Admission Control in Damper-based Deterministic Networks

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Keywords : *Deterministic networks, damper, column generation, branch-and-Price.*

1 Problem statement and complexity

Deterministic networking with end-to-end delay guarantees is becoming a must for a wide-range of Internet applications. In this context, *dampers* are used to guarantee deterministic end-to-end (E2E) delay and bounded jitter in Large Deterministic Networks (LDN). The concept was introduced by Verma et al. [1], where a per-flow regulator is placed at every node to compensate the time between a maximum queuing delay and the delay experienced at the previous hop. This work extends the original LDN [2] architecture by relaxing the need for clock synchronization between devices. Here, we introduce the Admission Control problem in a Damper-based deterministic Networks (ACDN) to decide about flows' acceptance along with shaping patterns at ingress nodes and routing paths to satisfy ES2 delay requirements.

An instance of ACDN is given by a pair (G, F). The graph $G = (V, A)$ is a digraph representing the network topology, where V is the set of devices and A is the set of links. For $v \in V$, it is associated a capacity c_v, and for $a = (i, j) \in A$ it is associated a delay l_a and a capacity c_a. The set F represents the demands (i.e. flows) that need to be admitted. Each flow $f \in F$ is characterized by a source $s_f \in V$ and a destination $t_f \in V$; a throughput r_f ; a maximum end-to-end delay ; a set of possible transmission patterns Π_f such that each $\pi \in \Pi_f$ has a reservation $\beta(f, \pi)$, and a shaping delay $d(f, \pi)$. For a flow $f \in F$, Φ_f will denote the set of path-pattern pairs such that the maximum E2E delay constraint is respected. The ACDN consists in maximizing the total throughput of admitted flows by selecting for each flow at most one element in Φ_f, in such a way that node and arc capacity constraints are respected. The ACDN is NP-Complete even with a single pattern per flow, infinite delay and infinite nodes capacity. In this case, the problem reduces to a general multicommodity flow problem [3].

2 ILP path formulation, algorithm and results

For $f \in F, (p, \pi) \in \Phi_f$, let $x_f^{p,\pi}$ be the binary variable that takes 1 if the path-pattern (p, π) is selected for flow f, and 0 if not. The problem is equivalent to the following ILP path formulation called ACDN Formulation (ACDNF) :

$$\textbf{ACDNF} \max \sum_{f \in F} \sum_{(p,\pi) \in \Phi_f} r_f x_f^{p,\pi}$$

$$\sum_{(p,\pi) \in \Phi_f} x_f^{p,\pi} \leq 1 \qquad f \in F, \qquad \text{(1. routing and shaping)}$$

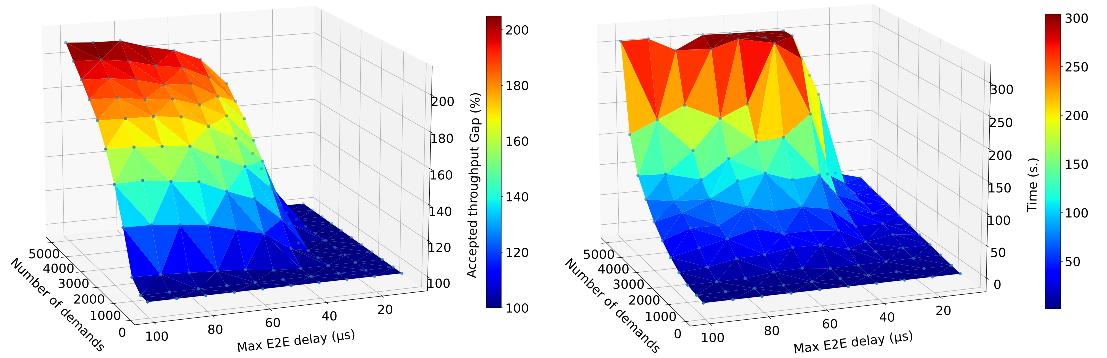
$$\sum_{f \in F} \sum_{(p,\pi) \in \Phi_f : a \in p} \beta(f, \pi) x_f^{p,\pi} \leq c_a \quad a \in A, \qquad \text{(2. arc capacity)}$$

$$\sum_{f \in F} \sum_{(p,\pi) \in \Phi_f : v \in p} \beta(f, \pi) x_f^{p,\pi} \leq c_v \quad v \in V, \qquad \text{(3. node capacity)}$$

$$x_f^{p,\pi} \in \{0, 1\} \qquad f \in F, (p, \pi) \in \Phi_f \qquad \text{(4. integrality)}$$

Constraints (1) are routing constraints, they ensure that each accepted flow has exactly one path-pattern couple. Constraints (2), and (3) are respectively link capacity and node capacity constraints. Finally, (4) are integrality constraints. Note that we may have an exponential number of variables in ACDNF as the number of paths in general graphs is exponential.

Based on a Column Generation algorithm with an eXact Rounding procedure (CGX), we design a heuristic to solve ACDNF. Here, the pricing problem for column generation is a constrained shortest path. Our approach to solving it is to use the Lagrange Relaxation Aggregated Cost (LARAC) algorithm [4]. The numerical results of Figure 1 show the efficiency of CGX algorithm to obtain high quality solutions, with comparaison to OSPF routing, in a short time.



(a) Accepted throughput gap between CGX and OSPF.

(b) Computational time for CGX (s).

FIG. 1 – Admission control results for CGX and OSPF routing : sensitivity to requirements in terms of E2E delay and number of demands.

3 Perspectives

For future work we will design a Branch-and-Price algorithm in order to solve the problem at optimality. Moreover, the control plane algorithm we have introduced in this paper is an offline algorithm. An interesting direction of this work is to study and design an efficient online algorithm to solve the admission control problem.

Références

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