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# Analysis of multiple users load on networks when inflows are separated into the shortest paths

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## Abstract:

Two methods of transmitting different types of flows via shortest paths are studied in computer simulations on a multicommodity networking model. In the first situation, the magnitudes of the transferred internodal streams are identical. In the case of the other, an egalitarian distributing is referred to as distributing the identical resource across every pairings of nodes. The complete load upon the network's edges as a result of the concurrent transfer of every one of the internodal streams is assumed. The suggested technique provides assured estimations of the network's individual greatest cost of materials and achievable loading on the edges when sending splitting internodal streams via the shortest paths discovered. The findings of a comparison of the equalize distributions of streams and resources for network that have various structures are provided. The algorithm method has a parabolic approximation of the total amount of procedures necessary.

*Keywords* — **distribution of internodal flows and loads, load modeling, multicommodity flow model, Peak network load.**

## I. INTRODUCTION

The current article continue the investigation of control of flow challenges regarding geographic separated systems of communication [1, 2]. The generated edges load are investigated using an equalizing flow distribution approach as a component of computations on a multiproduct networking model. The inter-node workload is defined as the entire amount of capacity allotted in a network that guarantees the transfer of a specific type of data flow. The edge load is defined as the total of all arc flows of different sorts traveling along a certain edge. The total permitted networks edge load that occurs when inter-node information flows are simultaneously transmitted for all pairs of correspondents, is considered set [3]. Two management The approaches and dispatch route principles are investigated. In the first instance, the allocation is of interstitial flows equal to each other is carried out, in the second, a non—discriminatory distribution is determined, in which all pairs of correspondents are allocated the same resources. When transferring every flow kind across all short paths, an assessment of unit costs is carried out. We can figure out distributions by analyzing the results of the experiments edge loadings for the described management strategies in multi-user networks with various structural features. Streaming models are currently used in the creation, development and operation of telecommunication systems [4-6]. These frameworks are particularly useful for searching for methods of management and developing dispatch norms for the allocation of flow, load, and other assets in multi-user network [7, 8]. The section presents results from investigation into the development of split approaches [9, 10]. Distribution of load algorithms and methods for attaining reconciling distribution of intermittent flows across diverse pathways. This study employs exponential estimate of processing costs to determine all short pathways [11, 12].

## II. STATISTICAL MODELS

We shall utilize the multi-product flow transmission model's mathematical language to design a multi-user communications system[13, 14]. The system G is defined via means of collections $\langle V, R, U, P\rangle$ number of nodes (vertices) of the network $V = \{v_1, v_2, \ldots, v_n, \ldots, v_N\}$; borders that are not oriented $R = \{r_1, r_2, \ldots, r_k, \ldots, r_E\}$; concerned with arc $U = \{u_1, u_2, \ldots, u_k, \ldots, u_{2E}\}$ ; correspondence node pairs $P = \{p_1, p_2, \ldots, p_M\}$. The assumption would be that the network has There are not any loops with duplicate edges. On a multi-user networking G, $M = N(N-1)$ self-governing, non-interchangeable and equal various forms of inter-node fluxes are studied [15, 16].

An edge $r_k \in R$ connects adjacent vertices $v_{nk}$ and $v_{jk}$. Each edge $r_k$is assigned two oriented arcs $u_k$ and $u_{k+E}$ from the ensemble $U$. The arches $\{u_k, u_{k+E}\}$control the onward and reverse direction of stream transmission lengthways the advantage $r_k$ among the conclusion vertex $v_{nk}$and $v_{jk}$.

Every couples of correspondent points $p_m$ after the established $P$ is assigned to: A certain amount of resource vertices $s_m$, from $s_m$ an effort stream of the $m_{th}$ kind joins a network; this receiver The amount of vertices $t_m$, after $t_m$ the stream of the $m_{th}$ kind disconnects from the system. Let us mean by $z_m$ the intrinsic value that the internode flowing of the $m_{th}$ join network information using a node the amount $s_m$ and leaving the network's connectivity based on the number of nodes $t_m$; $x_{mk}$ and $x_{m(k+E)}$ the flow of $m_{th}$ kind, that is propagated through arcs $u_k$ and $u_{k+E}$ in accordance with the transmission direction, $x_{mk} \geq 0, x_{m(k+E)} \geq 0$ , $m = \overline{1, M}, k = \overline{1, E}$; $S(v_n)$ the number of arcs through whence the stream departs each node $v_n$; $T(v_n)$ is the collection of inbound arcs along which the flow reaches nodes[17, 18]. The arrangement of the settings $S(v_n)$ and $T(v_n)$ is generated in a unique way during the subsequent process. Give it a little edge $r_k \in R$ link vertices along the integers n and j in such a way as $n < j$. At that time the oriented arc $u_k = (v_n, v_j)$, directed from the vertex $v_n$ to $v_j$, is believed to be emanating via the vertices $v_n$and its amount $k$ is entered into the established $S(v_n)$, and the arc $u_{k+E}$, directed from $v_j$ to $v_n$, is included for $v_n$ and its number $k+E$ is placed in the list $T(v_n)$. Arc $u_k$ is incoming for $v_j$, and its number $k$ falls into $T(v_j)$, and arc $u_{k+E}$ is extroverted, and numerous $k+E$ is included on the schedule of arcs that are leaving $S(v_j)$.

wthin all network nodes $v_n \in V, n = \overline{1, N}$, The criteria for every kind of stream conservation needs to be fulfilled streams:

$$\sum_{i \in S(v_n)} x_{mi} - \sum_{i \in T(vn)} x_{mi} = \begin{cases} z_m, & if\ v_n = v_{s_m}; \\ -z_m, & if\ v_n = v_{t_m}; \\ 0\ otherwise, \end{cases}$$

$$n = \overline{1, N}, m = \overline{1, M}, x_{mi} \geq 0,\ z_m \geq 0. \qquad (1)$$

The significance $z_m$ is the same as the data entered internode stream $m_{th}$ kind passing through the point of origin to the receiver $p_m$ pairs when distributing flows $x_{mi}$ along arcs networks.

Every edge $r_k \in R$ A number that is not negative has been given $d_k$, This establishes the overall maximum allowable stream as can be transferred down the edge $r_k$ Both orientations. The capability vector's components $d = (d_1, d_2, \ldots, d_k, \ldots, d_E)$ are numbers that are positive $d_k > 0$. The vector d imposes the subsequent constraints on the total of all streams communicated through the edge: $r_k$ concurrently:

$$\sum_{m=1}^{M} x_{mk} + x_{m(k+E)} \leq d_k,\ x_{mk} \geq 0, x_{m(k+E)} \geq 0, k = \overline{1, E} \qquad (2)$$

Convexity is defined by constraint (1) and (2). polyhedral established of permissible values of the inter-node flowing vector elements $z = (z_1, z_2, \ldots, z_m\ \ldots, z_M)$:

$Z(d) = \{z \geq 0\, |\exists\, x \geq 0 :$ $(z, x)$ satisfy $(1), (2)\}$ . The performance of network edges can be measured in traditional flows and understood as a resources restriction within the scope of this limitation. The total value of network capacity $D(0) = \sum_{k=1}^{E} d_k$ is regarded as granted. For each corresponding node pair $p_m \in P$, aimed at some admissible internode stream $\tilde{z}_m$and arc fluxes that correspond $\tilde{x}_{mk}, k = \overline{1, 2E}$, The value on

$$\tilde{y}_m = \sum_{i=1}^{2E} \tilde{x}_{mi}\ , m = \overline{1, M},$$

Characterizes the while communication, there is a burden on the network an internode stream on value $\tilde{z}_m$to the initial node $s_m$ towards the receiving node $s_m$. The value $\tilde{y}_m$ displays what The ability of the whole network is necessary for arc stream transmission $\tilde{x}_{mk}$. Within framework of model, the proportion of edge and internode flows $\tilde{w}_m = \tilde{y}_m / \tilde{z}_m$, $m = \overline{1, M}$, might be seen as the particular expenses incurred by the network when sending a unit stream of the $m_{th}$ kind amongst nodes $s_m$ and $t_m$ with arc flows $\tilde{x}_{mi}$ . The quantities $\bar{z}_m = \tilde{z}_m / \tilde{y}_m$ and $\bar{x}_{mi} = \tilde{x}_{mi} / \tilde{y}_m$, $m = \overline{1, M}, i = \overline{1, E}$, relate to the pair's internodal flows at a unit load $p_m$.

Enter the number that represents the edges' maximum weight (PC load) of the $k_{th}$ connection with concurrent transferring of all inter-node communications currents $\tilde{z}_m$:

$$\tilde{\Delta}_k = \sum_{m=1}^{M} (\tilde{x}_{mk} + \tilde{x}_{m(k+E)}), k = \overline{1, E}$$

## III. DISTRIBUTION OF INTER-NODE FLOWING THROUGH THE SHORTEST AVAILABLE ROUTE

To calculate the lowest possible unit cost for different equating management techniques, we used the (splitting of the flowing through the shortest available route), which allows you to distribute interstitial flows via paths having of a minimal amount of edges[19, 20]. When experimenting at the initial the road, for each pair of nodes $p_m = (s_m, t_m)1$ in the network $G(0)$, the collection of every one of the shortest routes is determined, they are then employed as the communication pathways of the $m_{th}$ type of flow

$$H^0(m) = \{h^1(m), h^2(m), \dots, h^j(m), \dots, h^{J(m)}(m)\}.$$

Here $h^j(m) = \{k_1^j, k_2^j, \dots, k_{\mu(m)}^j(m)\}$

Edge number list in the $j_{th}$ smallest distance adjacent nodes $s_m$ and $t_m$, where $\mu_{(m)}$ is the total amount of edges that make up the shortest pathway. $h^j(m)$ ; $J(m)$ is the amount of shortest paths available for $m_{th}$ couple. To assess the possibility of "splitting" a flow along different routes, at the first stage, for each pair $p_m \in P$, an internode flow $z_m^j = 1$ is transmitted along each route $h^j(m)$ from $H^0(m)$ .The value $z_m^0$ is calculated, numerically equal to the sum of unit flows that simultaneously are transmitted along all shortest routes from node $s_m$ to node $t_m$:

$$z_m^0 = \sum_{j=1}^{J(m)} z_m^j = J(m)$$

The normalizing coefficient is calculated

$$\xi_m^0 = \frac{1}{z_m^0}, z_m^0 \neq 0, m = \overline{1, M}$$

Values of the indicator function

$$\eta_k^j(m) = \begin{cases} 1, r_k \in R, k \in h^i(m) \\ 0 \text{ otherwise} \end{cases}$$

And the edge loads are calculated

$$\Delta_k^0(m) = \xi_m^0 \sum_{j=1}^{J(m)} \eta_k^j(m), m = \overline{1, M}, k = \overline{1, E},$$

Which will occur when a single internode flow is transmitted from node sm to node tm simultaneously following all of the most direct routes connecting $H^0(m)$. During the computational experiments, it was assumed that the aggregate workload on all networking edges does not may exceed $D(0)$. For a given $D(0)$, the maximum permissible PC loads are calculated:

$$\alpha^{**}(0) = \sum_{m=1}^{M} \Delta_k^0(m) = \Delta_k^*(z), \sum_{k=1}^{E} \Delta_k^*(z) = D(0).$$

Edge total loads $\Delta_k^*(z)$ arise on a network with simultaneously communication of internode flows $z_m^{**}(0) = \alpha^{**}(0)$ for all pairs $p_m \in P$ and the total internode flow $\sum_{m=1}^{M} z_m^{**} = M\alpha^{**}(0)$. To estimate PC loads with an equalized the dispersion of resulting internode weights across every node couples $p_m \in P$, the procedure is also used. At the first stage, edge loads are determined with $m = \overline{1, M}$ and $k = \overline{1, E}$, When sending, the device takes the quickest path possible $H^0(m) = m = \overline{1, M}$ . Aimed at every pair $p_m \in P$ loads are calculated

$$y_m^0 = \sum_{k=1}^{E} \sum_{j=1}^{J(m)} \eta_k^j(m) = \mu(m)J(m), \ m = \overline{1, M},$$

Normalizing coefficients

$$\theta_m^0 = \frac{1}{y_m^0}, y_m^0 \neq 0, \quad m = \overline{1, M},$$

and downloads

$$\Delta_k^0(m) = \theta_m^0 \sum_{j=1}^{J(m)} \eta_k^j(m), \quad m = \overline{1, M}, k = \overline{1, E},$$

For which along all routes $H^0(m) = m, m = \overline{1, M}$, the resulting internode loads $y_m^1 = \theta_m^0 y_m^0$ will be equal to one. PC loads are detected

$$\beta^{**} = \sum_{j=1}^{M} \Delta_k^0(m) = \Delta_k^*(y), \sum_{k=1}^{E} \Delta_k^*(y) = D(0).$$

And interstitial flows

$z_m(y^{**}) = \beta^{**}\theta_m^0 z_m^0, m = \overline{1, M}.$

## IV. EXPERIMENTATION WITH COMPUTATION

The computation experimentation was undertaken out using networked system models. presented in Fig. 1. Each network has 67 nodes. Normalization was performed during the computing experiment, and the overall capacity for both of networks was the similar:

$\sum_{k=1}^{E} \Delta_k^*(.) = D(0) = 68\ 254.$

The outcomes of computer experiments conducted using the technique are presented.

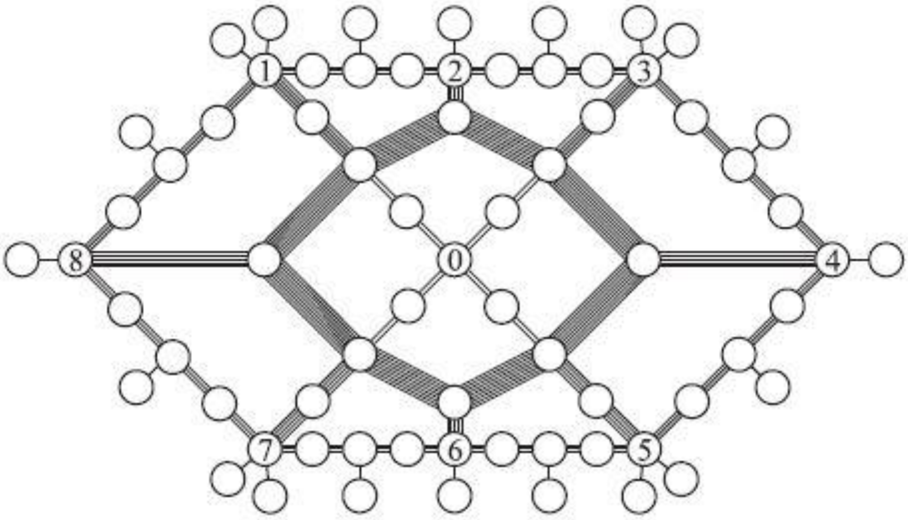


Fig. 1 The edge stresses that occur in the foundation and ring network

Table I
THE VALUES OF STREAMS AND DOWNLOADS IN THE CORE AND RING NETWORK

| Network | Median of flows | Sum of inter-node flows | Unit costs | The norm of the vector of PC downloads |
|---|---|---|---|---|
| Basic | | | | |
| $z^{**}$ | 1.83 | 8668 | 7.7 | 9208 |
| $z(y^{**})$ | 1.80 | 12808 | 5,3 | 9008 |
| The ring | | | | |
| $z^{**}$ | 2.3 | 11748 | 5.6 | 9518 |
| $z(y^{**})$ | 2.2 | 15648 | 4.2 | 9158 |

in Figure 1 and the Table 1, the values of streams and downloads are indicated in flow units and in relative units. At the end of the experiments, based on the obtained values $\Delta_k^*(z)$ (network loads with an equalizing distribution of interstitial flows) and $\Delta_k^*(y)$ (loads with an equalizing distribution of interstitial loads) are calculated

$\Delta_{min}(z) = \min_k\{\Delta_k^*(z)\},\ \Delta_{min}(y) = \min_k\{\Delta_k^*(y)\}, k = \overline{1, E}$;

$$\delta_k(z) = \frac{\Delta_k^*(z)}{\Delta_{min}(z)}, \delta_k(y) = \frac{\Delta_k^*(y)}{\Delta_{min}(y)}, k = \overline{1, E}, \Delta_{min}(.) \neq 0.$$

Schematic representations of networks in Fig. 1 correspond to the distribution of relative loads $\delta_k(.)$ on the edges of the network. In the core network (see Fig. 1) the greatest load is on the ring and edges originating at the middle of the network. In a ring network (Fig. 1), the maximum load falls on the additional the inner ring's edges and the outer ring's edges connecting the outside ring to the inner one. In both networks, a single relative load on hanging edges corresponds to their own information flows in the absence of transit ones.

The results collected in the table indicate the median and total values are both of inter-node flows are significantly higher inside the network of rings, with the same total allowable load in both networks. The specific costs of transmitting flows with equal inter-node loads reach a minimum value in the network of ring. The median numbers of edge load in the core network are 51% greater than on the network of ring.

## V. CONCLUSIONS

The work analyzes the load distribution at the edges and evaluates the specific resource costs with concurrent transfer on inter-node streams of different types and an equalizing control method. The got median values of the distributions of inter-node flows can be perceived as representational estimates of functionality of the network in an unclear situation, non-interchangeability of flows and equality of correspondents. All inter-node Streams with results that are under the median can be communication to the network. simultaneously. In a ring network, the specific costs of flow transmission and the median values of edge loads are significantly lower than in the base network. Average unit costs allow us to assess the effectiveness of resource make use of while changing the network structure.

The proposed method of splitting flows along all shortest routes makes it possible to analyze the network load taking into account the splitting of each type of flow. The resulting aggregated indicators for nodes in networks that may be employed in constructing routing tables, preparing repair and maintenance timetables for emergency operations and in case of disapprovingly dangerous damage.

The defined method allows for a preliminary assessment of a network design built on the basis of additional ways to communicate while keeping their overall number constant. Computational experiments have shown that changing the structure and load of edges while going from the bottom towards the ring one can meaningfully increase inter-node traffic, despite the fact that the overall number on franchised channels in the two networks is the identical.

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