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CONTROL AND GAME-THEORETIC TOOLS FOR COMMUNICATION NETWORKS

SURVEY

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Abstract. Communication networks, such as the Internet or ATM networks, can be viewed as large-scale systems with multiple levels of decision making, involving service providers (at the higher level) and individual users (at the lower level). Among the decisions that each user is faced with, which are generally guided by an appropriate performance index, are (i) at what (flow) rate to inject packets into the network, and (ii) how to adjust these rates in response to (delayed) congestion information received from the network. Occasionally, users are also faced with the task of making decisions on routing, again based on information received from the network. Among the decisions the network service providers are faced with, on the other hand, are what to charge for the offered resources (such as bandwidth on each link), on what basis to admit users to the network, and whether or not to add additional capacity to any of the links—all driven by revenue maximization.

Modelling and analyzing such systems, as well as architecting such networks and constructing routing and congestion control policies have presented, and continue to present challenges of mathematical, engineering and economic nature. This overview paper dwells on a number of issues that arise in this context, and presents mathematical models that capture the decision making processes at the higher as well as the lower levels, as well as tools to resolve them. The model for the former is game-theoretic, with the service provider being the revenue-maximizing price-setter and the users being utility maximizing price-takers, with the decisions made on a slower time scale. For the lower level, on the other hand, the model is a large-scale nonlinear control system with uncertain delays, which operates on a relatively faster time scale and with decentralization. The underlying issues are numerous, including optimum pricing, admission control, routing, and capacity expansion at the higher level, and stability of decentralized and distributed rate control algorithms at the lower level.

Key Words. Networks; control theory; game theory; information technology; communications.