Research and Development of Improved Routing Mechanism with Load Balancing in Communication Network

Oleksandr Lemeshko, Anastasiia Kruhlova, Anna Zhuravlova, Oleksandra Yeremenko
V.V. Popovskyy Department of Infocommunication Engineering
Kharkiv National University of Radio Electronics
Kharkiv, Ukraine
oleksandr.lemeshko@nure.ua, anastasiia.kruhlova@nure.ua, anna.zhuravlova@nure.ua, oleksandra.yeremenko@nure.ua

Abstract

A study of an improved mathematical model of routing with load balancing in a communication network based on Traffic Engineering is presented. The mathematical model allows formalizing the case of network construction, when each access network to increase fault-tolerance is switched simultaneously not to one but several gateways. The advantage of the solution is improving the load balancing level according to the criterion of Traffic Engineering by ensuring the distribution of traffic at the access level between several gateways that create one virtual default gateways.

Graph Presentation of the Network

Structure of communication network is described by the graph: $G=(M,L)$

Set of vertices: $M=R\bigcup V$

which includes two disjoint subsets:

$R=\{R_i, i=\overline{1,m}\}$ and $V=\{V_j, j=\overline{1,v}\}$

In turn, R also includes two subsets:

$m^+=\left|R^+\right|$ - total number of edge routers;

$m^-=\left|R^-\right|$ - total number of transit routers in core network;

R_j^+ is a subset modeling those edge routers that form a virtual router for jth access network, described by the vertex V_j

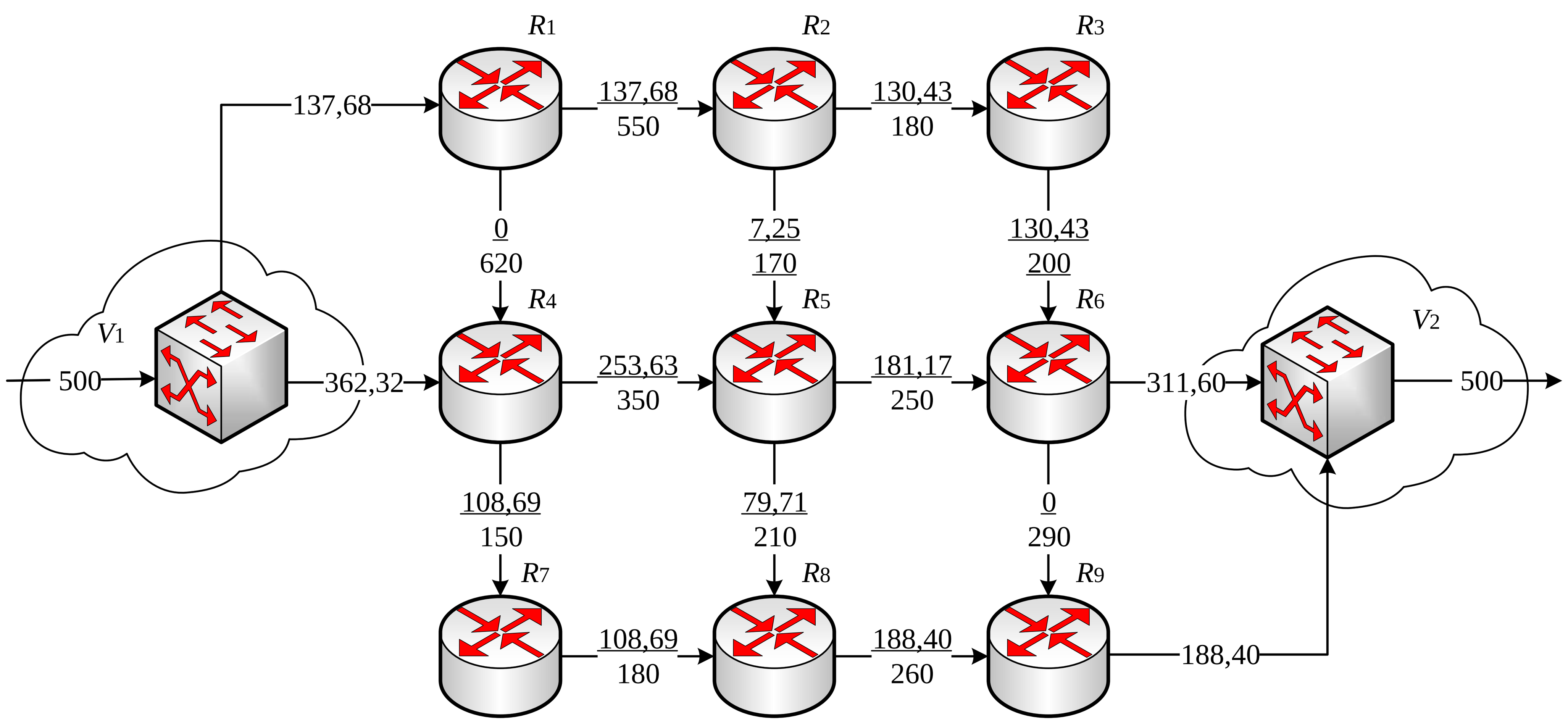
$\varphi_{i,j}$ - $E_{i,j}$ link`s capacity

Set of arcs: $L=E\bigcup W$

Core network links: $E=\{E_{i,j}, i,j=\overline{1,m}, i\neq j\}$

Access network links: $W=\{W_{i,j}, i=\overline{1,v}, j=\overline{1,m^+}\}$

Numerical Research



Numerical research had shown that when load balancing was implemented both at the access and network levels, the network was able to service even the flow of packets with maximum intensity. Figure shows the order of load balancing at the access and network levels at 500 1/s. The packet flow received from the first access network was balanced between the first and fourth routers in the proportion of 27.5 by 72.5%.

Introduction

- Among the directions of implementing the Traffic Engineering (TE) principles in networks is the improvement of routing protocols, which concerns the support of a multipath routing strategy. Most of the existing routing protocols have been extended by Traffic Engineering. However, they are still based on algorithms to find the shortest path on the graph.
- A highly efficient network load balancing by routing means can be ensured by improving the relevant mathematical models and methods that would serve as a theoretical basis for promising solutions in the field.

Flow-Based Routing Model with Load Balancing

Let K be the set of flows incoming to the edge routers from the access networks.

For each kth flow correspond the following parameters:

V_s^k is the access network, which is the source of the kth flow;
V_d^k is the access network, which is the destination of the kth flow;
λ^k is the mean intensity of the of the kth flow, measured in packets per second (1\s).

It is necessary to calculate the three types of **control variables**:

$x_{i,j}^k$ is the routing variable (the fraction of the kth flow in the link $E_{i,j}$);
$y_{i,j}^k$ is the access variable (the fraction of kth flow in the access line $W_{i,j}$);
$z_{j,i}^k$ is the access variable (the fraction of the kth flow in the access line $W_{j,i}$).

Multipath path routing conditions:

$$0\le x_{i,j}^k\le 1 \qquad (1)$$

$$0\le y_{i,j}^k\le 1 \text{ and } 0\le z_{j,i}^k\le 1 \qquad (3)$$

Single path routing conditions:

$$y_{i,j}^k\in\{0;1\} \text{ and } z_{j,i}^k\in\{0;1\} \qquad (2)$$

Packet loss prevention conditions:

$$\sum_{R_j\in R_p^+} y_{p,j}^k=1 \quad V_p=V_s^k \qquad (4)$$

$$\sum_{R_j\in R_h^+} z_{j,h}^k=1 \quad V_h=V_d^k \qquad (5)$$

Conditions of **flow conservation**:

$$\begin{cases}\sum\limits_{j:E_{i,j}\in E} x_{i,j}^k-\sum\limits_{j:E_{j,i}\in E} x_{j,i}^k=0;\ k\in K,\ R_i\in R^-;\\ \sum\limits_{j:E_{i,j}\in E} x_{i,j}^k-\sum\limits_{j:E_{j,i}\in E} x_{j,i}^k=y_{p,i}^k;\ k\in K,\ R_i\in R^+, V_p=V_s^k;\\ \sum\limits_{j:E_{i,j}\in E} x_{i,j}^k-\sum\limits_{j:E_{j,i}\in E} x_{j,i}^k=-z_{i,h}^k;\ k\in K,\ R_i\in R^+, V_h=V_d^k.\end{cases} \qquad (6)$$

Overload prevention conditions:

$$\sum_{k\in K}\lambda^k x_{i,j}^k\le\alpha\varphi_{i,j} \qquad (8)$$

$$0\le\alpha\le 1 \qquad (9)$$

α is the upper bound of the network link utilization.

As an **optimality criterion** it is advisable to choose a minimum of the following objective function:

$$\min_{x,y,z,\alpha}\ \alpha \qquad (10)$$

In the core network, the traffic was transferred via five routes:

- $R_1\to R_2\to R_3\to R_6$ with an intensity of 130.43 1/s;
- $R_4\to R_5\to R_6$ with an intensity of 181.17 1/s;
- $R_1\to R_2\to R_5\to R_8\to R_9$ with an intensity of 7.25 1/s;
- $R_1\to R_4\to R_7\to R_8\to R_9$ with an intensity of 72.46 1/s;
- $R_4\to R_7\to R_8\to R_9$ with an intensity of 108.69 1/s.

From the core network to the second access network, the traffic came through the sixth and ninth routers in the proportion of 62.3 by 37.7%.

Conclusion

Research and development of the improved mathematical model of routing with loading balancing in a communication network, which corresponds to principles of the Traffic Engineering concept, is presented. The results of the numerical study confirmed the effectiveness of the proposed improved solution. Reduction of the upper bound of the network links utilization has a positive effect on the quantitative values of the main Quality of Service indicators, namely the average end-to-end delay, jitter, and the probability of packet loss.