The Model and the Method of Two-Level Routing in Mpls Network

Alexander V. Lemeshko — Technical Sciences and The Scientific Adviser TCS Department Kharkov national university of radio Electronics Lenina ave., 14, Kharkov, 61166, UKRAINE, e-mail: avlem@mail.ru

Dmytro V. Andrushko — TCS Department Kharkov National University of Radio Electronics Lenina ave, 14, Kharkov, 61166, UKRAINE e-mail: da@kture.kharkov.ua

Ahmad M. Hailan — TCS Department Kharkov national university of radio electronics Lenina ave, 14, Kharkov, 61166, UKRAINE e-mail: onlineahmeds@mail.ru

Abstract

In the article mathematical model for routing in the MPLS network is proposed. Also method of two-level routing on the basis of goal coordination principle in the MPLS network is offered. The method is used to increase the scalability of flow-based routing strategies.

Keywords : MPLS, routing, QoS, NGN .

المستخلص

في البحث اقتراح نموذج رياضي للتوجيه في الشبكة بواسطة التبديل متعدد البروتوكولات باستخدام المؤشرات التعريفية (**MPLS**) . ويعرض أيضاً طريقة توجيه من مستويين بالاعتماد على مبدأ تنسيق الهدف في شبكة التبديل متعدد البروتوكولات باستخدام المؤشرات التعريفية (**MPLS**). هذه الطريقة استخدمت لتحسين وموازنة أداء إستراتيجية التوجيه.

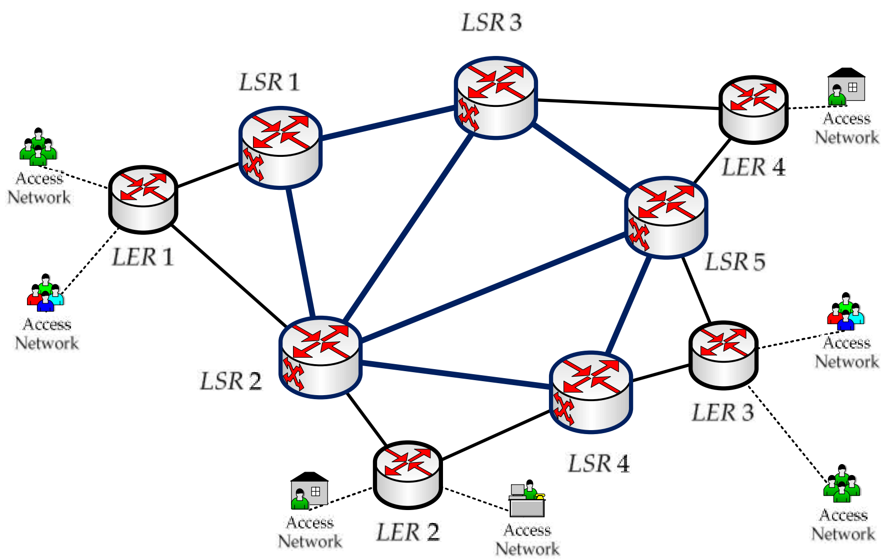
1. Introduction

MPLS technology (*Multiprotocol Label Switching*) currently considered as the main transport platform for modern telecommunication systems [1, 2]. During it development previous experience of transport technologies such as IP (*Internet Protocol*) and ATM (*Asynchronous Transfer Mode*) was considered. That’s why combination of IP-routing principles and high speed ATM-switching was implemented in MPLS technology. As a result MPLS use virtual connections with source-based routing that significantly expands the capabilities of quality of service (*QoS*) support in this technology. However, along with the advantages, MPLS has number of disadvantages specific to traditional routing technologies. First of all, these are problems of routing scalability in case of telecommunication system territorial distribution, increase of network nodes number and their coherence, permanent user traffic grows and expansion of QoS parameters list.

Analysis has shown [3, 4] that the main way to improve existing and develop new routing protocols is to reevaluate routing mathematical models and methods which is, first of all, associated with the transition to the flow-based models. Such models, comparing to the graph-based take into account structural and functional parameters of telecommunication system and the traffic characteristics. In order to improve scalability of flow-based models, effective solutions are based on the principles of multi-level (hierarchical) routing [5, 6] traditionally used. Due to this, current paper introduces the routing mathematical model that belongs to the multi-level flow-based routing models class and adapted to features of MPLS-networks engineering and functioning.

2. The structural description of MPLS-network

Let's MPLS-network structure Figure (1) is described by graph $G=(M,E)$, where M – is the set of nodes and E – is the set of transmission paths in the network Figure (2) .



Figure(1). Example of MPLS-network structure.

According to MPLS engineering principles the whole set of nodes can be divided into two subsets: $M^{+}=\{M_r^{+}, r=\overline{1,m_{LER}}\}$ – is the label edge routers subset (LER) and

$M^- = \{M_j^-, j = \overline{1, m_{LSR}}\}$ – is the label switching routers subset of (*LSR*). Each arc $(i, j) \in E$ of the graph presents transmission path in the network and appropriate bandwidth φ_{ij} associated with this path. The set of received user (access networks) traffics K depending on which label edge router received can be decomposed into the subsets $\{K_r, r = \overline{1, m_{LER}}\}$, where K_r – is the set of traffics received by r-th *LER*. Then each traffic from the K_r-set has series of the following parameters:

M_r^+ – r-th *LER* which receives k-th traffic (source node);

M_p^+ – p-th *LER* via which k-th traffic leaves *MPLS*-network (destination node);

λ^{k_r} – rate (speed) of the k_r-th traffic, i.e. k-th traffic which r-th *LER receives*.

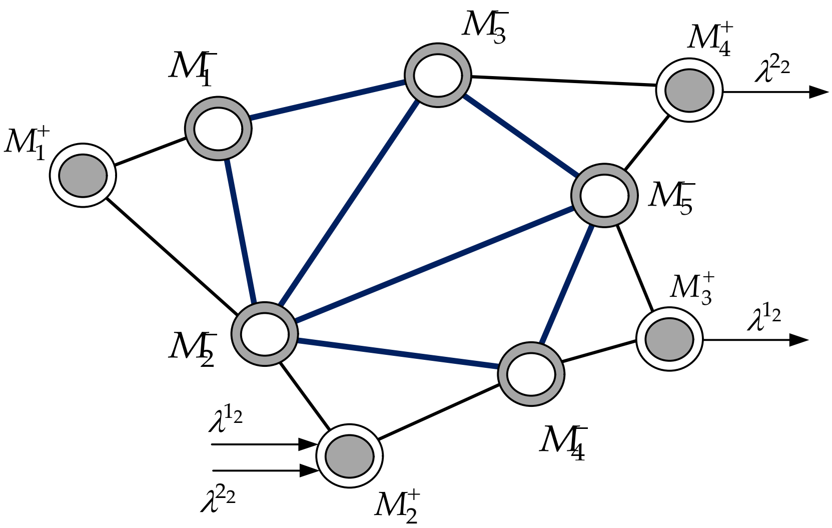


Figure (2). Graph model of MPLS-network.

For example, Figure (2) shows rates of two traffics (λ^{1_2} and λ^{2_2}) entering the second *LER* and destined for fourth and third *LER* respectively.

3. Functional description of MPLS-network

During the routing problems solving using flow-based models in MPLS-network, it is required to calculate one or set of paths (*Label Switching Path, LSP*) between a pair of edge sender-receiver nodes and determine the traffic distribution order between them according to given rate. Let's use two-level scheme of calculation to increase scalability of routing tasks solving:

on the lower layer – desired routes are calculated independently at each LER for the traffics that come to particular LER from subscribers (*network access traffic*);

on the upper layer – solutions obtained on the lower layer are coordinated in order to prevent the probable transmission paths overload in the network due to the routing decisions decentralization.

Then for each r-th *LER* routing variables $x_{ij}^{k_r}$ characterize traffic rate of the k_r-th traffic in the path $(i,j) \in E$. In order to prevent packet loss at the routers and in the network in general, during the routing variables calculation it is necessary to keep conditions of the flow conservation:

$$\begin{cases} \sum\limits_{j:(i,j)\in E} x_{ij}^{k_r} - \sum\limits_{j:(j,i)\in E} x_{ji}^{k_r} = \lambda^{k_r} & \text{if} \quad k_r \in K_r\,, \quad i = M_r^+; \\ \sum\limits_{j:(i,j)\in E} x_{ij}^{k_r} - \sum\limits_{j:(j,i)\in E} x_{ji}^{k_r} = 0 & \text{if} \quad k_r \in K_r\,, \quad i \neq M_r^+, M_p^+; \\ \sum\limits_{j:(i,j)\in E} x_{ij}^{k_r} - \sum\limits_{j:(j,i)\in E} x_{ji}^{k_r} = -\lambda^{k_r} & \text{if} \quad k_r \in K_r\,, \quad i = M_p^+. \end{cases} \tag{1}$$

The system of equations-conditions (1) should be executed for each traffic which enters any label edge router (*LER*). Besides, in order to prevent possible transmission path overload in *MPLS*-network it is important to fulfill following conditions (by number of transmission paths):

$$\sum_{r\in M^+} \sum_{k_r\in K_r} x_{ij}^{k_r} \le \varphi_{ij}\,;\ (i,j) \in E\,. \tag{2}$$

Please note, that in case of decentralized routing variables calculation it's impossible to take into account condition (2) for each particular LER explicitly, because each edge router determines *LSP* for user traffic which comes without information about calculation results of the adjacent LER. Due to this let's write conditions (2) in the following form:

$$\sum_{k_r\in K_r} x_{ij}^{k_r} \le \varphi_{ij} - \sum_{\substack{s\in M^+\\ s\neq r}} \sum_{k_s\in K_s} x_{ij}^{k_s}\,;\ r\in M^+,\ (i,j) \in E\,. \tag{3}$$

Expression (3) means that the traffic, routed from r-th *LER* should not exceed available bandwidth in transmission path, which remained after traffics from other edge routers were served.

According to the physical meaning of the routing variables they should meet these requirements:

$$0 \le x_{ij}^{k_r} \le \lambda^{k_r} . \tag{4}$$

In vector-matrix form conditions (3) can be written as:

$$B_r \cdot \vec{x}_r \le \sum_{\substack{s \in M^+ \\ s \ne r}} B_s \vec{x}_s . \tag{5}$$

During the vector $\vec{x}_r$ variables calculation, a minimum of following goal function should be used as optimality criterion for obtained solutions:

$$\min_x F \quad \text{at} \quad F = \sum_{r \in M^+} \vec{x}_r^t H_r \vec{x}_r , \tag{6}$$

where H_r – diagonal positive matrix of channels metrics; $[]^t$ – vector (matrix) transpose operation.

Then, switching to an unconditional extreme problem it is necessary to maximize a Lagrangian by Lagrange multipliers (ρ and μ):

$$\min_x F = \max_\mu L ,$$

Where,

$$L = \sum_{r \in M^+} \vec{x}_r^t H_r \vec{x}_r + \sum_{r \in M^+} \mu_r^t (B_r \cdot \vec{x}_r - \sum_{\substack{s \in M^+ \\ s \ne r}} B_s \vec{x}_s) . \tag{7}$$

4. The goal coordination method usage for multilevel routing strategy implementation

To solve the formulated optimization problem let's use the method of the goal coordination [7, 8] for this purpose let`s represent Lagrangian (7) in such form:

$$L = \sum_{r \in M^+} \vec{x}_r^t H_r \vec{x}_r + \sum_{r \in M^+} \mu_r^t B_r \vec{x}_r + \sum_{r \in M^+} \mu_r^t \sum_{\substack{s \in M^+ \\ s \ne r}} B_s \vec{x}_s . \tag{8}$$

Assuming that μ_r are constant, last item in expression (8) can be interpreted as:

$$\sum_{r \in M^*} \mu_r^t \sum_{\substack{s \in M^+ \\ s \neq r}} C_{rs} \vec{x}_s = \sum_{r \in M^+} \sum_{\substack{s \in M^+ \\ s \neq r}} \mu_r^t B_s \vec{x}_s ,$$

then expression (8) can be written as:

$$L = \sum_{r \in M^+} L_r ,$$

Where,

$$L_r = \vec{x}_r^t H_r \vec{x}_r + \mu_r^t B_r \vec{x}_r - \sum_{\substack{s \in M^+ \\ s \neq r}} \mu_s^t B_r \vec{x}_r \tag{9}$$

So, function (9) takes a separable form while general *MPLS*-network routing problem is decomposed with the set of routing problems (by the edge routers number) where each r-th *LER`s* routing problem which consists of vector $\vec{x}_r$ calculation reduced to the minimization of the Lagrangian L_r. The expression (9) minimization task determines the lower calculation layer - LER-layer. On the upper layer (*LSR*-layer) the main task of which is the coordination of solutions obtained at the lower layer in order to avoid network transmission paths overload (2), modification of the Lagrange multipliers vector implemented during the following gradient procedure execution:

$$\mu_r(\alpha + 1) = \mu_r(\alpha) + \nabla \mu_r , \tag{10}$$

where $\nabla \mu_r$ – gradient of the function calculated using the solutions from the routing problems ($\vec{x}_r^*$) solving on the upper layer at each particular r-th *LER* ($r \in M^+$), i.e:

$$\nabla \mu_r(x)\Big|_{x = x^*} = B_r \vec{x}_r^* - \sum_{\substack{s \in M^+ \\ s \neq r}} B_s \vec{x}_s^* . \tag{11}$$

The general scheme of a two-level routing in MPLS-network is shown in the Figure (3).

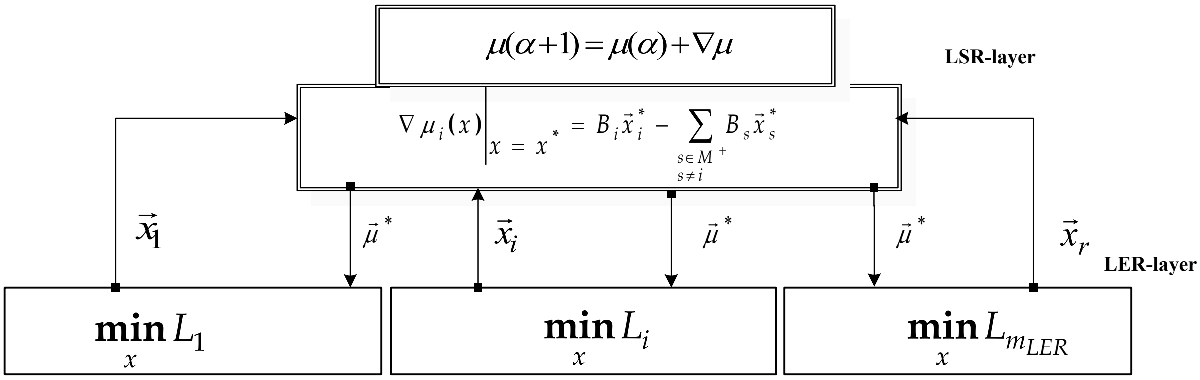


Figure (3). Computing circuit of two-layer routing in MPLS-network supporting traffic engineering technique.

5. Researching method hierarchical-coordination routing in MPLS-network

During the analysis of the hierarchical-coordination routing method structure and its content, it is necessary to notice that its effectiveness mostly determined by the rate of its optimal solution convergence when gradient (11) equals zero. For clarity and ease of calculations, convergence rate was measured by the number of iterative procedures (N_{it}) of Lagrange multipliers calculation on the second level of this method hierarchy. From the point of routing decision scalability the service traffic volume, including data about the network status and control information, was depended proportionally on the number of the coordinating procedure iterations. That is why it is important that the number of such iterations was minimal. The following network characteristics and parameters of the model were varied during the research as follows :

- Number of channels in the network core, i.e. between LSR-routers (N): from N=3 to N=16;
- Normalized network load (n), which means the ratio of external incoming traffic total rate to the total TCS bandwidth: from 0 to 0.95;
- Type of the objective function (OF), which may be linear [6] or quadratic (6).

According to results analysis, this method converges to the optimal solution at the average of 3-4 iterations as shown in Figure (4).

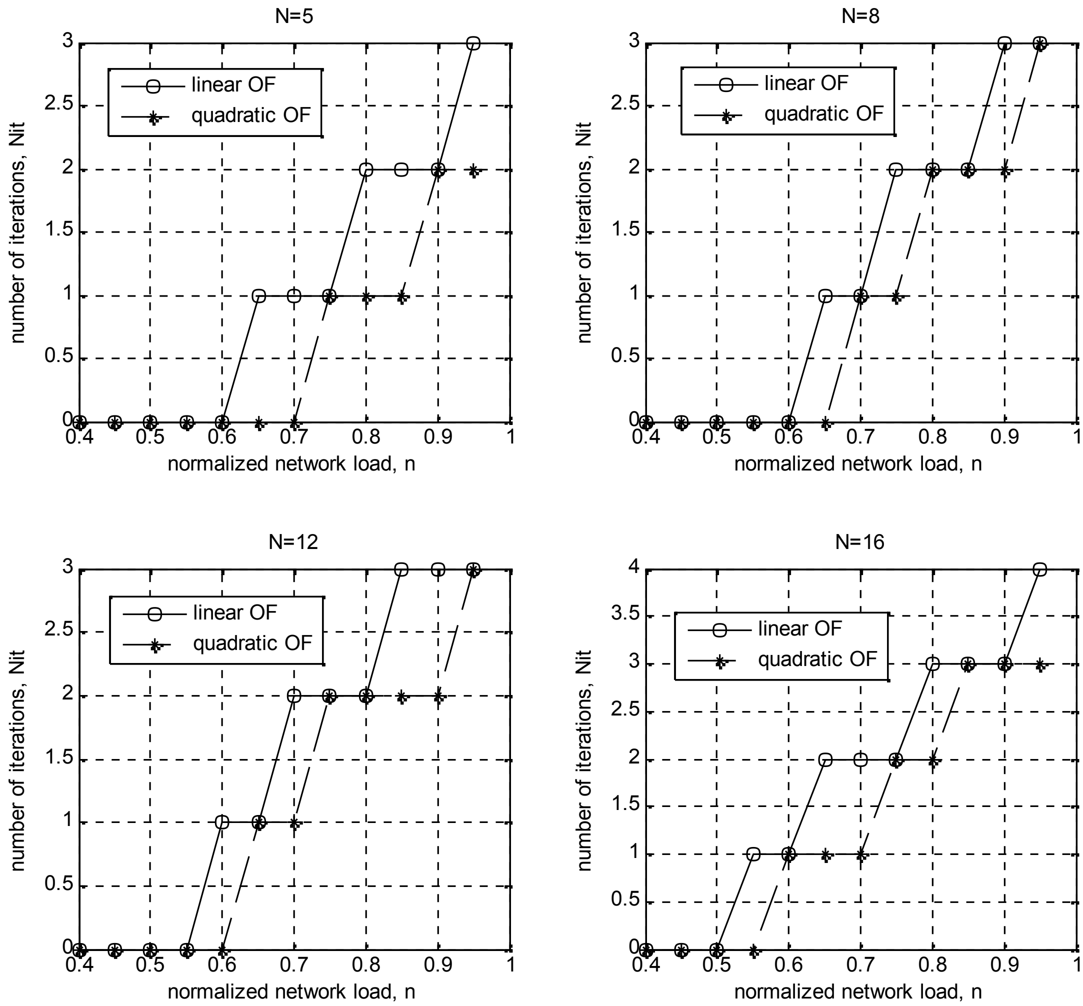


Figure (4). Analysis of the method convergence to the optimal solution for different network structures and network load.

Number of the coordinating procedure iterations (9)-(10) was increasing with the growth of the transmission channels number between the LSR-routers and the incoming traffic rate. Quadratic OF usage provides not such rapid increase of the iterations number as linear OF. Reducing iterations number was reached through more efficient load balancing, since using a quadratic objective function (6) in the routing model provides better load balancing compared to the linear OF optimization [6] at the same external load . It was due to linear OF usage during load increase. In this case the multipath routing strategy implemented with consecutive new path activation in case of currently used routes overloading. Simultaneous load balancing on all possible paths implemented when the quadratic OF used, which provides better utilization of network resources, at the same time the number of iterations (10) - (11) in the method decreased in order to avoid overloading the TP network. Additionally, when we use the quadratic objective function the coordination process is improving (average at 5-10% more). In the case of the normalized network load $n \leq 0.5...0.55$ it was not necessary to coordinate solutions by the upper level, because it was enough to provide load balancing on the network paths to prevent TP TCS overloading.

6. Conclusion

Hereby, in this paper the flow-based model of a two-level routing in a MPLS-network proposed, which is represented by the expressions (1)-(6). During the mathematical model of routing optimization problem solving, the principle of goal coordination was used (7)-(11). Due to this, procedure of routing variables calculation acquired two-level character. On the lower layer (*LER*-layer) a set of paths for traffic entering *LER is* calculated and on the upper layer (*LSR*-layer) solutions obtained on the LER-layer (routing variables) were coordinated in order to prevent transmission path`s overload. The functions of the coordinator in the MPLS-network may be assigned to one of the transit routers.

The main purpose of the proposed two-level solution implementation is to increase the scalability of flow-based routing strategies because usage of the centralized schemes is inertial and resource-consuming while MPLS-network dimension grows. The benefit of goal coordination method usage is simplicity of computational problems (10) - (11) on the LSR-layer as in accordance with the paradigm of «stupid network» maintained in MPLS-networks, all «intellectual» functions are concentrated on edge routers (*LER*-layer). In the case of considering MPLS-network as a set of interconnected sub networks the routing process can also be interpreted as a multi-level with additional hierarchical levels allocation.

7. References

[1] *Olveĭn V.* The structure and implementation of modern technologies MPLS. Publisher: Vilyams, Dialektika, 2004, Serie: Cisco Press. – 480 p.

[2] *Álvarez S.* QoS for IP/MPLS networks. – Cisco Press, 2006. – 299 p.

[3] *Simha A., Osborne E.* Traffic Engineering with MPLS. Cisco Press, 2002. – 608 p.

[4] *Medhi D., Ramasamy K.* Network routing: algorithms, protocols, and architectures. – Morgan Kaufmann Publishers, 2007. – 788 p.

[5]*Pióro M., Medhi D.* Routing, Flow, and Capacity Design in Communication and Computer Networks. – Morgan Kaufmann, 2004. – 765 p.

[6]*He T.,Wang S., Zhang M.* A Routing Algorithm for Traffic Engineering in MPLS Networks // Journal of Nanjing University of Posts and Telecommunications(Natural Science). – 2010. – P. 381-395.

[7]*Na Lin, Tao Yang, Li-xue Song*. A New QoS Multicast Routing Algorithm for MPLS-TE // International Conference on Measuring Technology and Mechatronics Automation icmtma – 2010. – Vol. 1. – P.192-195.

[8]*Oubaha J., Habbani A., Elkoutbi M.* Multi-criteria path optimization in MPLS networks / J. Oubaha, A. Habbani, M. Elkoutbi // Communications and Mobile Network (ISVC) – 2010, 5th International Symposium. – 2010. – P. 1-4

[9]*Burns J. E., Ott T. J., De Kock J. M., Krzesinski A. E.* Path selection and bandwidth allocation in MPLS networks: a non-linear programming approach // Proc. Internet Performance and Control of Network Systems, 2003. - Vol. 52. - Issues 2-3. – P. 133-152.

[10] *Cherubini D., Fanni A., Mereu A., Frangioni A., Murgia C., Scutellà M.G., Zuddas P.* Linear programming models for traffic engineering in 100% survivable networks under combined IS–IS/OSPF and MPLS-TE / D. Cherubini, A. Fanni, A. Mereu, A. Frangioni, C. Murgia, M.G. Scutellà, P. Zuddas // Computers & Operations Research. – Vol. 38, issue 12. – 2011. – P. 1805-1815.

[11] Lemeshko O.V. Ahmad M. Hailan, Starkova O.V. Multi-level traffic management in the MPLS-TE DiffServ network // 11-th International Conference «The experience of designing and application of CAD systems in microelectronics» Polyana-Svalyava-(Zakarpattya), UKRAINE 23 - 25 February 2011: Publishing House of Lviv Polytechnic, 2011. – P. 118-120.

[12] *Lemeshko O., Ahmad M. Hailan, Ali S. Ali.* A flow-based model of two-level routing in multiservice network // Modern Problems of Radio Engineering, Telecommunications and Computer Science. Proceedings of the international Conference TCSET'2010. – Lviv-Slavsko: Publishing House of Lviv Polytechnic, 2010. – P. 225.

[13] *Mesarovic M.D., Macko D., Takahara, Y.* Theory of hierarchical multilevel systems, Academic Press, New York and London, 1970. – 294 p.

[14] Systems: decomposition, optimisation, and control / edited by M. G. Singh, A. Titli, and Laboratoire d'automa-tique et d'analyse des systemes du C.N.R.S. Oxford; New York: Pergamon Press, 1978. – 645 p.