Stochastic Networks (M24)

Frank Kelly

Communication networks underpin our modern world, and provide fascinating and challenging examples of large-scale stochastic systems. This course uses stochastic models to shed light on important issues in the design and control of communication networks.

Randomness arises in communication systems at many levels: for example, the initiation and termination times of calls in a telephone network, or the statistical structure of the arrival streams of packets at routers in the Internet. How can routing, flow control and connection acceptance algorithms be designed to work well in uncertain and random environments? And can we design these algorithms using simple local rules so that they produce coherent and purposeful behaviour at the macroscopic level?

The first two parts of the course will describe a variety of classical models that can be used to help understand the performance of large-scale stochastic networks. Queueing and loss networks will be studied, as well as random access schemes and the concept of an effective bandwidth. Parallels will be drawn with models from physics, and with models of traffic in road networks.

The third part of the course will more recently developed models of packet traffic and of congestion control algorithms in the Internet. This is an area of some practical importance, with network operators, hardware and software vendors, and regulators actively seeking ways of delivering new services reliably and effectively. The complex interplay between end-systems and the network has attracted the attention of economists as well as mathematicians and engineers.

We describe enough of the technological background to communication networks to motivate our models, but no more. Some of the ideas described in the book are finding application in financial, energy, and economic networks as computing and communication technologies transform these areas. But communication networks currently provide the richest and best developed area of application within which to present a connected account of the ideas.

Desirable previous knowledge

Mathematics that will be assumed to be known before the start of the course: Part IB Optimization and Markov Chains. Familiarity with Part II Applied Probability would be useful, but is not assumed.

Introductory reading

A feeling for some of the ideas of the course can be taken from

The mathematics of traffic in networks. In *Princeton Companion to Mathematics* (Edited by Timothy Gowers; June Barrow-Green and Imre Leader, associate editors) Princeton University Press, 2008. 862-870.

Literature

Reference 3 is the course text.

1. B. Hajek *Communication Network Analysis.*

2. F.P. Kelly *Reversibility and Stochastic Networks.* Cambridge University Press, 2011.

3. F. Kelly and E. Yudovina *Stochastic Networks.* Cambridge University Press, 2014.
4. R. Srikant and L. Ying *Communication Networks: An Optimization, Control and Stochastic Networks Perspective.* Cambridge University Press, 2013.

Additional support

Examples sheets will be provided and associated examples classes will be given. There will be a one-hour revision class in the Easter Term.