COMPUTING LOSSES IN PACKETLESS NETWORK SIMULATIONS

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Abstract – We define the problem of computing per-link losses in the fluid-flow approximation of a packet switching network, useful for the packetless simulation of high-speed packet switching networks.

Keywords – Simulation, graph theory, fluid-flow approximation

I. INTRODUCTION

Simulation is a frequently used tool for problems in packet switching networks. The usefulness of simulation stems not only from the difficulty in finding analytical solutions, since most of the problems in this field are NP-hard, but also from the fact that simulation can contribute very much to understanding of the system being analyzed, beyond answers to the original questions. The creation of a simulation model is the first occasion where certain things are taken into account. Specification of the simulated system can (and often does) reveal errors or ambiguities in the system design. Therefore, simulation can be very helpful in avoiding expensive future updating of the deployed systems. Nevertheless, simulation at the packet level is a very resource-consuming process, particularly in the case of high-speed networks. Due to the great amount of flow multiplexing in these networks, however, good enough approximations may be obtained by packetless fluid-flow approximations when we are interested in the evaluation of the macroscopic behaviour but not in microscopic, packet-level effects.

In the next section we define the problem of computing per-link losses in the fluid-flow approximation of a packet switching network.

II. FORMULATION OF THE PROBLEM

A. Problem data

Let $G=(V,E)$ be a directed graph and $c:E\rightarrow\mathbb{R}^+$ an assignment of capacities to the edges, representing a (packet switching) network. Let P be a set of acyclic paths between every source vertex s and every destination vertex d, denoted by $p_{s,d}$, $s,d\in V:s\neq d$, and assume integer routing of flows. Let F be the matrix of traffic demands, denoting the demand between vertex s and vertex d by $f_{s,d}$. Assume that $f_{s,s}=0,\forall s\in V$.

B. Problem description

The edges may have insufficient capacity to transport all the flows offered to them; in this case, there will be losses in each of the flows traversing the edge, proportional to the amount of that flow offered to the edge, that is, all flows traversing an edge (i,j) will be affected by a transmission factor $0<t_{i,j}\leq 1$.

Let us denote the fraction of flow $f_{s,d}$ that arrives at vertex $i\in V$ by $o^i_{s,d}$. Obviously, $o^s_{s,d}=f_{s,d}$. For any other vertex $j\in V$, $o^j_{s,d}=\sum_{i\in V:(i,j)\prec p_{s,d}} t_{i,j}o^i_{s,d}$, where the notation $(i,j)\prec p_{s,d}$ means that (i,j) is a proper subset of $p_{s,d}$, that is, i and j are consecutive elements of $p_{s,d}$ (in an acyclic path there is at most one such term).

If we denote by $a_{i,j}$ the aggregate flow offered to edge (i,j), then $a_{i,j}=\sum_{s,d\in V:(i,j)\prec p_{s,d}} o^i_{s,d}$. The value of the transmission factor may be computed from $a_{i,j}$ and $c_{i,j}$ as follows:

$$t_{i,j}=\begin{cases} c_{i,j}/a_{i,j} & \Leftarrow \quad a_{i,j}>c_{i,j} \\ 1 & \Leftarrow \quad a_{i,j}\leq c_{i,j}\end{cases}$$

The problem is to find an efficient method for computing the values of $t_{i,j}$.