Call Admission Control and Routing Control in Communication Networks via Dynamic Programming with State Aggregation

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Abstract

The Call Admission Control (CAC) and Routing Control (RC) problems for communication networks have been formulated as stochastic control problems; due to their complexity, a large number of suboptimal solutions have been proposed for these problems ([1],[2]) and some partial analyses have been carried out. Indeed, because of this complexity, it is impossible to implement even the proposed suboptimal solutions when the entire system model is formulated at any realistic level of detail. However, among the recent analyses of interest, Dziong and Mason [1] obtained suboptimal solutions by assuming statistical independence of the network links, and Marbach *et al.* [2] obtained an approximation result by the method of neuro-dynamic programming.

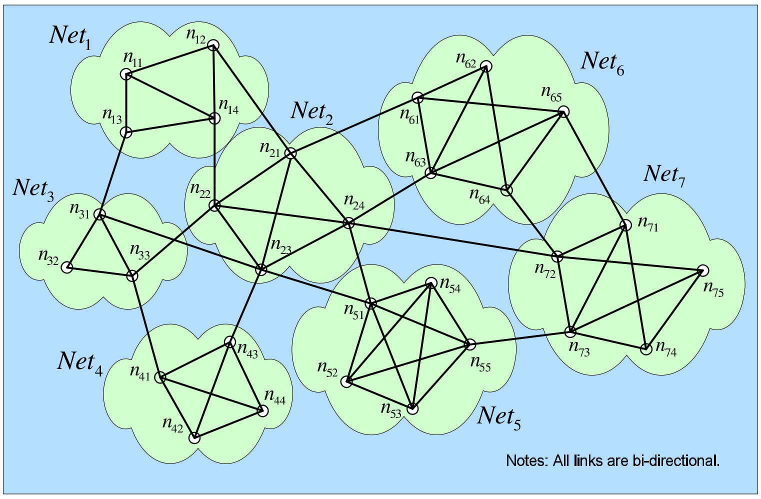

Figure 1: An aggregated communication network

In this work, we formulate optimal stochastic network control within the framework of piecewise deterministic processes (PDP) [3]. CAC and RC problems in integrated communication networks are then formulated and analysed via stochastic dynamic programming. Due to the Markovian structure of the model, optimal control laws are current state dependent, in other words, the optimal control $u^0 \in \mathcal{U}$ is a state dependent (*i.e.* Markovian) control satisfying:

$$\inf_{u\in\mathcal{U}[s,T]} E\Big\{\int_s^T g(t,x_{t^-},u_t(x_s^{t^-},e_s^t))dt|\mathcal{F}_s^w\Big\} = \inf_{u\in\mathcal{U}^M[s,T]} E\Big\{\int_s^T g(t,x_{t^-},u_t(x_{t^-},e_t))dt|\mathcal{F}_s^w\Big\}$$
$$= E\Big\{\int_s^T g(t,x_{t^-},u_t^0(x_{t^-},e_t))dt|\mathcal{F}_s^w\Big\},$$

where x is the system state, e is the point process of call requests and departures, $\mathcal{U}$ is a general class of control laws, $\mathcal{U}^M$ is the class of Markovian control laws, $(\mathcal{F}_s^w)_{s\in\mathbf{R}_+}$ is the family of observation σ-fields and $g(.)$ is a loss function.

In particular, CAC and RC problems in Poisson communication networks are formulated and analysed in this work as discrete-time stochastic control problems.

To contend with the problems arising from complexity, the present work provides a novel hierarchical control mechanism. We introduce the so-called *doubly stochastic networks* where the local state processes are randomized in the control calculation at specific instants and the resulting extended high level state processes are Markovian, as in

$$P\big((x^H_{t^H_{k+m}},Q_{t^H_{k+m}})\in\Gamma|\,\sigma(x^H_{t^H_j},Q_{t^H_j}),j=1,\cdots,k\big) = P\big((x^H_{t^H_{k+m}},Q_{t^H_{k+m}}))\in\Gamma|\,\sigma(x^H_{t^H_k},Q_{t^H_k})\big),$$

where here the subscript H denotes the high level or aggregated version of a variable and Q is a high level capacity measure.

Sub-optimal solutions, $\hat{J}(s,T;\xi_0)$ to the CAC and RC control problems for the underlying networks are then obtained via solutions of a lower layer of stochastic control problems which take as input the solution to the higher (*i.e.* aggregrated) control problem, as shown in:

$$\hat{J}(s,T;\xi_0) = \inf_{u^H\in\mathcal{U}^H[s,T]} E\Big\{\int_s^T g(x_t^H,Q_t^H,u^H)dr$$
$$+\sum_{j=0}^{\infty}\sum_{i=0}^{K} \inf_{u^i\in\mathcal{U}^i(t_j^H,t_{j+1}^H]} \int_{t_j^H}^{t_{j+1}^H} g(x_t^i,u^i)dv\Big\},$$

where, $\mathcal{U}^i$ denotes the class of controls defined for the i-th aggregation cell.

Current research is focussed on estimating the suboptimality of hierarchical control laws obtained using the doubly stochastic network control methodology and extending this methodology to local, or distributed, control laws.

References

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[3] M.H.A. Davis, *Markov Models and Optimization*, Chapman & Hall, 1993.