

# Guest Editorial

## Design, Implementation, and Analysis of Communication Protocols

COMMUNICATION protocols are the foundation of modern communication networks, including the Internet, intelligent networks and wireless networks. The availability of reliable and high performance communication protocols has become indispensable in our daily life for us to conduct business and to exchange information more than ever before. This makes the correctness, robustness, and performance of protocols crucial for communications as that of algorithms for computer sciences. This issue of the JOURNAL ON SELECTED AREAS IN COMMUNICATIONS (JSAC) is devoted to a study of communication protocol design, implementation, analysis and testing with a focus on new concepts, advances, approaches, and experiences.

Eight articles cover a range of aspects of protocol design and implementations.

Routing protocol design is essential for reliable and efficient information and data transmission. "Multipath Routing for Video Delivery over Bandwidth-Limited Networks" addresses the need of end-to-end bandwidth requirement for video data transmission and proposes multipath routing, where the video takes multiple paths to reach its destination(s), thereby increasing the aggregate throughput. The design of border gateway protocol (BGP), an important Internet protocol, is studied in "Improved BGP Convergence via Ghost Flushing," where a minor modification of BGP is proposed to reduce the time for route convergence and stability after a node failure, and BGP is also discussed in "Advertising Interdomain QoS Routing Information," where the authors propose an extension of BGP for efficiently advertising the available bandwidth and the delay information of routes. Over the years, a large number of papers have been published on improving BGP performance. While appreciating the scientific merits of these two new improvements one might ask: given the growth and needs of Internet, is it time to design a new, more scalable and secure protocol to replace BGP?

As usual, control is an important aspect of protocol design for its reliability and performance. "On Designing Self-Tuning Controllers for AQM Routers Supporting TCP Flows Based on Pole Placement" explores the simple pole placement technique in the classical control theory for the controllers for active queue management in Internet protocol (IP) routers to support transmission control protocol (TCP) flows. It proposes two self-tuning controllers with a good active queue management (AQM) performance reacting very quickly to changing system loads. "Leveraging Single Rate Schemes in Multiple Rate

Multicast Congestion Control Design" proposes a new approach to multiple rate congestion control for layered multicast sessions, combining the benefits of single rate congestion control with the scalability of multiple rates. Efficient scheduling is another channel for improving network throughput and reliability. With the demand from its increasing applications and wide deployment, "Improving Protocol Capacity for UDP/TCP Traffic with Model-based Frame Scheduling in IEEE 802.11-operated WLANs" develops a model-based frame scheduling scheme to enhance the capacity of IEEE 802.11-operated wireless local area networks (LANs) for both TCP and user datagram protocol (UDP) traffic, while reducing the delay.

Aside from the main stream of activities on routing and control, protocol design has to address the requirements from other network application needs, such as efficient and robust data collection as in "A Coordinated Data Collection Approach: Design, Evaluation, and Comparison," where the authors propose coordinated data collection of a large amount of data from several different hosts to a single destination in a wide-area network, and also network resource reservation and provisioning as in "A Scalable Model for Interbandwidth Broker Resource Reservation and Provisioning," where a scalable model for interbandwidth broker resource reservation and provisioning is proposed for reducing admission control time and for coping with scalability problems.

Network protocol design has as a long history as network itself with enormous achievements in engineering and applications. However, there is little scientific foundation of protocol design; it has been mostly an engineering effort. Recently, there is a call for science of design (SoD), appealing for a scientific foundation of system designs: <http://www.nsf.gov/pubs/2004/nsf04552/nsf04552.htm>. While there is no doubt of its necessity it apparently requires a breakthrough advancement to lay a scientific foundation for protocol design.

No matter how novel and elegant a protocol design is, it cannot provide a desirable network system unless it is verified by a rigorous analysis for its correctness and performance and unless it is tested for conformance and interoperability of its implementation.

"SeSFJava Harness: Service and Assertion Checking for Protocol Implementations" formally verifies and tests the implementation of a network protocol for its conformance to the required services based on an assertion checking. Rather than testing general protocols, "A Framework for Systematic Evaluation of Multicast Congestion Control Protocols" is focused on multicast congestion control protocol testing, based on an

appropriate model from protocol specifications and correctness conditions, and devises an automated search engine to generate error scenarios for an evaluation. Different than testing for conformance of a protocol to its specification, interoperability testing is on the interfaces of integrated protocol system components. “Interoperability Test Generation and Minimization for Communication Protocols Based on the Multiple Stimuli Principle” presents an automatic test generation and minimization method for testing interoperability of communications protocols, based on a technique of composing finite-state machines, minimizing the number of increased test cases due to the multiple stimuli without jeopardizing transition coverage.

“A Cryptographically Sound Security Proof of the Needham–Schroeder–Lowe Public-Key Protocol” verifies the security property of the well-known Needham–Schroeder–Lowe public-key protocol for entity authentication against arbitrary active attacks if it is implemented using standard provably secure cryptographic primitives. It differs from traditional formal methods based security proofs in that the results are not restricted to properties in terms of an abstract (Dolev–Yao) model, but in fact carry over to the actual cryptographic algorithms used. Moreover, the proof techniques used are well-suited for a machine-assisted formal proof, e.g., using a theorem-prover.

With the advancement of networking technologies, performance analysis remains important for estimating a designed protocol and for improving its performances. “An Improved Packet Collision Analysis for Multi-Bluetooth Piconets Considering Frequency-Hopping Guard Time Effect” analyzes the interference problem of Bluetooth piconet to predict the packet collision effect in a multipiconet environment, taking

into account the frequency-hopping guard time effect in Bluetooth baseband. “Performance Analysis of IEEE 802.11e Contention-Based Channel Access” examines another wireless protocol: IEEE 802.11e, for supporting quality-of-service (QoS) in wireless LAN with a study of the performance of enhanced distributed channel access (EDCA) and the fundamental medium access control (MAC).

We are deeply indebted to the authors for their support, the reviewers for their conscientious works, the JSAC Editor-in-Chief and the Editorial Board for their encouragement and advice, and the readers for their interest that has motivated and guided the whole effort for this issue.

ED BRINKSMA, *Guest Editor*  
Department of Computer Science  
University of Twente  
Enschede, 7500 AE The Netherlands

RUIBING HAO, *Guest Editor*  
Bell Labs Research China, Lucent Technologies  
Beijing, 100084 China

DAVID LEE, *Guest Editor*  
Department of Computer Sciences and Engineering  
The Ohio State University  
Columbus, OH 43210 USA

RAYMOND E. MILLER, *Guest Editor*  
Department of Computer Science  
University of Maryland  
College Park, MD 20742 USA

C.-T. LEE, *J-SAC Board Representative*



**Ed Brinksma** holds the Chair of Formal Methods and Tools at the University of Twente, Enschede, The Netherlands. His work concentrates on the application of formal methods to reactive systems, ranging from fundamental contributions to industrial applications, as well as methodological issues. In the past, he has contributed to areas such as communication protocol specification, specification-based test generation, stochastic process algebra, and guided model checking. His research group participates in a great number of (inter)national research projects with both academic and industrial partners, including the European IST Projects AMETIST (timed systems) and ARTIST (embedded systems). He is on the Editorial Boards of the Springer International Journals of *Software Tools for Technology Transfer* (STTT) and *Software and System Modeling* (SoSym). He is a founding member of the Steering Committee of the TACAS Conference, and has served on the steering committees of PSTV/FORTE, ETAPS, and PAPM. His current interests include testing theory for real-time systems, modeling and analysis of hybrid systems, and real-time scheduling synthesis.

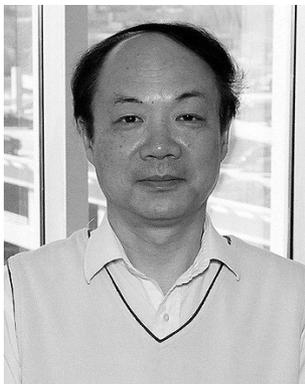
Dr. Brinksma served as an Editor for the IEEE TRANSACTIONS ON SOFTWARE ENGINEERING.



**Ruibing Hao** (M'99–SM'04) received the B.S., M.S., and Ph.D. degrees in computer science from Tsinghua University, Beijing, China, in 1993, 1994, and 1997, respectively.

In March 2001, he joined Bell Laboratories Research China, Lucent Technologies, Beijing, as a Functional Manager and now is the Technical Manager of the Next-Generation Internet Research Group. Prior to his current post, he was a Member of Technical Staff in the Network Research Laboratory, Central Bell Labs, Murray Hill, NJ, from 1999 to 2001. From 1998 to 1999, he was a Postdoctoral Research Fellow in the Department of Computer Science, Purdue University, West Lafayette, IN. From 1997 to 1998, he was a Lecturer in the Department of Computer Science, Tsinghua University, and the Technical Secretary of State Super 863 High-Tech Plan Steering Committee, China. His research interest includes Internet routing, backbone router architecture, network protocol design and testing, automated network fault management, network computing, and network security. He has published over 50 refereed papers in the various journals and conferences in the above areas and holds two U.S. patents.

Dr. Hao is a member of the Association for Computing Machinery (ACM), the IEEE Computer Society and Communication Society, and the Technical Committee of Internet, China Computer Federation. He is a Guest Editor for the Special Issue on Design, Analysis, and Implementation of Communication Protocols of the IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS. He served as the Technical Program Committee Member for INFOCOM 2002, 2004 and 2005, ICDCS 2004, Applied Computing 2004, and ACM SIGCOMM 1st Asia Workshop. He was the winner of the Best Paper Award at the International Federation on Information Processing (IFIP) in 2000. He was also awarded the Third Prize of the National Science and Technology Advancement Award of China in 1997.



**David Lee** (M'87–F'97) received the M.S. and Ph.D. degrees in computer science from Columbia University, New York, in 1985.

He is the Ohio Board of Regents Distinguished Professor at The Ohio State University, Columbus. His current research interests are network protocol system security, integration, interoperability, and reliability.

Dr. Lee won the IFIP International Conference PSTV-FORTE Best Paper Award in 2000. He is a Senior Editor for the IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS and an Associate Editor for the *Journal of Complexity*. He was Program Co-Chair of the IEEE INFOCOM 2002, the IEEE ICNP 1994 and 2000, General Co-Chair of ICNP 1996, Steering Committee Co-Chair of ICNP, Steering Committee Chair of Sigcomm Asia Workshop, and a Counselor at the National Natural Science Foundation of China.



**Raymond E. Miller** (S'54–M'58–F'70–LF'94) received the Ph.D. degree from the University of Illinois, Urbana–Champaign, in 1957.

He was a Research Staff Member at IBM T. J. Watson Research Center, Yorktown Heights, NY, from 1957 to 1980. He was a Professor in the School of Information and Computer Science, Georgia Institute of Technology, Atlanta, from 1980 to 1989 and Director of the School from 1980 to 1987. He was a Professor of Computer Science, University of Maryland, College Park, from 1989 to 2002. He is currently Professor Emeritus at both the Georgia Institute of Technology and the University of Maryland. He was founding Director of the NASA Center of Excellence in Space Data and Information Sciences at Goddard Space Flight Center from 1988 to 1993. He is an Editor for the *Journal of Computer and System Sciences* and *Algorithmica International Journal*, and on the Editorial Boards of the *Journal of Trends in Networking and Communications* and the *Journal on Special Topics in Mobile Networks and Applications (MONET)*. He has written over 100 technical papers in the areas of theoretical computer science, computer organization, parallel

computation, networking, and communication protocols.

Dr. Miller is a Fellow of the American Association for the Advancement of Science (AAAS) and the Association for Computing Machinery (ACM). He has served on the Council of the ACM, the Board of Governors of the IEEE Computer Society, and the Board of the Computing Research Association. He was President of the Computing Sciences Accreditation Board from 1985 to 1987. He was a member of the Steering Committee for the IEEE/ACM TRANSACTIONS ON NETWORKING from 1992 to 2004 and is a Steering Committee Member of the IEEE International Conference on Network Protocols. He was an Editor for the *Journal of the ACM* from 1969 to 1979, serving as Editor-in-Chief from 1972 to 1976. He is the recipient of the 2002 Association for Computing Machinery (ACM) Distinguished Service Award.