# PACKET ROUTING BASED ON CHANNELS BANDWIDTH AND NUMBER OF HOPS 

© Obelovska K., Roman V., Liskevych O., 2014


#### Abstract

A modified routing algorithm for computer networks is proposed. It takes into account path bandwidth path and the number of intermediate nodes.


Keywords: computer network, routing table, bandwidth, hop.

## Introduction

The main function of the computer network is packets routing from the source machine to the destination. One of the main protocols used for routing within an autonomous system of Internet is OSPF protocol (Open Shortest Path First), described in RFC 2328 standard. Most router vendors now support OSPF.

## 1. Problem Definition

Protocol OSPF calculates the shortest path using Dijkstra's algorithm. The algorithm considers each router as a tree node. Total cost of access from source node to each destination node is calculated, and shortest path is chosen based on access cost. As the cost of the path (metric) default metric based on bandwidth is used. The higher the bandwidth, the lower path cost is, and so the packet will be sent though the path with maximum bandwidth [1, 2]. Based on the tree of shortest paths routing table is built.

Input data for Dijkstra's algorithm is weighted graph corresponding to the network topology. The weights of edges are based on node bandwidth. Let us call such weight - metric 1 (M1). The disadvantage of the above described approach is that the packet transportation path takes into account only one network parameter (bandwidth by default). However, it is possible that for other criteria chosen path is not optimal or even not satisfactory. There are a number of works devoted to the improvement of routing packets, for example [3-5]. In this paper, we propose to take into account the number of intermediate nodes (routers) on the path to the destination node in addition to the M1 metric while building routing tables. Let us call this parameter - metric 2 (M2). Each router on the way to destination adds a delay that increases the packet transfer time. Thus a number of intermediate nodes is an important optimization metric. Specific applications, like voice transmission, will benefit if sending packets through the path with less intermediate nodes, even if it's bandwidth is not high.

## 2. Building routing tables using combined metric based on path bandwidth and the number of transit nodes

Input data for bandwidth-based routing algorithms are network topology and its channels bandwidth. Shortest paths tree, calculated by Dijkstra algorithm is optimized by the criteria of maximum aggregate path bandwidth. No additional data is required to create routing table based on both channel bandwidth and the number of intermediate nodes.

To minimize the number of intermediate nodes on the path, let us assign " 1 " weight to all nodes and use original Dijkstra's algorithm. Optimization criteria in this case is the number of transitions (hops) on the path from the source node to the destination.

Routing table now can be build based on analysis of routes found by Dijkstra's algorithm for both M1 and M2 metrics.

Let us illustrate the above described approach on the network example shown on Fig.1.


Fig. 1. Network topology with channels weights based on bandwidth
Dijkstra's algorithm is used to create path table from node A (fig. 2) based on metric M1:

| Node | Route | L1 | N1 |
| :--- | :--- | ---: | ---: | ---: |
| A | A | 0 | 0 |
| B | AB | 2 | 1 |
| C | ABCCD | 4 | 2 |
| D | ABCD | 6 | 3 |
| E | ABCDE | 8 | 4 |
| F | ABCDEF | 10 | 5 |
| G | ABCDEFG | 12 | 6 |
| H | ABCDEFGH | 14 | 7 |
| I | ABCDEFGHI | 16 | 8 |
| J | ABCDEFGHIJ | 18 | 9 |
| K | ABCDEFGHIJK | 20 | 10 |
| L | AL | 2 | 1 |
| M | AM | 4 | 1 |
| N | AMN | 10 | 2 |
| O | AO | 4 | 1 |
| P | AOP | 14 | 2. |

Fig. 2. Path table from node A to all other nodes according the metric M1.
In the path table on Fig. 2 the following notation is used:
L1 - optimization criteria - aggregate path weight based on metric M1 (bandwidth);
N 1 - number of hops on the way to the remote host.
Now let us create a table of paths from node A according to the M2 metric. The optimization will be done by the criteria of the minimum number of intermediate nodes. The weight of channels associated with bandwidth in this case is not taken into account by Dijkstra's algorithm. The resultant path table based on M2 metric M2 is shown on fig. 3:

| Node | Route | L2 | N2 |
| :--- | :--- | ---: | ---: |
| A | A | 0 | 0 |
| B | AB | 2 | 1 |
| C | ABC | 4 | 2 |
| D | ABCD | 6 | 3 |
| E | ABCDE | 8 | 4 |
| F | AMNGF | 16 | 4 |
| G | AM N G | 14 | 3 |
| H | AM NGH | 16 | 4 |
| I | AOPI | 18 | 3 |
| J | ALKJ | 24 | 3 |
| K | ALK | 22 | 2 |
| L | AL | 2 | 1 |
| M | AM | 4 | 1 |
| N | AMN | 10 | 2 |
| O | AO | 4 | 1 |
| P | AOP | 14 | 2 |

Fig. 3. Path table from node A to all other nodes according the metric M2.
In the table path on Fig. 3 the following notation is used:
N2 - optimization criterion (metric M2 that determines the number of hops between end nodes);
L 2 - the total weight of the path, which is the sum of the weights of individual paths based on channel bandwidth.
As can be seen from the Figures 2 and 3, table of paths obtained using different criteria are different. Thus routing tables created on their base will differ too.
Let us for example examine the paths from node A to node K by the two metrics.
According to Dijkstra's algorithm for metric M1 we obtain the following path: A, B, C, D, E, F, G, H, I, J, K. It provides the minimum possible for a given network total weight equal to 20, and runs through 9 intermediate nodes.
To illustrate the rules used to build routing table records let us assign network nodes on Fig. 1 following IP-address:

| A-O | 10.0 .0 .1 |
| :---: | :---: |
| A-M | 20.0 .0 .1 |
| A-B | 30.0 .0 .1 |
| A-L | 40.0 .0 .1 |


| O-A | 10.0 .0 .2 |
| :--- | :---: |
| M-A | 20.0 .0 .2 |
| B-A | 30.0 .0 .2 |
| L-A | 40.0 .0 .2 |


| K-J | 50.0 .0 .2 |
| :---: | :---: |
| C-B | 60.0 .0 .2 |
| F-E | 70.0 .0 .2 |
| G-N | 80.0 .0 .2 |


| S-F | 80.0 .0 .3 |
| :---: | :---: |
| $\mathrm{I}-\mathrm{P}$ | 90.0 .0 .2 |
| $\mathrm{I}-\mathrm{H}$ | 100.0 .0 .2 |
|  |  |

The following record will be added to node A routing table for path from node A to node K, based on path tree constructed by metric M1:

Table 2. Node A routing table fragment, built on the metric 1

| Destination <br> node | Gateway | Interface | Metric |  |
| :---: | :---: | :---: | :---: | :---: |
| 50.0 .0 .0 | 30.0 .0 .2 | 30.0 .0 .1 | 20 |  |

In this table: Destination node - IP-address of the destination node; Gateway - IP-address of the next node; Interface - IP-address of node A port; Metric - weight of path from the current node to the destination node, found on the criteria of maximizing the total bandwidth path. According to Dijkstra's algorithm for the metric 2 , a completely different path from node A to node K was obtained. This is A-L-K path, which has only one intermediate node and total weight of bandwidth equal 2. The following record will be added to node A routing table for path from node A to node K , based on path tree constructed by metric M2:

Table 3. Node A routing table fragment, built on the metric 2

| Destination <br> node | Gateway | Interface | Metric |
| :---: | :---: | :---: | :---: |
| 50.0 .0 .0 | 40.0 .0 .2 | 40.0 .0 .1 | 22 |

This example illustrates significant difference between the routes from node A to node K received by different metrics. Routes details are captured in table 4.

Table 4. Parameters paths between nodes $A$ and $K$ obtained by two metrics

|  | Metric |  | End nodes |  | Path weight based on bandwidth |
| :--- | :--- | :--- | :--- | :---: | :---: |
| Number of intermediate nodes |  |  |  |  |  |
| 1 | Metric M1 | A | K | 20 | 9 |
| 2 | Metric M2 | A | K | 22 | 1 |

From presented results one can see that the path optimized by the criteria of minimal number of intermediate nodes have only $10 \%$ less bandwidth than the maximum possible. The number of intermediate nodes decreased 9 times, instead nine intermediate routers we obtained only one. Obviously, this will reduce the time delay due to packet processing in routers. If reduced by $10 \%$ bandwidth is sufficient for application use, metric M2 is advisable to use for resulting A-K route construction (table 3).

In general, it is necessary to define rules to select routes from tables obtained using metrics 1 and 2 into the final routing table.

Route selection based on combined metric is needed only when there are alternative routes (the routes built using metrics 1 and 2 differ). Analysis should be done to select the route which is more efficient considering both two metrics.

Let us introduce the following parameters for path selection:

- K1 - the ratio of the total weight of the routes, built using metrics 2 and 1 ;
- K2 - the ratio of the numbers of intermediate nodes in the routes, built using metrics 1 and 2.
For L1> 0 and N2> 1 :

$$
\begin{gather*}
\mathrm{K} 1=\mathrm{L} 2 / \mathrm{L} 1, \\
\mathrm{~K} 2=(\mathrm{N} 1-1) /(\mathrm{N} 2-1) . \tag{121}
\end{gather*}
$$

$\mathrm{K} 1_{\text {max }}$ and $\mathrm{K} 2_{\text {min }}$ thresholds should be defined for final route selection. Threshold values may differ depending on specific application. Metric 1 may be used by default, and Metric 2 - when both (3) and (4) are true.

$$
\begin{align*}
& \mathrm{K} 1 \leq \mathrm{K} 1_{\text {max }}, \\
& \mathrm{K} 2 \geq \mathrm{K} 2_{\text {min }} .
\end{align*}
$$

For illustration needs let us have $\mathrm{K} 1_{\text {max }}=1,2$ and $\mathrm{K} 2_{\text {min }}=1,5$. Using these thresholds to select route between two available options (Figures 2 and 3) we will obtain the following final routing table for node A

| Node | Route | L3 | N3 |
| :--- | :--- | :--- | :--- | :--- |
| A | A | 0 | 0 |
| B | AB | 2 | 1 |
| C | ABC | 4 | 2 |
| D | ABCD | 6 | 3 |
| E | ABCDE | 8 | 4 |
| F | ABCDEF | 10 | 5 |
| G | AMNG | 14 | 3 |
| H | AMNGH | 16 | 4 |
| I | AOPI | 18 | 3 |
| J | ABCDEFGHIJ | 18 | 9 |
| K | ALK | 22 | 2 |
| L | AL | 2 | 1 |
| M | AM | 4 | 1 |
| N | AMN | 10 | 2 |
| O | AO | 4 | 1 |
| P | AOP | 14 | 2. |

Fig. 4. Node A Path table for combined metric
The following notation is used in Figure 4: N3 - number of hops on the path between interacting nodes; L3 - the total weight of the path, based on network bandwidth.
Figure 4 data now may be used to create routing table for node A. Fragment of routing table, based on the combined metric is shown in Fig. 5.

| Destination <br> node | Gateway | Interface | Metrica <br> L3 | Metrica <br> N3 |
| :---: | :---: | :---: | :---: | :---: |
| 60.0 .0 .0 | 30.0 .0 .2 | 30.0 .0 .1 | 4 | 2 |
| 80.0 .0 .0 | 20.0 .0 .2 | 20.0 .0 .1 | 14 | 3 |
| 100.0 .0 .0 | 10.0 .0 .2 | 10.0 .0 .1 | 18 | 3 |
| 50.0 .0 .0 | 40.0 .0 .2 | 40.0 .0 .1 | 22 | 2 |

Fig. 5. Node A Routing table fragment for combined metric

## Conclusion

A modified algorithm for constructing routing tables is proposed. It takes into account two characteristics of the network: the channels bandwidth and the number of intermediate nodes on the path. Selecting paths with fewer intermediate nodes with sufficient bandwidth decreases traffic delays.
The proposed approach can be extended by adding new metrics that characterize other network parameters. Introduction of new metrics require additional information about the network and additional weighting coefficients to compare effectiveness of routes obtained using different metrics.

1. OSPF Design Guide. - [Електронний ресурс]. Режим доступу: http://www.cisco.com/clen/us/support/docs/ip/open-shortest-path-first-ospf/7039-1.html\#t 6. 2. Олифер В.Г., Олифер Н.А. Компьютерные сети. Приниипь, технологии, протоколь:: Учебник для вузов. 4-е изд. СПб: Питер, 2012. - 944 с. З. Кузнецов Н.А., Фетисов В.Н. Алгоритм Дейкстры с улучшенной робастностью для управления маршрутизаиией в IP-сетях. Автоматика и телемеаника. 2008, № 2, с. 80-85. 4. Чуба I. В. Метод марирутизаиії у гетерогенних комп'ютерних мережах на основі аналізу ієрархій: автореф. дис. на здобуття наук. ступеня канд. техн. наук : 05.13 .05 / Чуба Ірина Вікторівна ; Національний авіаційний університет - К. : [б. в.], 2008. - 20 с. 5. Обельовська К., Русаков А. Модифікований алгоритм марирутизаиії для зменшення перевантажень ресурсів комп'ютерних мереж. Вісник НУ "Львівська політехніка" N 663 "Комп'ютерні науки та інформаиійні технології". Львів, 2010. - с. 223-228.
