An Approach to Optimization of the Links' Load in the MPLS Domain

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Abstract –**The problem with the optimization of MPLS (Multi Protocol Label Switching) network is discussed in terms of finding such label switching paths (LSP) for all flows in the network, which would provide minimal load on the links in it, as collaboration of the protocol of the third layer (IS-IS or OSPF) and MPLS is reported. The proposed analytical model is reduced to optimization problem which is solved using linear optimization. Researches have been made for this algorithm and the results are presented.**

Keywords – **MPLS, optimization problem, load minimizing on the links.**

I. Introduction

Nowadays, network services are proposed to customers in an environment of strong competition, so in general it is not possible and justified fully or multiple booking even at the critical points because it would significantly increase the cost of network services. Therefore, an important activity related with the availability of the network services is the restoration of services in their planned quality after accidents and failures. This rises the necessity of using network protocols, allowing application of quick and automated solutions for network recovery after failures, as the most popular solution nowadays for the NGN networks is the MPLS technology [2],[8].

This IP/MPLS network offers universal transport media, providing the need of reliability and QoS, which is achieved by the two methods – recovery and protection. The recovery takes less network resources than the defense and it is used more often by ISPs. But which link will be alternative in case of primary link' fails is a subjective decision, not always optimal and in some cases after the switching of traffic on backup connection, it appears that it has not sufficient capacity to absorb all the traffic and some packets are dropped and not delivered. Therefore solutions, in which the alternative links must have sufficient capacity to be possible to minimize packet's loss, are being searched. However, these solutions must take into account the willingness of ISPs to minimize the cost of money and the amount of occupied resources.

II. Related works

In recent years, several studies focus on the recovery path in the network because users need paths with low latency, high throughput and a small number of lost packets [1],[3],[4],[5],[9],[10],[11],[12]. Many critical applications require greater flexibility than the one provided by the current Internet routing. Due to these facts, some authors [5],[7],[11] use configuration files of the network devices to investigate and remove anomalies in the traffic and the reasons, which are rising the recovery of the path. Other authors [3], [12] propose solutions to overcome this problem by predicting the behavior of network traffic. In some cases, however, route recalculation can take minutes to switch traffic on it. During this period, loss of many packets is possible. In addition, periodic failures can cause repeated rerouting, causing routing instability. To overcome this problem in previous years, researches of the ISP were focused on routing algorithms with multiple paths routing [9],[10]. Studies show that it is possible to be provided a set of alternative paths in scalable network as with protocols from third layer of the OSI model, so as with MPLS. In most cases, the searched solutions are targeted at already built and operating networks, but a little focus on the first, off-line phase of pre-defined LSPs in the network.

Several authors propose different analytical models for the evaluation of quality indicators for MPLS network [13], the viability of the MPLS network [6], evaluation of service quality in the MPLS network (in terms of average delay and number of lost packets for different classes of services)[14],[15], structural synthesis of the MPLS network with constraint (quality of service to achieve a minimum price)[16]. Typical for these studies is that they examine the behavior of MPLS in an ideal environment in which accidents do not occur and does not require switching a packet of back-up links. The authors report latency factors in MPLS switches and distribute flows simultaneously on two factors - the average latency and the number of packet loss.

One factor not considered in the above solutions is the chosen by the administrator of the network policy for the classification of traffic. Another factor not considered in these decisions is the retain of optimal spare capacity for each port, which if necessary, by using this link as an alternative would absorb both peak traffic on this line and the temporarily transferred from other link traffic on it. The capabilities of MPLS port should include adequate reserve capacity above the average peak load in order to take on short peaks in traffic. However, if the spare capacity is too large, the higher expenses are not justified. Therefore, the revision of the average peak load and comparing it with the capacity of the port can provide opportunities to reduce its size. Different organizations follow different principles, but as a general rule of practice is considered the average peak load to be 60-70% for MPLS port (or up to 30-40% if the port is part of the backup configuration)[17]. These percentages are obtained based only on empirical experience.

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Routers in the MPLS network receive packets not only with MPLS labels. They exchange information for the building of correct layer 3 routing tables. Meanwhile, with signaling protocols, they exchange information for MPLS labels with which to manage the routing of LSP. Part of the IP packets can be routed without labeling based on the routing decisions of layer 3.

The most frequently used signaling protocol is RSVP-TE , in which's configuration are set as the primary and back-up links. In determining the LSP is included the priority of the flow, as it gives the new LSP the right to replace the existing one if the new flow has higher priority than the old. This allows high-priority LSP to be set optimally, whether there are existing reservations on the links on this LSP, but only if those reservations have lower priority. When needed a rerouted LSP, LSPs with higher priority are more likely to find an alternate route than those with lower priority. But these packages in lower priority flows may be lost due to insufficient capacity of the connections.

As an indicator of the network congestion is used the maximum load of the link. When the static routing is used and the traffic is linearly increasing, the minimization of this parameter will provide the maximum linear growth of the traffic before its need of rerouting.

III. Definition of the Problem

The purpose of this study is finding the optimal primary and backup LSPs in the MPLS domain to achieve minimal loaded in links and minimal loss of traffic at a failure.

Let G = (N, E) is a finite undirected graph, representing the MPLS network, where N is the number of nodes (routers), E is the number of edges(links). On each of the edge (i,j)$\in$ E is assigned a weight c_{ij}, representing link capacity in Mbps. Each node can be both source and destination of traffic. Source-node s(f) and the receiving node t(f) may not have direct contact with each other, but for the purposes of the model is necessary to exist at least one route between them. Let F is the set of source-receiver pairs and d^f_{st} is the maximal requested by the administrator traffic that passes by the pair $f_{st} \in$ F. Apparently

$$d^f_{st} \geq 0 \tag{1}$$

For d^f_{st} also can be set the number u_{st}, which limits the bandwidth of the edge:

$$0 \leq d^f_{st} \leq u_{st}. \tag{2}$$

Let X(m,k) is the routing matrix whose elements are rational numbers in the interval [0,1]. They represent part of the flow of f_{st} , which is routed by the protocol of the third layer (IS-IS or OSPF) on the edge (i, j). The rows of the matrix correspond to the edges and the columns of source-receiver pairs. The sources generate a flow which flows in the direction of edges, possibly through the intermediate points and gets to the receivers. Quantitative measure of the total flow that will run on the network is determined by these requirements.

The load $H^{(k)}_{\Sigma}$ on edge (i,j) is presented as a total sum of the loads $h^{(k)}_{ij}$ of all the flows in this edge, where k is priority of flow:

$$H^{(k)}_{\Sigma} = \sum_{j=1}^{n}\sum_{i=1}^{n} h^{(k)}_{ij} \tag{3}$$

For the purposes of the study are examined the following variables of the model:

u_{max}: maximum load on all arcs

is^f: the part of the requested traffic d^f, routed from IS-IS/OPF, [bit/s]

w^f_{ij}: the part of the requested traffic d^f, transmitted by LSP, and routed from MPLS

$\overline{T}_{cp}$: average time of delay in MPLS network flow with priority k as at the links, and in the routers

LP_k – probability of packet loss with priority k, which is calculated as:

$$LP_k = 1 - \prod_{s,t\in E}(1 - P^{(k)}_{lose(s,t)}) \tag{4}$$

Where $P^{(k)}_{lose(s,t)}$ - the probability of all virtual channels, on which is configured to transmit the flow with priority k, are filled with a capacity of flows with higher priority or equal to this (i.e. from 0 to k-1)

The problem of finding optimal LSPs in MPLS network, minimizing the load on the links between nodes is formulated as follows: it is necessary to find such a distribution of flow $f_{ij}{}^{q}$ thus minimizing the maximum flow μ_{ij} based on flows and on priorities , collaborate working with the third layer protocol (IS-IS or OSPF) and MPLS, while load edges is minimized. This optimal distribution of flows is expected to increase the spare capacity of links.

Solving such a problem in structural synthesis of the network is available in [16], but their solution is only to newly-developed network. As a final result is the lowering of its price. Solving this problem in terms of planning, but non-constructed network is expected to achieve the same result. Unlike the quoted decisions, this proposal can be applied to a functioning network with real traffic. When a failure giving rise to recovery at peak times of load occurs, the increasing of spare capacity on links (in particular those used as backup) will reduce congestion and minimize the packet loss of the lower priority traffic.

Then the problem of finding optimal LSPs in the MPLS network, minimizing the load on the links between nodes can be expressed analytically as following:

Target function: $min\ u_{max}$ (5)

Restrictive conditions:

$$\sum_{f\in F} is^f x^f_{ij} + \sum_{f\in F} w^f_{ij} \leq u_{\max} c_{ij}, \ (i,j) \epsilon E \tag{6}$$

$$\sum_{(i,j)\in A} w^f_{ji} - \sum_{(i,j)\in A} w^f_{ij} = \begin{cases} -d^f + is^f, if\ i = s(f) \\ d^f - is^f, if\ i = t(f) \\ 0, in\ the\ other\ cases \end{cases}, \ i\epsilon N, f\epsilon F \tag{7}$$

$$LP_k \leq LP_{k,fixed} \tag{8}$$

$$T^{\kappa}_{cp} \leq T^{\kappa}_{fixed} \tag{9}$$

$$w^f_{ij} \geq 0 \quad ,(i,j)\ \epsilon\ A,\ f\epsilon F \tag{10}$$

$$d^f \ge is^f \ge 0, \; f\epsilon F \qquad (11)$$

Objective function reflects the maximum value of the load that has to be minimized. When solving the model for each f is appearing an optimal set of paths in G from source node s(f) to the receiving node t(f), i.e. optimal number of LSPs.

IV. Solving the Optimization Problem

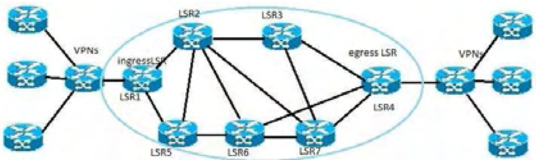

Fig. 1. Experimental MPLS Network

Restrictions on the amount of data in the Solver of Excel (up to 200 cells), exceed the maximum amount of currently existing networks (largest MPLS backbone network is realized in Canadian Telecom - 100 LSR, for comparison, in Bulgaria consists of 50 LSR). It is presented a suggested solution based on the experimental network, which is presented on the fig. 1.

Cost of all links is 1000Mbps and purpose is to reach to less than 60% of each link capacity (600Mbps). Starting matrix is presented on Fig. 2. On Fig. 3. and Fig.4 are presented target cell, constraints, cells which be changed, options. On Fig. 5. is presented final matrix with optimal decision. On Fig. 6. and Fig. 7. are presented answer report.

	LSP1-2	LSR1-3-2	LSP1-3	LSP1-2-3	LSP2-3	LSP2-1-3	LSP2-1	LSP2-3-1	LSP3-1	LSP3-2-1	LSP3-2	LSP3-1-2	sumHij
lsr1-lsr2	200	300	0	0	0	0	0	0	0	0	0	0	650
lsr1-lsr3	0	0	150	350	0	0	0	0	0	0	0	0	600
lsr2-lsr3	0	0	0	0	350	150	0	0	0	0	0	0	950
lsr2-lsr1	0	0	0	0	0	0	250	250	0	0	0	0	600
lsr3-lsr1	0	0	0	0	0	0	0	0	300	200	0	0	650
lsr3-lsr2	0	0	0	0	0	0	0	0	0	0	400	100	900
													4350

Fig. 2. Part of Starting Matrix

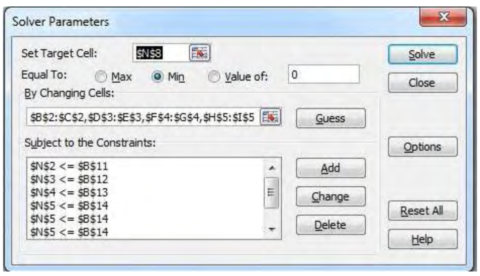

Fig. 3. Solver Parameters

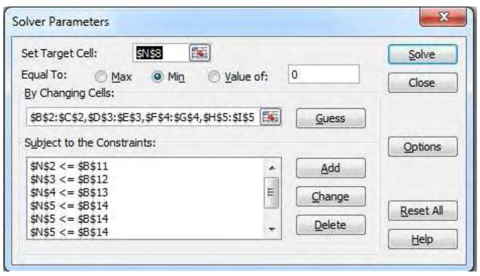

Fig. 4. Solver Options

	LSP1-2	LSR1-3-2	LSP1-3	LSP1-2-3	LSP2-3	LSP2-1-3	LSP2-1	LSP2-3-1	LSP3-1	LSP3-2-1	LSP3-2	LSP3-1-2	sumHij
lsr1-lsr2	500	0	0	0	0	0	0	0	0	0	0	0	500
lsr1-lsr3	0	0	500	0	0	0	0	0	0	0	0	0	500
lsr2-lsr3	0	0	0	0	500	0	0	0	0	0	0	0	500
lsr2-lsr1	0	0	0	0	0	0	500	0	0	0	0	0	500
lsr3-lsr1	0	0	0	0	0	0	0	0	500	0	0	0	500
lsr3-lsr2	0	0	0	0	0	0	0	0	0	0	500	0	500
													3000

Fig. 5. Part of final matrix

Microsoft Excel 12.0 Answer Report
Worksheet: [Book2]Sheet2
Report Created: 3/13/2012 6:54:08 AM

Target Cell (Value Of)

Cell	Name	Original Value	Final Value
$N$8	sumHij	4350	3000

Adjustable Cells

Cell	Name	Original Value	Final Value
$B$2	lsr1-lsr2 LSP1-2	200	500
$C$2	lsr1-lsr2 LSR1-3-2	300	0
$D$3	lsr1-lsr3 LSP1-3	150	500
$E$3	lsr1-lsr3 LSP1-2-3	350	0
$F$4	lsr2-lsr3 LSP2-3	350	500
$G$4	lsr2-lsr3 LSP2-1-3	150	0
$H$5	lsr2-lsr1 LSP2-1	250	500
$I$5	lsr2-lsr1 LSP2-3-1	250	0
$J$6	lsr3-lsr1 LSP3-1	300	500
$K$6	lsr3-lsr1 LSP3-2-1	200	0
$L$7	lsr3-lsr2 LSP3-2	400	500
$M$7	lsr3-lsr2 LSP3-1-2	100	0

Fig. 6. Optimal Decision-Report

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$N$2	lsr1-lsr2 sumHij	600	$N$2<=$B$11	Binding	0
$N$3	lsr1-lsr3 sumHij	600	$N$3<=$B$12	Binding	0
$N$4	lsr2-lsr3 sumHij	600	$N$4<=$B$13	Binding	0
$N$5	lsr2-lsr1 sumHij	600	$N$5<=$B$14	Binding	0
$N$5	lsr2-lsr1 sumHij	600	$N$5<=$B$14	Binding	0
$N$5	lsr2-lsr1 sumHij	600	$N$5<=$B$14	Binding	0
$N$6	lsr3-lsr1 sumHij	600	$N$6<=$B$15	Binding	0
$N$7	lsr3-lsr2 sumHij	600	$N$7<=$B$16	Binding	0

Fig. 7. Optimal Decision-Report

V. Experimental Results

For the purpose of the experiment each node has incoming traffic as shown on the unit LSR1 and it is entered by 3 types of traffic with different priority (0,1,2) and for these three types of traffic output node can be any node, as shown node LSR4. For the experiment will be considered only incoming flows LSR1, reaching and output of the network LSR4. These three types of traffic pass through the same channels (LSR1-LSR2-LSR3-LSR4). By increasing the intensity of traffic with priority 0 remains less spare capacity for other types of traffic on this road, which at one point leads to the arrest of the rest packets in queues of the nodes in order to leave capacity for the high priority traffic.

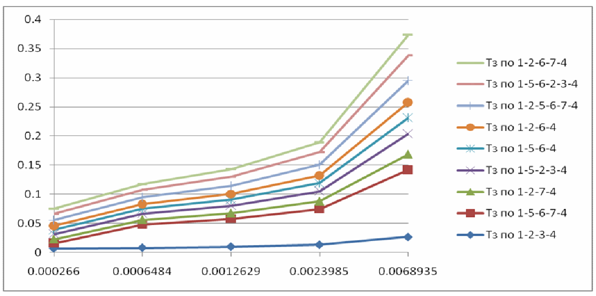

Fig. 8. Average Time to Pass a Package from Traffic with Priority 2 before the Optimization of the Load Experimental MPLS Network

During unloading the path, however (eg routing of lower priority traffic without overlapping arcs on the path LSR1-LSR5-LSR6-LSR4), a balanced load of links in the network is given, which leads to optimal loading of links in the network and shorter retention times in it.

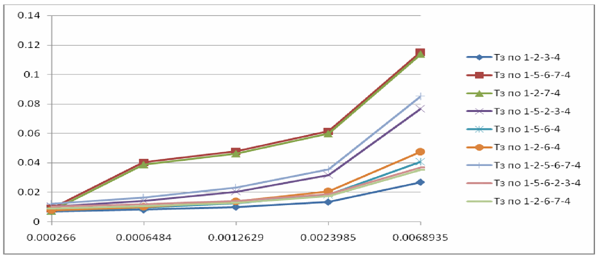

Fig. 9. Average Time to Pass a Package from Traffic with Priority 2 after the Optimization of the Load Experimental MPLS Network

Thus, Fig. 8. shows the average time for passage of packets of the traffic in the experimental lower priority MPLS network when it is not achieved optimization of load links, and Fig. 9. - after achieving the optimization. It is clear that when achieving a balanced load, average retention time of the longest roads is decreased by almost 3 times when the network is intensive load and is almost the same with the minimal selected network's load and at the shortest routes.

VI. CONCLUSION

The problem of optimizing the MPLS network is discussed in terms of finding such LSPs for all flows in the network to provide the minimum load on any links in it and is proposed an analytical model for solving this task. Account is taken of the collaborate work of the the third layer protocol (IS-IS or OSPF) and MPLS, so that the load on the links between the nodes in the network would be minimized. A solution is presented with Solver at Excel. There have been experimental studies of that algorithm and the results are presented.

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