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Multiflow Model for Routing and Policing Traffic in Infocommunication Network

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Abstract: *Thus the article offers the model represented by algebraic equations and inequalities for routing and policing traffic in infocommunication network. The novelty of the model is as follows: multiflow nature of modern ICN is taken into account (1), i.e. a set of flows circling between different pairs of network routers are considered simultaneously; coherent formalization of processes of traffic routing and policing within the model that has lower dimensionality in comparison to known earlier is provided; the choice of optimality criterion, use of which allows to implement multipath routing with consequent inclusion of paths as well as to organize limitation of flow intensity on all the used routs simultaneously depending on their characteristics and flow priority. According to the results of the analysis conducted we offer recommendations for choosing relation in numerical values of routing metrics and service denial regarding the provision of the given values for the main QoS characteristics, e.g. average packet delay. The model can be used as a basis for perspective protocol decisions aimed at coherence of solutions for the tasks of traffic routing and policing. Further development of the given model is possible under full account of stochastic characteristics of packet flows circling in the network.*

Keywords: *Model; Routing, Traffic, Flow, Priority, Quality of Service, Network.*

I. Introduction

Rapid progress in technologies of info communication networks (ICN) and increase of their performance is first of all connected with the development of fiber optic communications. Never the less the problem of overloading still remains an important task. Under high ICN overload provision of the given values of Quality of Service (QoS) characteristics is possible only at the account of policing (limiting) the traffic coming on edge network nodes [1]-[3]. Considering multiservice nature of modern ICN limitations of the intensity with service denials should be related more to low priority flows on the overloaded areas of network. Thus the process of traffic policing should be adaptive basing on the constant monitoring ICN states – load of communication links and routers, flow characteristics and QoS requirements. One of the important requirements is provision of maximal level of consistency between means of traffic policing and routing protocols.

Despite a rather wide spectrum of currently applied network mechanisms and protocols consistent solution for local tasks of traffic control is not provided. The existing methods for traffic control that are responsible for its formation, distribution (routing) and limitation have distributive nature and base on the information of an average rate stated in SLA (Service-Level Agreement) and network topology [1]-[3]. In order to solve each task of control we should apply different means such as Traffic Shaping and Committed Access Rate for traffic formation, for routing tasks we use such protocols as IGRP (Interior Gateway Routing Protocol), OSPF (Open Shortest Path First), PNNI (Private Network – to – Network Interface) [4]-[6] etc. These means work consequently and in the best case they define initial data for each other while solving tasks of traffic control. Besides models for traffic control that are heuristic by their meaning such as shortest path search, token bucket and lucky bucket are not able to take into account changes in the current load of a network node and characteristics of traffics of other users; they are also not coherent. This in its turn decreases considerably the effectiveness of means of control and visibly restricts their application area in ICN.

II. Problem statement

Thus the reason of the low consistency level in solving tasks of traffic control is not only the problem of the technical implementation of the given requirement; it is more connected with complexity of formalization of these tasks within the single model. In this case the actual scientific and practical problem is the development of the complex model able to describe consistently the processes of routing and policing traffic in ICN that could be a basis of perspective protocols for traffic management.

III. Model for traffic routing and policing in infocommunication network

Currently we know several approaches within which attempts to develop such model were made. The most successful among them are [7]-[11]. In [7] a model of consistently solving tasks of traffic policing using implementation of precomputation routing is given. This model suggests that the problem of these paths computation is preliminary solved and it is necessary only to provide distribution of the flows coming into ICN along the given routs. In [8], [9] two-index model that does not require path precomputation is offered and investigated. This model is based on the model of flow-based routing, i.e. it considers flow structure of modern network traffic. Although a model in [8], [9] possesses rather high dimensionality [10] that has negative influence on perspectives of its computing and software implementation. That is why the given articles offers to use three-index model of flow-based routing in [10], [11] as a basic one.

Let the structure of the network be described with oriented graph $G=(M,E)$, where M is a set of nodes (ICN routers) and E is a set of arcs (communication links). For each arc $(i,j)\in E$ has its bandwidth φ_{ij}. Besides, let K be a set of flows, circling in the network.

Regarding multiflow nature of modern ICN as well as necessity of joint description of traffic routing and policing processes the condition of flow conservation on routers and in ICN in general obtains the next form:

$$r_{i,j}^{k}(1-\alpha_{i,j}^{k})+\sum_{m\in M_k}x_{m,j}^{k,i}=\sum_{s\in M_s}x_{i,j}^{k,s}\,, \tag{1}$$

where $x_{m,j}^{k,i}$ is intensity of the k-th flow of packets that must be sent from the m-th to the j-th node via the i-th node;

$\alpha_{i,j}^{k}$ is a portion of the k-th packet flow from the m-th node to the j-th node that was denied in service;

$r_{i,j}^{k}$ is intensity of the k-th packet flow arriving to the i-th node from access networks (network users) for their further transmission to the j-th node;

M_k is a set of adjacent nodes for the i-th node from which they can receive packets;

M_s is a set of adjacent nodes for the i-th node to which it can send packets.

Then the condition of loop absence in computing routs of packet delivery in the network can be written as [10], [11]

$$M_k\bigcap M_s=\varnothing\,. \tag{2}$$

In its turn the condition of absence of ICN communication channel overload is as follows:

$$\sum_{k}\sum_{j}x_{m,j}^{k,i}\le\varphi_{k,i}\,,\ (m,i)\in E\,. \tag{3}$$

Routing variables $x_{k,j}^{i}$ and dropping variables $\alpha_{i,j}$ should be given several important restrictions as

$$0\le x_{m,j}^{k,i}\le r_{i,j}\,, \tag{4}$$

$$0\le\alpha_{i,j}^{k}\le 1\,. \tag{5}$$

Fulfillment of the condition (4) provides implementation of multipath routing strategy Introduction of the condition (5) allows to use adaptive flow limitation under possible overload of communication channels of the network in general.

Computation of control variables $x_{m,j}^{k,i}$ and $\alpha_{i,j}^{k}$ should be made consistently providing minimization of available network (channel) resources usage. In this case it is necessary to present initial task as optimized with the following target function subjected to minimization:

$$J=\sum_{k}\sum_{m}\sum_{j}\sum_{i}f_{m}^{i}x_{m,j}^{k,i}+\sum_{k}\sum_{i}\sum_{j}\alpha_{i,j}^{k}f_{i,j}^{k}\alpha_{i,j}^{k}\,, \tag{6}$$

where $f_{m,j}^{k,i}$ is routing metrics for the links given by the arc $(m,i)\in E$; $f_{i,j}^{k}$ is metrics of service denials that depends directly on the priority of k-th flow.

Such choice of target function was made due to the results of the investigation of models that were known earlier [8], [9]. The choice of linear form $\sum_{k}\sum_{m}\sum_{j}\sum_{i}f_{m}^{i}x_{m,j}^{k,i}$ guaranties realization of multipath routing with consequent inclusion of paths and usage of quadratic form $\sum_{k}\sum_{i}\sum_{j}\alpha_{i,j}^{k}f_{i,j}^{k}\alpha_{i,j}^{k}$ allows to organize limitation of flow intensity on all used routs simultaneously depending on their characteristics and priority of flow.

In [8], [9] it is showed that denial metrics should be chosen by their numerical values that are bigger than routing metrics. Relation between metrics is largely determined by the structure of the network: the amount of communication channels, routers and their connectivity. As the results of conducted investigations have shown (fig. 1) by choosing the relation between metrics of routing and service denials

$$d = f_{i,j}^{k} \big/ f_{m,j}^{k,i}, \quad (7)$$

it is possible to regulate maximal allowed average end-to-end delivery of packets in ICN for any flow. However when the value of d is getting higher, traffic proofing begins at the border of ICN under higher intensity of the flow $r_{i,j}^{k}$, i.e. the higher is d, the lower will be the amount of denials. While obtaining the analysis of the results in order to make the example more vivid we adopted hypothesis that the work of routing interface was simulated by the queuing systems M/M/1.

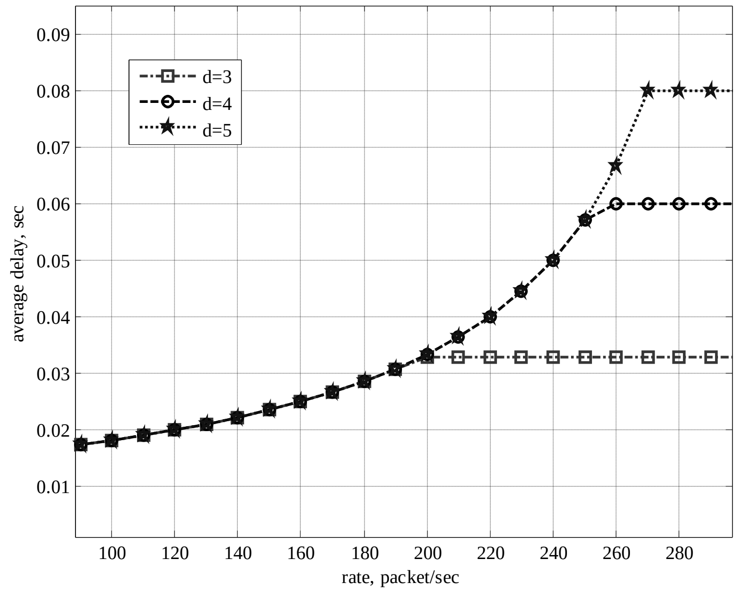

Fig. 1. The results of the analysis for the influence of relation between metrics of routing and service denial on the nature of decisions connected with traffic routing and policing

By the same way it is possible to control other QoS characteristics, e.g. jitter and probability of packet loss. Besides numerical value of the parameter d (7) for each flow can be specified in the course of infocommunication network functioning according to the changes of QoS requirements.

IV. Conclusions

Thus the article offers the model represented by algebraic equations and inequalities (1)-(6) for routing and policing traffic in infocommunication network. The novelty of the model is as follows:

1. Multiflow nature of modern ICN is taken into account (1), i.e. a set of flows circling between different pairs of network routers are considered simultaneously;
2. Coherent formalization of processes of traffic routing and policing within the model that has lower dimensionality in comparison to known earlier is provided;
3. The choice of optimality criterion (6), use of which allows to implement multipath routing with consequent inclusion of paths as well as to organize limitation of flow intensity on all the used routs simultaneously depending on their characteristics and flow priority.

According to the results of the analysis conducted we offer recommendations for choosing relation in numerical values of routing metrics ($f_{m,j}^{k,i}$) and service denial ($f_{i,j}^{k}$) regarding the provision of the given values for the main QoS characteristics, e.g. average packet delay. The model (1)-(6) can be used as a basis for perspective protocol decisions aimed at coherence of solutions for the tasks of traffic routing and policing. Further development of the given model is possible under full account of stochastic characteristics of packet flows circling in the network.

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