Guest Editorial

THE RECENT advances in networking architectures and the emergence of new services have spurred unprecedented progress in network management. Indeed, new management tools and systems have been developed to meet the demands from industry for managing complex networks. Such progress has been accompanied by and often is the result of growing research activities in this area. Fundamental issues are being identified, and innovative approaches are being drawn from other disciplines into network management research. These activities begin to change the nature of network management solutions, which were traditionally *ad hoc* and implementation-centric. It is time, therefore, for a special issue which presents a collection of the recent advances in network management fundamentals and applications.

This special issue called for contributions in various aspects of network management. As the result, 18 papers are selected, eight of which are invited. The papers cover both traditional and topical areas, each of which is highlighted as follows.

1) *Collection of Management Information:* Three papers are devoted to collections of management information, which is considered to be an important first step for network management. A common focus is on how to achieve efficient data collection for large and complex networks. The paper by D. Breitgand *et al.* investigates the problem of browsing large management-information-base tables. The paper proposes a binary search algorithm, and demonstrates the efficiency in terms of time and bandwidth consumption of monitoring data. The paper by M. Dilman and D. Raz focuses on reducing the polling/transmitting of unnecessary management data. The key idea is to combine event reporting with polling, which leads to an efficient reactive-monitoring algorithm, with up to 90% saving on the amount of monitoring traffic. The paper by Y. Lin and M. Chan proposes a monitoring approach for measuring service level agreement (SLA) over large networks with many nodes and flows. The approach combines aggregation and refinement to offer a compromise between scalability and accuracy.

2) *Measurement-Based Network Management:* Five papers contribute to this rapidly growing area of research, on extracting pertinent information from measurements, and making use of it for network management. The paper by E. Bouillet *et al.* proposes a framework for quality-of-service (QoS)-centered SLA measurements, and their real-time management in multiservice packet networks. Three areas are investigated jointly in this framework: SLA monitoring, classification of route status using measured SLA, routing, and resource management. The paper by N. Duffield *et al.* investigates multicast loss inference of internal network links with incomplete information. The incomplete information results from missing measurements due to either unreliable transport protocol or multicast receivers, and expectation-maximization algorithm is applied to provide an approximation to maximum-likelihood estimation. The paper by C. Ji and A. Elwalid addresses the scalability of measurement-based network monitoring based on multicast inference. The scalability is characterized by the growth rate of the number of measurements needed with respect to the size of the network, and the missing data formulation is used to show when the scalability is achievable. The paper by S. Ma and J. Hellerstein is concerned with detecting from event data, mutually dependent patterns, which result from certain network faults. Data-mining approaches are applied and the efficiency of the proposed approaches is demonstrated. The paper by M. Núñez *et al.* applies temporal-data-mining approaches for automatic discovery of rules for predicting network management events. Chaotic theory is used for detecting chaos (unpredictable patterns) in sequences of events, and the proposed approach is used for discovering and predicting alarms in a computer network.

3) *Routing Information:* The paper by A. Shaikh *et al.* considers how to efficiently create a network view of intra-domain topology through developing an OSPF topology server. Design strategies are proposed and evaluated for management-plane-approach based on simple network management protocol and control-plane-approach based on link state advertisement. The paper by B. Fortz and M. Thorup addresses how to adapt OSPF weights to changing network conditions such as network faults, hot spots or traffic demands. The emphasis is on improving performance by optimizing a small number of weights.

4) *Management and Control of Optical Networks:* Five papers focus on this emerging area in network management and control. The paper by J. Wei begins with an overview on key architectural, management and control issues for Internet protocol (IP)-wavelength division multiplexing (WDM) networks. The paper then presents an integrated framework of traffic-engineering for IP-WDM networks, where multiprotocol label switching is utilized for IP load balancing, and a re-configurable WDM network is used for bandwidth expansion. The paper by P. Saengudomlert and M. Medard presents an approach for monitoring transparent optical nodes, which are vulnerable to failures. A novel monitoring system of bit-error-probability is proposed, and an analysis is given to access the performance. The paper by E. Modiano and A. Narula-Tam addresses the issue of survivable lightpath routing, in the presence of a link failure, for WDM networks. Necessary and sufficient conditions are provided for routing to be survivable, and effective re-

laxation is applied to integer linear programming to find survivable routes. The paper by M. Clouqueur and W. Grover presents availability analysis of span-restorable mesh networks. The paper shows that a span-restorable network can be robust under dual-failure events against which they are not specifically designed, and then quantifies how the availability of services benefits from the investment of restorability. The paper by M. Médard *et al.* concludes this topic area of the special issue by presenting a network management architecture for robust packet routing in mesh optical access networks [local larea network or metropolitan area network (MAN)]. The proposed architecture allows bandwidth sharing within a wavelength without the need of acting on or buffering individual packets, and is robust to a single link or node failure.

5) *Network Control, and Management Framework:* Three papers are loosely connected to discuss these two topics. The paper by G. Urvoy-Keller *et al.* proposes and evaluates a traffic management scheme which provides deterministic QoS guarantees for multimedia constraint sources in a multipoint to point network. An upper bound on the end-end delay is derived, and two admission control algorithms, one centralized and the other distributed, are introduced and discussed. The paper by T. Chen and S. S. Liu develops an analytical framework to model and compare centralized and distributed approaches for network management. Network monitoring and data search based on agents are examined for each of these approaches, and tradeoffs are discussed to lend a basis for approach selection. The paper by A. Papavassiliou *et al.* describes the use of mobile agents for developing market-based routes in the future multioperator network marketplace. A genetic algorithm is proposed to identify optimal resource allocation strategies, and the agent-framework is used to facilitate collection and dissemination of management data and distributed operation of the algorithms.

The collection of these papers accomplishes moderately the original goal of the special issue. A lot of important work though is not included due to space limitation. Submissions were also lacking on certain topics. This, however, may be interpreted that fundamental work is still much needed in this broad area of research. We hope that this special issue would help stimulate further research activities and advancement in network management.

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VINCENT W. S. CHAN, *Guest Editor*
Massachusetts Institute of Technology
Department of Electrical Engineering and Computer Science
Cambridge, MA 02139

ANWAR ELWALID, *Guest Editor*
Bell Laboratories, Lucent Technologies
Department of Mathematics of Networks and Systems
Murray Hill, NJ 07974

CHUANYI JI, *Guest Editor*
Georgia Institute of Technology
Department of Electrical and Computer Engineering
Atlanta, GA 30332

YACHAM YEMINI, *Guest Editor*
Columbia University
Department of Computer Science
New York, NY 10027

CHIN -TAU LEA, *JSAC Board Representative*

Vincent W. S. Chan (S'69–M'88–SM'92–F'94) received the B.S. and M.S. degrees, in 1971, the EE degree, in 1972, and the Ph.D. degree, in 1974, in electrical engineering from Massachusetts Institute of Technology (MIT), Cambridge, MA, in the area of communications.

He is the Joan and Irwin Jacob Professor of Electrical Engineering and Computer Science and Aeronautics and Astronautics, and Director of the Laboratory for Information and Decision Systems at MIT. From 1974 to 1977, he was an Assistant Professor with the School of Electrical Engineering at Cornell University, Ithaca, NY. He joined Lincoln Laboratory, in 1977 as a Staff Member of the Satellite Communication System Engineering Group. In January 1981, he became the Assistant Leader of the Communication Technology Group starting a research and development program on optical space communications. In July 1983, he formed and became Leader of the Optical Communication Technology Group and Manager of the LITE (Laser Intersatellite Transmission Experiment) Program. He was formerly the Head of the Communications and Information Technology Division of Lincoln Laboratory and served as the principal investigator of a new Next Generation Internet Consortium (ONRAMP) formed among AT&T, Cabletron, MIT, and JDS Fitel. On January 1, 1999, he became the Director of the Laboratory for Information and Decision Systems on the MIT Campus and serves on the faculty as the Joan and Irwin Jacob Professor of Electrical Engineering and Computer Science and Aeronautics and Astronautics. His research interests are in optical communications, wireless communications, space communications and networks.

Dr. Chan is a Fellow of the IEEE and the Optical Society of America.

Anwar Elwalid received the B.S. degree in Electrical Engineering from Polytechnic Institute of New York, Brooklyn, and the M.S. and Ph.D. degrees in Electrical Engineering from Columbia University, NY.

He is with Bell Labs, Lucent Technologies, Murray Hill, NJ, where he is a Distinguished Member of Technical Staff (DMTS). Since 1991, he has been with the Mathematics of Networks and Systems Research Department at Bell Labs, Murray Hill, NJ, where he developed theory and algorithms for network resource management and QoS support, and for the analysis and engineering of multimedia traffic. He holds several patents. His current research interests include IP and optical network architectures, traffic engineering, and stochastic systems. He has been active in the Traffic Engineering and MPLS Working Groups of the Internet Engineering Task Force (IETF). He served on the executive and technical program committees of several conferences.

Dr. Elwalid is a member of Tau Beta Pi (National Engineering Honor Society) and Sigma Xi.

Chuanyi Ji (S'85–M'91) received the B.S. degree (honors) from Tsinghua University, Beijing, China, in 1983, the M.S. degree from University of Pennsylvania, Philadelphia, PA, in 1986, and the Ph.D. degree from California Institute of Technology, Pasadena, CA, in 1992, all in Electrical Engineering.

She is an Associate Professor at the Department of Electrical and Computer Engineering at Georgia Institute of Technology, Atlanta, GA. She was on the faculty at Rensselaer Polytechnic Institute from 1991 to 2001. She spent her sabbatical at Bell Labs, Lucent Technologies, in 1999, and was a visiting faculty at Massachusetts Institute of Technology (MIT), Cambridge, MA, in the Fall 2000. Her research lies in the areas of network management and control, and adaptive learning systems. Her research interests are in understanding and managing complex networks, applications of adaptive learning systems to network management, learning algorithms and theory.

Dr. Ji received the CAREER award from NSF, in 1995, and the Early Career award from Rensselaer Polytechnic Institute, Troy, NY, in 2000.

Yacham Yemini is a Faculty Member with the Computer Science Department at Columbia University, NY. He founded and is Director of the Distributed Computing and Communications (DCC) Lab. His research interests include networking technologies, network management, active networks, high-performance protocol processing, and storage networks. He has authored over 200 publications and 11 patents. Technologies created at the DCC Lab have been widely exported to thousands of sites and commercialized by several companies. He has also been a Founder of three companies: Comverse Technology (1983), an S&P 500 and Nasdaq 100 company, a leading vendor of telecom voice messaging; System Managements Arts (1993), a leading vendor of automated network fault management system; and Activium (2000), a company developing next generation storage networks. He has additionally served as a strategic advisor or board member with over 25 technology companies.