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Introduction. Stochastic networks: from theory to practice

This special feature in the *Proceedings of the Royal Society A*, originated in an advanced workshop entitled 'Stochastic networks and Internet technology', which was held for a week, in September 2007, under the auspices of the Mathematics Department of the Scuola Normale Superiore in Pisa, Italy, at the Centro Ennio de Giorgi. During this advanced workshop, some 25 researchers attended from disciplines such as computer science, communications engineering, statistical mechanics, mathematical physics, and biology. The workshop addressed mathematical methods, mainly based on probability models, to investigate the behaviour of large-scale networked systems, such as the Internet, but also animal populations or even gene regulatory networks, and explored many similarities between these models. The special feature emerged from the lectures presented at this meeting, after a selection based on the submissions that were thoroughly and independently refereed according to the standard procedures applied by the *Proceedings of the Royal Society A*.

The resulting set of five papers that are published together in this issue address distinct but related issues in complex networks, with an obvious common theoretical or experimental thread that is based on probability models, and with relevance to different scientific areas.

The paper on 'Intelligibility and first passage times in complex urban networks', by Blanchard & Volchenkov (2008), links graph properties of networks to the stochastic dynamics in time of the network as a whole. As such, the paper is relevant to transportation networks in general, including data transport networks. Gellman's (2008) paper on 'Oscillations in self-aware networks' is inspired by a new trend in research on the Internet, which proposes to replace the static routing rules for networks based on simple shortest path algorithms, with routing algorithms that select paths for data packets that are based on the instantaneously observed state of the network, so as to improve the satisfaction (or quality of service) of the network's end-users. However, the danger is that such algorithms will change the paths being used too infrequently, leading to undesirable side effects; the paper uses experiments on a real test bed to show that such undesirable side effects in fact remain quite limited. The fundamental performance limits of modern wireless networks are explored in the paper 'Scaling laws for delay-sensitive traffic in Rayleigh fading networks' by Karamchandani & Franceschetti (2008). Previous research has obtained results inspired by information theory that indicate how the throughput capacity of the network depends, in the limit, on delay and size. This paper re-examines this issue in the presence of an important practical phenomenon in wireless channels,

One contribution of 6 to a Special Feature 'Stochastic networks: from theory to practice'.

known as time-dependent fading. The work on 'Emergence of network structure in models of collective evolution and evolutionary dynamics', by Jensen (2008), examines networks that are dynamically modified over time by effects that simulate evolution. These effects are modelled using plausible probabilistic heuristics and the resulting network properties are simulated and analysed. The final paper, on a 'Network of interacting synthetic molecules in steady state', by Gelenbe (2008), makes a contribution to the theoretical analysis of chemical reactions using methods that have been developed in the context of queuing theory. We show that for a class of significant reactions that include both binary and monomolecular reactions, with the possibility of repeated reactions that can generate arbitrarily large molecules, the joint probability distribution of the number of resulting new or original molecules in steady state is given by a product of Poisson distributions, provided that the total inflow rate of molecules into the reaction network is equal to the total outflow rate.

Thus, this special feature shows how very similar modelling and analysis methods that are common to a variety of networked systems can yield significant advances in a wide variety of important and multidisciplinary application areas in chemistry, biology, transportation systems, computer science and communications engineering.

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