile edition of this product has slightly reduced functionality because of the

differences between .NET Compact Framework and .NET Framework and a poor screen resolution (QVGA) in most PDAs and communicators.

The project consists of two main parts: core and user application. The core contains implementation of optimization algorithms, base classes and base collections, serialization to XML and a component for graph visualization and is compiled to a library. The user application is compiled to executable file and provides interaction with the user.

More detailed description of the user interface, also supplemented with the screenshots could be found in [8]. All information about graph is stored in XML files. Such choice was made because of hierarchical structure and „human-readability” of this format.

3. Testing optimization possibilities on typical networks

The application allows calculating minimal paths and maximal flows between two nodes in the telecommunication network. For these purposes own algorithms based on the classical shortest path (Dijkstra, Floyd) and the maximal flow (Ford-Fulkerson) ones were developed.

Optimization possibilities of the computer system were demonstrated on the networks with ring and mesh topologies in [10]. This article contains another example of network with ring topology. Network topologies chosen for testing were similar to those in [9]. Examples of networks with these topologies are shown on fig. 1. Models of networks with ring and mesh topologies are situated from the left and right sides of the figure correspondingly.

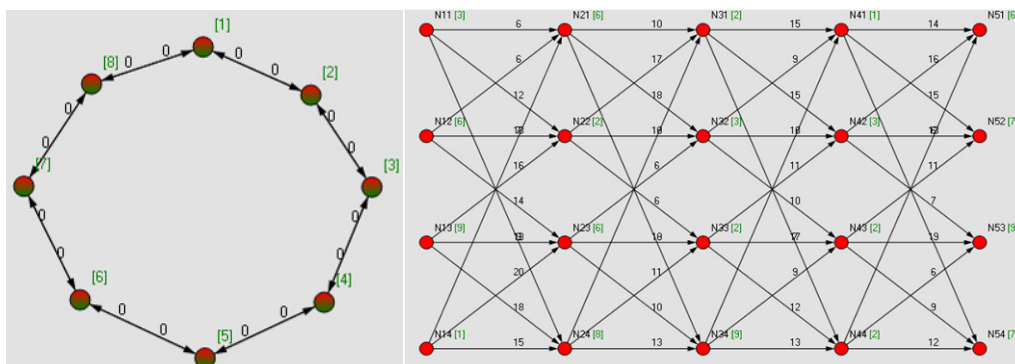


Fig. 1. A sample of networks with different topologies
Rys. 1. Przykład sieci z różnymi topologiami

Additionally tests on large networks with random topology were performed in [10] and a performance evaluation of the developed computer system was made. In this article tests on the model of real telecommunication network are also presented.

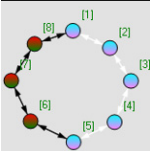
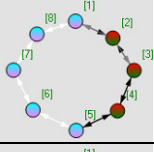
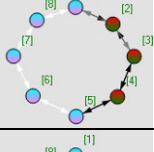
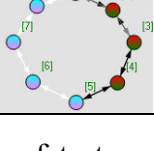
3.1. Networks with ring, mesh and random topologies

Ring topology network chosen for testing contains 8 nodes which form a ring. All nodes are named consequently from N1 to N8. Delay on each node is equal to 1 ms in idle mode, 8 ms in overloaded mode and various values between 1 ms and 8 ms in normal mode. Each node is connected with two neighbors in both directions. Nodes and connections between them could be disabled at the any moment of time. Carrying capacity of each channel is equal to 1,5 Gbps. Now let's consider the following situations:

1. Calculate the shortest path from N1 to N5. All the nodes are in normal mode.
2. Calculate the shortest path from N1 to N5. All the nodes are in normal mode. Connection between N1 and N2 is disabled.
3. Calculate the shortest path from N1 to N5. Nodes N2, N3 and N4 are overloaded, all the others – in normal mode.
4. Calculate the shortest path from N1 to N5. Nodes N7 and N8 idle, all the others – in normal mode.

Table 1

Testing results in the network with ring topology

No	Scheme	Source and destination nodes	Resulting path	Signal passing time	Maximal flow
1		N1 – N5	N1 – N2 – N3 – N4 – N5	9 ms	3,0 Gbps
2		N1 – N5	N1 – N8 – N7 – N6 – N5	21 ms	1,5 Gbps
3		N1 – N5	N1 – N8 – N7 – N6 – N5	21 ms	3,0 Gbps
4		N1 – N5	N1 – N8 – N7 – N6 – N5	8 ms	3,0 Gbps

Results of tests are shown in the table 1. Calculated paths are highlighted with white color. As it could be easily observed, different operating modes change signal delay of the nodes in telecommunication network. Therefore, system recalculates the shortest path taking new values into account. This could be observed on situations 1, 3 and 4 when some of the nodes change their operating modes from normal to overloaded and idle correspondingly.

When some connection is getting disabled, system recalculates the new path for the signal. This is demonstrated in situations 1 and 2. Obviously, when one more connection will be disabled in the network with such topology, the system will be unable to find the path. From the other side, operating mode changing has no influence on the maximal carrying capacity. It decreases when one of the connections is getting disabled because traffic can now go in only one way.

This example shows that system can effectively redistribute transportation flows in case of failure on some node of connection in the telecommunication network. Also flows are getting redistributed when nodes change their operating modes, and therefore, signal delay on them.

Mesh topology network is demonstrated on example and analyzed in [10]. Network with mesh topology is much more stable than the ring one. Even after connections in the entire row are disabled, the system is still able to find alternative way. After a few connections are disabled, the shortest path grows because of disabling some of the alternative paths for the signals. In the network with such topology all nodes or all connections from one layer must be disabled to make the system unable finding some paths.

Networks with random topology were used for performance evaluation. Performance tests were performed and analyzed in [10]. For a network containing about 100 nodes and about 1000 connections average shortest path calculation time was 20-25 milliseconds. The average calculation time strongly depends on quantity of nodes and connections between them, so for a network with 1000 nodes and 10000 connections it reaches one second. All tests were performed on a laptop with 1,8 GHz dual core processor. It's important to note that processors on pocket PCs and communicators are much slower so it will take more time to perform the same operations there.

However, most models of real telecommunication networks are much smaller so this is quite acceptable performance for these purposes. For example, model of city telecommunication network analyzed in [8] consists from only 16 nodes and 19 connections. This is much less than the size of the considered network with random topology.

3.2. Real telecommunication network

The graph containing main lines of TCN "Ukrtelecom" in Ukraine was chosen for testing as the model of real telecommunication network. Some of the tests were performed on this graph in [10]. In this article other examples are given. As it was already mentioned in [10], the graph consists of 42 nodes and 72 edges and is sparse one. Many of the optimization algorithms perform much faster on the sparse graphs. Model of the network is shown on fig. 2 below. Among 42 nodes 7 are central ones and they are displayed larger on the figure.

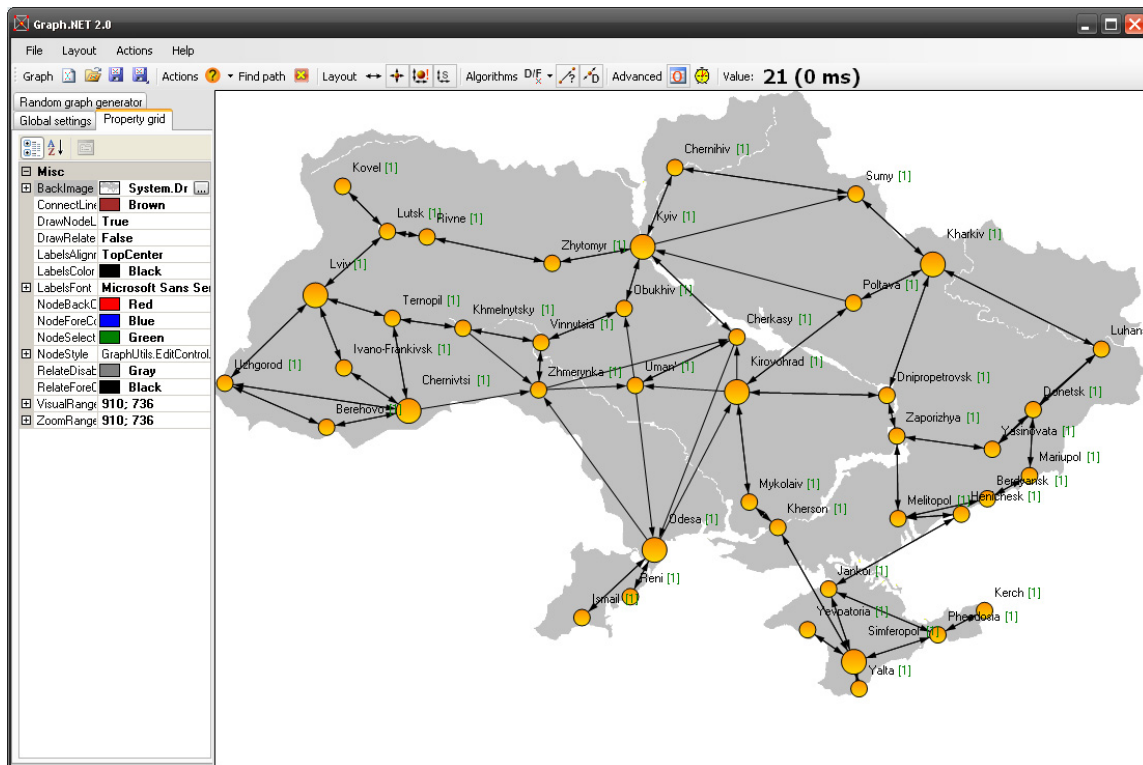


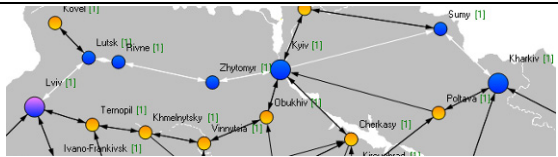
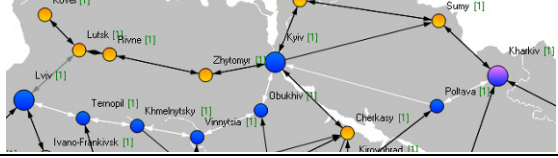
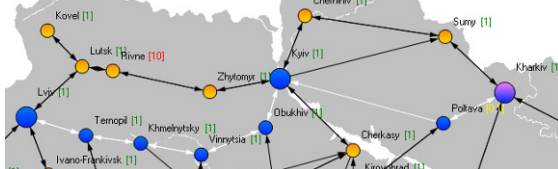

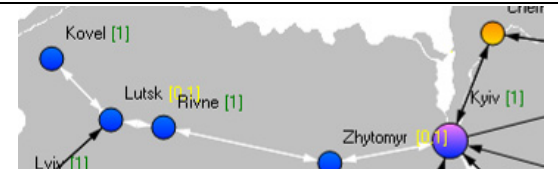
Fig. 2. A model of national-wide telecommunication network in Ukraine
 Rys. 2. Model sieci telekomunikacyjnej państwowej na Ukrainie

For simplicity of demonstration let's consider carrying capacity of lines connecting central nodes be equal to 2,5 Gbps and 1,0 Gbps for lines connecting peripheral nodes. Delay time on node for normal operating mode let be equal to 1,0 ms; for idle and overloaded mode – 0,1 ms and 10 ms correspondingly. Now let's consider the following situations:

1. Calculate the shortest path and the maximal flow between “Lviv” and “Kharkiv” (both are central nodes). All nodes are in normal operating mode.
2. Calculate the shortest path and the maximal flow between “Lviv” and “Kharkiv”. Connection between “Lviv” and “Lutsk” is disabled.
3. Calculate the shortest path and the maximal flow between “Lviv” and “Kharkiv”. Node “Poltava” idles, “Rivne” in overloaded mode.
4. Calculate the shortest path and the maximal flow between “Kyiv” and “Kovel”. First node is central, second is peripheral. All nodes are in normal operating mode.
5. Calculate the shortest path and the maximal flow between “Kyiv” and “Kovel”. Node “Rivne” is in normal operating mode, other nodes idle.
6. Calculate the shortest path and the maximal flow between “Kyiv” and “Kovel”. Connection between “Lviv” and “Lutsk” is disabled.

Calculation results are shown in the table 2. Nodes and connections between them which belong to the shortest paths are highlighted. Disabled connections are marked with grey color.

Table 2
Testing results in the telecommunication network of Ukraine

No	Source	Destination	Resulting path	Signal passing time	Maximal flow
1	Lviv	Kharkiv		5,0 ms	5,0 Gbps
2	Lviv	Kharkiv		6,0 ms	2,5 Gbps
3	Lviv	Kharkiv		5,1 ms	5,0 Gbps
4	Kyiv	Kovel		3,0 ms	1,0 Gbps
5	Kyiv	Kovel		1,2 ms	1,0 Gbps
6	Kyiv	Kovel	Path doesn't exist	-	-

In the situations 2 one of the connections which belong to previously shortest path is now disabled. The system finds the longer alternative way. Therefore, maximal possible flow is also decreased in this situation. When some of the nodes in the telecommunication network change their operating modes, delay on them is also changed and the calculated previously minimal path may now be not the shortest one. In this case system must recalculate the shortest path. This is illustrated in situations 1 and 3. Some of the nodes on the alternative way have changed their operating mode to idle. This decreased delays on these nodes and this way becomes the shortest one. In the situation 4 the maximal possible flow is equal to carrying capacity of peripheral connection which is bottleneck in the entire path. In situation number 5 the shortest path remains the same so the system recalculates the signal passing time only. In the last situation the only available connection between nodes is disabled so the system displays an error message.

4. Conclusions

1. A problem of telecommunication network modeling and optimization using flow redistribution was described and a computer system for these purposes was created. Graph theory for the modeling was used.
2. Developed optimization algorithms are based on classical minimal path and maximal flow ones, but they are taking the features of telecommunication networks into account.
3. Flow redistribution in case of failure or operating mode changing was demonstrated on examples and analyzed.
4. Developed computer system is on the stage of further development. Currently this program could be used by operators of telecommunication networks in order to optimize their architecture and redistribute transportation flows in the best way.

REFERENCES

1. Zakharchenko M. V., Klymash M. M.: *Methods and Tools for Increase of Effectiveness in Optical Transportation Systems*. Lviv 2007.
2. Popovsky V. V.: *Base Mathematical Theory of Telecommunication systems*. SMIT company, Kharkov 2006.
3. Dijkstra E. W.: *A note on two problems in connexion with graphs*. *Numerische Mathematik*, 1959.
4. Ford L. R., Fulkerson D. R.: *Flows in networks*. Princeton university press, 1962.
5. Sedgewick R.: *Algorithms in C++. Part 5. Graph algorithms*. Princeton University – Diasoft, Kiev 2002.
6. Even S.: *Graph algorithms*. Computer science press, 1979.
7. Richter J.: *Applied Microsoft .NET Framework Programming*. Microsoft Press, 2001.
8. Dronyuk I., Koshulinsky R.: *Cross-platform solution for telecommunication networks simulation and management. Version for pocket PCs and smartphones*. *Proceedings of 14-th Polish Teletraffic Symposium, Gliwice 2007*, p. 141÷150.
9. Kaczmarek S., Nowak K.: *Comparison of centralized and decentralized preemption in MPLS networks*. *Proceedings of 14-th Polish Teletraffic Symposium, Gliwice 2007*, p. 259÷268.
10. Dronyuk I., Koshulinsky R.: *Computer system for telecommunication network modeling and flow redistribution*. *Contemporary Aspects of Computer Networks*, t.2, WKŁ, Warszawa 2008, p. 85÷92.

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Omówienie

W artykule opisano problemy modelowania oraz optymalizacji sieci telekomunikacyjnych z wykorzystaniem metody podziału przepływów. Opisano dokładnie podstawy teoretyczne wykorzystane przy projektowaniu oprogramowania.

Zaproponowano oprogramowanie do modelowania i obliczania optymalnego przesyłu sygnałów oraz podziału przepływów w sieciach telekomunikacyjnych. Opisano dwie wersje oprogramowania: dla zwykłych PC i pocket PC oraz dla smartfonów. Implementacja została opracowana w języku programowania C# zorientowanego dla .NET platformy w środowisku MS Visual Studio 2008. W realizacji algorytmów wyszukiwania minimalnej drogi i maksymalnego przepływu wzięto pod uwagę specyfikę sieci telekomunikacyjnych.

Opisano strukturę oprogramowania, przedstawiono jego interface oraz zasady działania. Podstawą teoretyczną oprogramowania jest klasyczna teoria grafów.

Przy obliczaniu minimalnej drogi jako kryterium optymalności przyjęto czas przesyłu sygnału przez łącze komunikacyjne; przy obliczaniu maksymalnego natężenia transmisji uwzględniono możliwość ustawienia różnej przepustowości łącza komunikacyjnego.

Oprogramowanie zostało przetestowane na różnych konfiguracjach sieci. Przedstawiono przykład modelowania państwowej sieci telekomunikacyjnej na Ukrainie.

Przewidywane obszary zastosowań obejmują operatorów sieci stacjonarnych i komórkowych.

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