Multicast Fast Re-Route Schemes for Multiflow Case

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Abstract – **Schemes for protection of a node, a link and a rout under fault-tolerant multicast routing are presented for a multiflow case. The schemes are based on a nonlinear flow model which has the conditions for preventing links overload modified for a case when not all flows can switch to backup routs but only some of them. Scheme operability is demonstrated on a numerical example which has proven effectiveness of the proposed solution for the multiflow case.**

Keywords – **flow-based model, fault-tolerance, routing, backup scheme, multicast flows.**

I. Introduction

Modern telecommunication networks (TCNs) are multiservice, i.e. they simultaneously provide several services on the basis of one transport platform. In addition to transmit traffic packets of IPTV service, distance learning, database replication, Web services multicast routing is used [1]-[3]. In order to improve quality of service different schemes of fault tolerant routing are used, which in particular are also based on provisions of the Fast Reroute concept. The schemes develop an approach proposed in [4]-[6], and they are based on nonlinear flow model in which the conditions for link overload prevention are modified for the case when only some flows can switch to backup routs but not all of them.

II. Mathematical Model for Multicast Flows Routing

In the developing of multicast routing model let us describe a network structure as oriented graph $\Gamma = (V, E)$, where $V = \{v_i, i = \overline{1,m}\}$ is a set of vertices – nodes (routers) of the network and $(i, j) \in E$ is a set of graph arcs modeling communication links (CL) in TCN. For each CL modeled by the arc $(i, j) \in E$ there is a given throughput measured in packets per second (1/s) and defined as $\varphi_{(i,j)}$. Each k-th flow is connected with several parameters: an average flow rate at the network entrance - r_k; source node - s_k;

$$d_k^* = \{d_k^1, d_k^2, ..., d_k^{m_k}\} \quad (1)$$

– set of destination nodes, where m_k is the number of packet receivers of k th flow.

While solving the problem of multicast routing it is necessary to calculate a set of Booleans

$$x_{(i,j)}^k \in \{0;1\}. \quad (2)$$

Each of them characterizes the intensity part of k th flow in CL $(i, j) \in E$; $k \in K$, where K denotes a set of flows in the network.

Routing variables (2) are limited by several constraints [4]:

$$\sum_{j:(i,j)\in E} x_{(i,j)}^k \ge 1 \;\; if \;\; k \in K, \; v_i = s_k \quad (3)$$

and also

$$\sum_{i:(i,j)\in E} x_{(i,j)}^k = 1 \;\; if \; k \in K; \; v_j \in d_k^*. \quad (4)$$

Each transit node $v_j \in V$, which can be any node, except for the source one, is given the following conditions:

$$\sum_{i:(i,j)\in E} x_{(i,j)}^k \ge x_{(j,p)}^k, \; k \in K; \; v_j \notin s_k. \quad (5)$$

The fulfillment of these conditions allows to have a flow in any communication link ($(j, p) \in E$) coming from the relay node only in that case when this flow comes on the given node at least via one incoming CL ($(i, j) \in E$).

In order to prevent cycle forming we add conditions into the proposed model:

$$\sum_{(i,j)\in E_\pi^i} x_{(i,j)}^k < \left|E_\pi^i\right|, \quad (6)$$

where E_π^i is a set of arcs forming i-th cycle according to their orientation; $\left|E_\pi^i\right|$ - denotes power of the set E_π^i.

The fulfillment of the condition (6) guarantees that the number of arcs used in multicast routing, composing any cycle is always smaller than the total number of arcs in this cycle.

III. Conditions For Fast Re-Route

In order to increase fault-tolerance routing together with the basic path having a root in the source node (s_k), we have to determine a backup path with the same root. From the mathematical point of view in order to determine the backup (reserved) path it is necessary to calculate additional variables $\bar{x}_{ij}^k$ characterizing a part of the k-th flow rate in the link $(i, j) \in E$ of the backup path alongside with arguments (2)-(6).

However with the purpose of preventing the primary and backup paths intersection with realization of different backups-schemes we add several additional restricting conditions that connect routing variables to calculate the primary and backup path trees. For example, while implementing protection scheme of (i, j)-link is the offered model (1)-(6) obtains such conditions [5], [6]:

$$x_{ij}^k \bar{x}_{ij}^k = 0 . \quad (7)$$

The fulfillment of these conditions guarantees the using of (i, j)-link by the single path, either the primary or backup.

In realization of the protection scheme for i-th node the model is added by the following term:

$$\sum_{i:(i,j)\in E} x_{ij}^k \bar{x}_{ij}^k = 0 . \quad (8)$$

The fulfillment of the given condition guarantees the using of i-th node (i.e. all incident to it links) by either the primary or backup path. To provide protection for the primary path the following condition-equality must be added to the model

$$\sum_{(i,j)\in E} x_{ij}^k \bar{x}_{ij}^k = 0 , \quad (9)$$

which equivalents to meeting of requirements regarding the absence of any common links in the primary or backup path.

Using the proposed model let's consider following two variants of its application, which characterized by the ability to prevent the overload of network links by flows which run through primary and backup routes. In the first case, when only primary paths flows consider, condition of the links overload prevention has the form:

$$\sum_{k\in K} r^k x_{ij}^k \le \varphi_{ij} ; \; (i, j) \in E . \quad (10)$$

Then, the required links bandwidth of the backup paths flows don't guaranteed and the additional restrictions on variables $\bar{x}_{ij}^k$ are not apply.

In the second case the availability of links bandwidth in the organization of both primary and backup paths checks at the solution of the fault-tolerant routing. Then following conditions enter:

$$\sum_{k\in K} \sum_{(ij)} r^k \left(\frac{x_{ij}^k + \bar{x}_{ij}^k}{x_{ij}^k \bar{x}_{ij}^k + 1} \right) \le \varphi_{ij} , \; (i, j) \in E , \quad (11)$$

in time of one path routing realization (2).

During the calculation of variables x_{ij}^k and $\bar{x}_{ij}^k$ while solving the problem of Fast ReRoute in network it is reasonable to minimize the following objective function:

$$F = \sum_{k\in K} \sum_{(i,j)\in E} c_{ij}^k x_{ij}^k + \sum_{k\in K} \sum_{(i,j)\in E} \bar{c}_{ij}^k \bar{x}_{ij}^k , \quad (12)$$

where c_{ij}^k and $\bar{c}_{ij}^k$ are links metrics which used in calculation of the primary and backup paths accordingly.

As a result of minimization of the equation (12) variables x_{ij}^k and $\bar{x}_{ij}^k$ are calculated what in practice means the determination of the two types of paths between a nodes (source and destinations) – the primary and backup ones. More over the order of using these routs by flows of users is determined simultaneously with their calculation. Besides in [5], [6] the necessity to implement the conditions is established:

$$\sum_{k\in K} \sum_{(i,j)\in E} c_{ij}^k x_{ij}^k \le \sum_{k\in K} \sum_{(i,j)\in E} \bar{c}_{ij}^k \bar{x}_{ij}^k . \quad (13)$$

The fulfillment of this condition guarantees that the primary path will be always more effective (more powerful in rate, packet delay), i.e. «shorter» than the backup one within the chosen routing metrics c_{ij}^k and $\bar{c}_{ij}^k$. While implementing of fault-tolerance in multicast flows the optimization task (12) with the constraints (1)-(11) and (13) belongs to the class of nonlinear programming that assumes using relevant calculating methods.

V. EXAMPLES

Let us consider an example of implementation of the proposed schemes (1)-(13) while solving the problem of single path fault-tolerant multicast routing in the network the topology of which is presented in the Figure 1. The network consists of six nodes (routers) and eight links bandwidth (packet per second, 1/s) of which is shown in graph arcs. For first flow: the source node is Node 1, destination nodes are Nodes 3, 5 and 6. The rate of first flow is 100 1/s. For second flow: the source node is Node 2, destination nodes are Nodes 4 and 6. The rate of second flow is 200 1/s. Let us assume that within the given example we implement multicast routing with minimization of the number of hops ($c_{ij}^k = 1$).

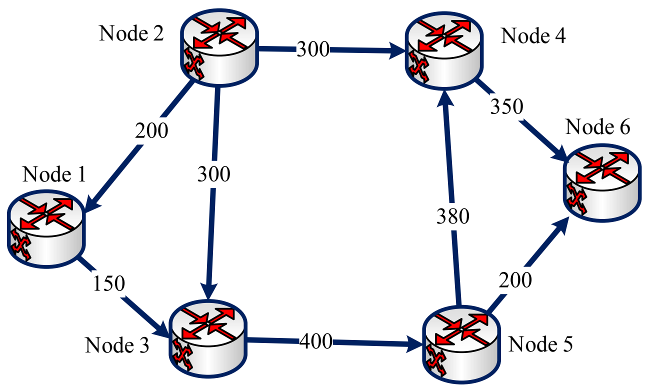
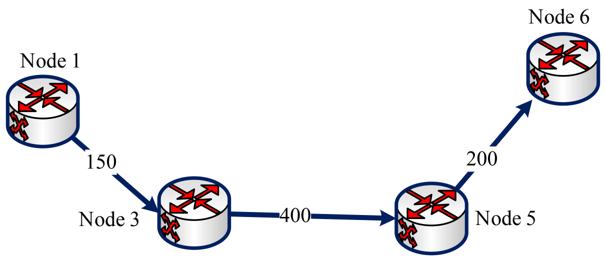
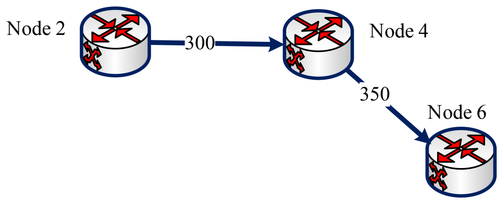


Fig. 1. The example of network topology

Figure 2 shows an example of the problem-solving for fault-tolerant routing in the network with (2, 4)-link protection. Then as the primary path for first flow we take the solution presented in Figure 2 a), and the "length" of the given path is minimal and it consists of 3 hops. Then as the primary path for second flow the solution presented in Figure 2 b) is taken, and the "length" of the given path is minimal and it consists of 2 hops.



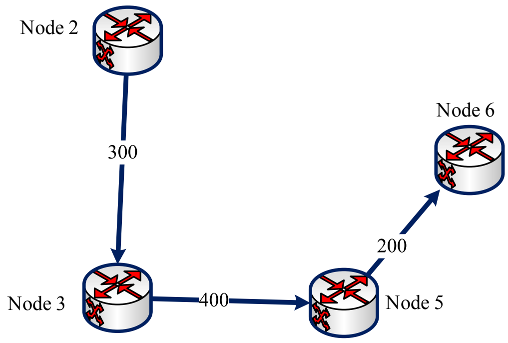
a – The primary path for first flow



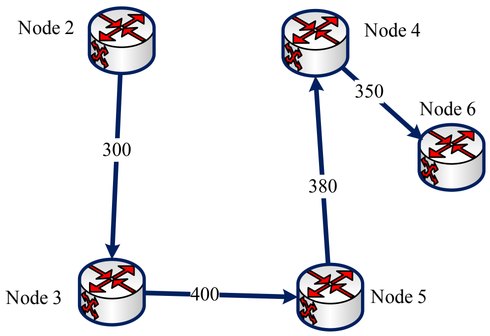
b – The primary path for second flow

Fig. 2. Set of primary paths for two flows

If use conditions (10) only when implementation of (2, 4)-link protection scheme, the backup path for second flow (Figure 3 a), that now includes 3 hops, does not contain any link (2, 4) in accordance with the implemented protection scheme.



a – The backup path for second flow if use conditions (10) only



b – The backup path for second flow if use conditions (11) only

Fig. 3. Implementation of (2, 4)-link protection scheme

Backup path (Figure 3 a) is the shortest and it consists of 3 hops, but has bandwidth of 200 1/s, because (5,6)-link has such bandwidth. Thus due to presence of two flows with the rates 100 and 200 1/s an overload will occur in this link. Using the condition (11) the solution shown in Figure 3 b) will be used as the desired backup path. This backup path (Figure 3 b) have 4 hops, i.e. overload does not occur, because shared links (3, 5) and (5, 4) have bandwidth larger than 300 1/s.

The above example demonstrates the advantages of using the proposed conditions of the links overload prevention (10) and (11) in the paper. In the considered case the fault of (2,4)-link has not caused a change in the transmission rout of first flow packets. However, it is not a rule, sometimes in order to prevent network overload under fault of one of its elements (a node, a link, a rout) within the proposed solution, re-route can simultaneously include several but not all flows in the network.

V. Conclusion

The schemes for protection of a node, a link and a rout under fault-tolerant multicast routing are presented for a multiflow case. The schemes develop an approach proposed in [4], [5],and they are based on nonlinear flow model in which the conditions for link overload prevention are modified for the case when only some flows can switch to backup routs but not all of them. This contributes to a great simplification of practical realization of solutions related to multicast Fast Re-Route in modern multiservice networks.

Operability of proposed backup schemes is demonstrated on the numerical example which has proven their effectiveness for the multiflow case.

References

[1] I. Hussain "Fault-Tolerant IP and MPLS Networks", Cisco Press, 2004, 336 p.

[2] A. Sundarrajan, S. Ramasubramanian "Fast Rerouting for IP Multicast Under Single Node Failures", *Global Communications Conference (GLOBECOM'2013),* Publisher: IEEE, pp. 2076 – 2081, Dec. 2013.

[3] A.S.-W. Tam, Xi Kang, H.J. Chao, "A Fast Reroute Scheme for IP Multicast", *Global Telecommunications Conference, 2009. GLOBECOM 2009.* Publisher: IEEE, pp. 1 – 7, Nov. 30 2009-Dec. 4 2009.

[4] O.V. Lemeshko, K.M. Arous "The flow-based model of multicast routing", *Microwave and Telecommunication Technology (CriMiCo),* 23rd International Crimean Conference, pp. 523-524, Sept. 2013.

[5] O. Lemeshko, A. Romanyuk, H. Kozlova "Design schemes for MPLS Fast ReRoute", *XIIth International Conference THE EXPERIENCE OF DESIGNING AND APPLICATION OF CAD SYSTEMS IN MICROELECTRONICS*, Polyana-Svalyava, 19-23 February 2013: Lviv Polytechnic, pp. 202-203, Feb. 2013.

[6] O.V. Lemeshko, H.V. Kozlova, A.A. Romanyuk, "Flow-based model of fault-tolerant routing in MPLS-network", *Microwave and Telecommunication Technology (CriMiCo)*, 2013 23rd International Crimean Conference, pp. 509 – 510, Sept. 2013.