PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Introductory remarks

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Introductory remarks

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The previous Royal Society Discussion Meeting which considered the future of telecommunications was in 1992, prophetically entitled 'Communications after AD 2000', and organized by Davies, Hilsum and Rudge (Davies *et al*. 1993). The last decade, however, has seen a revolution in this field. Although a very forward-looking and exciting discussion meeting at the time, many predictions made, and opinions voiced, in 1992 have been surpassed or proved very conservative. The growth in data traffic, the explosion of the Internet and the ability to route and process data have all grown, fuelled by research in TCP/IP, new network architectures and algorithms as well as high-speed routers. Research and development in fibre optics and associated optoelectronics as well as microelectronics has underpinned this growth. Wavelength division multiplexed (WDM) systems—an optical fibre transmission technology where a number of differently encoded wavelength channels are transmitted simultaneously to increase the transmission capacity of a single fibre—is now a reality. Yet the research and development in these areas of telecommunications has relentlessly moved ahead. To do so, many previously separate research areas of networking, mathematical modelling, and mathematical techniques, semiconductor physics and optoelectronics, optical fibre technology and nonlinear fibre optics, and underlying network economics have began to overlap to support the much faster progress from research laboratory curiosities to the stage of implementation. In a network these separate technologies cannot work in isolation, but must interact and cooperate to a previously unparalleled degree. We therefore felt that a new Discussion Meeting was timely that sought to bring together experts from across the whole field. However, although it is boldly entitled, 'Network modelling in the 21st century', we appreciate that it can provide no more than a snapshot of today that may be out of date rather quickly. Its primary purpose is, therefore, to provide an opportunity for both specialists and generalists to gain an overview of the whole field and observe some of the exciting developments within it.

The Discussion Meeting was divided into three areas, namely:

(1) modelling of traffic and quality of service requirements in new generation networks, and especially the debate on whether data/IP networks require a radically different approach to modelling and planning compared with conventional telecommunication networks;

(2) technologies in support of new network architectures, analogue and digital optical processing and wireless communications as well as router design issues—

research and design of very large electronic and optical routers to support this traffic growth and new types of traffic;

(3) network pricing and internet economics—how is the traffic demand and network capacity allocation to be managed in a future network?

The papers in this issue broadly follow these themes. Four papers discuss modelling of broadband networks with a focus on quality of service. The paper by Gibbens, Sargood, Kelly, Azmoodeh, Macfadyen (both father and son) provides an approach to service level agreements (SLAs) within a managed IP network with multiple levels of quality. The paper proposes an appropriate form of SLAs based on the throughputs of adaptive (TCP-like) connections averaged over prescribed periods of time. The authors present a quantitative framework for a network operator to study the important issues of provisioning and service differentiation. The paper by Roberts and Oueslati-Boulahia also considers the issue of providing quality of service in the Internet. The paper argues that, to achieve desired levels of quality, the network needs to be aware of flows in order to route and control traffic efficiently. The paper by Crowcroft surveys the mechanisms and approaches used in the Internet today to cope with the jungle of different applications, protocols and notions of quality. The author argues that the success of the Internet results from a loose organization of its various components. The papers in this issue broadly follow this division. The paper by Lanning, Mitra, Wang and Wright describes work on optimal planning by network operators for optical transport networks where 'disruptive' increases in capacity occur. Their results, derived within a precisely formulated optimization framework, are contrasted with those for voice networks, where the rate of technology change is much slower.

The enormous growth in optical communication technologies, led by advances in WDM and optical routing are highlighted in the papers by Glass and Sato, focusing on the aspects of optical network physical layer design, underlying photonic technologies and looking ahead to future research and developments. The key question here is whether optical technologies can be used for the new packet-based network architectures? Cotter describes the principles and techniques for digital optical processing—a possible competitor approach to the essentially analogue nature of WDM—in a paper on high-speed digital optical processing based on nonlinear switching and optical logic functions, including regeneration of optical signals, using semiconductor devices. The paper by Baroni describes an example for the design and planning of WDM optical topologies to cope with the growth of new services, while Zitterbart focuses on the design of electronic routers and search techniques to enable increased volumes of traffic to be processed and routed. Wireless networks have also seen tremendous growth in recent years. The paper by O'Reilly, Lane, Attard and Griffin reviews some of the technology options currently available in broadband wireless networks. The authors also consider in detail the synergies resulting from exploiting radio-over-fibre techniques to build more flexible broadband wireless networks.

The growth in the Internet and related technologies has also brought many new questions of how these networks will be used and how the usage can be charged for (and who pays?) without deleterious effects on the network capacity. Three papers provide a strong economic perspective to the modelling of communication networks, which was also reflected in the tone of discussion in the discussion meeting itself. The paper by Chu and Altmann reviews the findings of the INDEX project at the

University of California, Berkeley. In this project extensive market experiments have been carried out on pricing for Internet access with subjects recruited from faculty, staff and students on campus. Their findings provide an illuminating impression of how pricing structures affect usage. The paper by Mason illustrates the importance of a thorough economic framework within which to discuss and evaluate pricing schemes for the Internet. In particular, the paper argues that proposed pricing schemes must be robust to strategic behaviour on the part of firms and individuals. The paper by Kelly uses mathematical models to explore the rapidly growing Internet. The author argues that a simple packet network, together with intelligent end-nodes using natural congestion feedback information, may be able to support a rich range of services with differentiated qualities.

In conclusion, we are grateful to the authors and participants of the meeting for making it an exciting and a lively debated one and we look forward to the next decade of research in the areas covered in this issue, to see how many predictions made here prove to be correct and which will be surpassed by the breathtaking pace of new ideas.

Reference

Davies, D. E. N., Hilsum, C. & Rudge, A. W. 1993 *Communications after AD 2000*. Dordrecht: Kluwer.

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