Guest Editorial
Mission Critical Networking

Mission-Critical Networking (MCN) refers to networking for application domains where life or livelihood may be at risk. Typical application domains for MCN include critical infrastructure protection and operation, emergency and crisis intervention, healthcare services, and military operations. Such networking is essential for safety, security and economic vitality in our complex world characterized by uncertainty, heterogeneity, emergent behaviors, and the need for reliable and timely response. MCN should comprise networking technology, infrastructures and services that may alleviate the risk and directly enable and enhance connectivity for mission-critical information exchange among diverse, widely dispersed, mobile users.

A primary challenge to MCN is to deploy and dynamically configure and evolve communication networks that are trustworthy, resilient, autonomic, secure, adaptive, and rapidly deployable to support critical missions and their priorities. In order to operate effectively, the deployed networks should support services such as location determination of both authorized and unauthorized entities, Quality-of-Service (QoS) aware audio and video communication, emergency calling and alerting, and in-situ and remote sensing and control in a secure and effective manner. In addition, efficient operation of such networks that typically include numerous and heterogeneous resource-constrained components may benefit from cross-layer optimization, cognition, resource engineering, on-demand federation, and service-oriented architecture. Also important is the integration of MCN with the Internet to reduce cost of deployment and maintenance and to enhance reachability and ubiquity.

The Call for Papers attracted seventy submissions worldwide. After a rigorous review process, eleven papers have been selected for publication. The eleven accepted papers are divided into three categories. The first category includes three papers addressing quality of service issues in MCN. The second category is comprised of four papers addressing a variety of critical issues in securing MCN. Finally, the third category has four papers discussing configuration and data collection issues in MCN. An outline of the papers in each of these categories follows.

Category I: Quality-of-Service Issues: T.H. Szymanski and D. Gilbert in [1] address the interesting and challenging problem of provisioning mission-critical telerobotic control services over Internet backbone networks. Three critical requirements of these services include: (i) essentially 100% restoration capability; (ii) small and bounded end-to-end queuing delays; and (iii) very low-jitter communications. The authors present algorithms to provision mission-critical services over the Internet with essentially 100% restoration capability and essentially-perfect QoS. Mission-critical traffic is routed using the theory of shared backup protection paths or p-cycles, while background traffic is routed using multiple edge-disjoint paths. Mission-critical traffic is scheduled using the theory of recursive stochastic matrix decomposition to achieve two constraints: (i) near-minimal end-to-end queuing delay and jitter; and (ii) essentially-perfect QoS. To demonstrate the effectiveness of the proposed algorithms, extensive simulations of a saturated Internet backbone network supporting telerobotic services along with competing background traffic are reported.

In the second paper, Jiazhen Zhou and Cory Beard [2], contend that the admission control strategies currently employed by the Wireless Priority Service (WPS) of the public communication networks in support of emergency communications are not able to address dynamic traffic demands for different scenarios and locations. Existing WPS assume a standard profile for emergency and public demand at all locations. In contrast, the authors present an analytical modeling framework that creates flexible, adaptive algorithms for operators to easily use based on the specifics of each emergency scenario leading to significant improvements over existing solutions.

The third and final paper of this group by Tommaso Melodia and Ian F. Akyildiz deals with cross-layer QoS-aware communication for ultra wide band Wireless Multimedia Sensor Networks (WMSNs), Such networks comprise a crucial component of mission-critical networks to protect the operation of strategic national infrastructure, provide support to counteract emergencies and threats, and enhance infrastructure for tactical military operations. The authors propose a new cross-layer communication architecture based on the time hopping impulse radio ultra wide band technology with the objective to reliably and flexibly deliver QoS to heterogeneous applications in WMSNs, by leveraging and controlling interactions among different layers of the protocol stack according to applications requirements.

Category II: Security Issues: Unoma N. Okorafor and Deepa Kundur in [4] address security in routing and localization in directional wireless optical sensor networks. Such networks have the potential to provide gigabits per second speeds for relatively low power consumption enabling bursty traffic and longer network lifetime. Untethered sensor nodes communicate directionally via free space optical communications for mission critical settings in which high speed link guarantees in hostile environments are needed. The paper proposes a light-

Digital Object Identifier 10.1109/JSAC.2010.100601

weight security-aware integrated routing and localization approach that exploits the benefits of link directionality inherent to wireless optical sensor networks. The circuit-based algorithm, called SIRLoS, leverages the resources of the base station and a hierarchical network structure to identify topological information and detect security violations in neighborhood discovery and routing mechanisms.

In the second paper, Yingpei Zeng, Jiannong Cao, Shigeng Zhang, Shanqing Guo and Li Xie [5] address clone attacks on wireless sensor networks., where the adversary may compromise a few nodes, replicate them, insert arbitrary number of replicas into the network and then carry out many insider attacks. In this paper, the authors show that in order to avoid drawbacks in existing solutions, the replica-detection protocols must be non-deterministic and fully distributed (NDFD), and fulfill specific security requirements on witness selection. The authors show that Randomized Multicast, is NDFD and fulfills the security requirements, but has very high communication overhead. The authors then proposed two new NDFD protocols, RAndom WaLk (RAWL) and Table-Assisted RAndom WaLk (TRAWL), which fulfill the requirements while having only moderate communication and memory overheads.

In the third paper, MinJi Kim, Luísa Lima, Fang Zhao, João Barros, Muriel Médard, Ralf Koetter, Ton Kalker, and Keesook J. Han [6] address the susceptibility of random linear network coding used in peer-to-peer networks to Byzantine attacks. They show that even for a small probability of attack, the system fails with overwhelming probability. The authors then propose a novel bandwidth efficient signature scheme that allows packet-level Byzantine detection. This scheme allows one-hop containment of the contamination, and saves bandwidth by allowing nodes to detect and drop the contaminated packets.

In the forth and final paper of this group, Christina Pöpper, Mario Strasser, and Srdjan Čapkun [7], address the problem of jamming attacks on mission-critical messages that may be broadcast to a large and unknown number of receivers. It is important to maintain the integrity, authenticity, and ability to communicate such messages in the presence of jamming. Common techniques to counter jamming-based denial-of-service attacks such as Frequency Hopping (FH) and Direct Sequence Spread Spectrum (DSSS) cannot be applied in such settings because they depend on secret pairwise or group keys shared between the sender and receivers before the communication. The authors propose uncoordinated spread spectrum techniques that enable anti-jamming broadcast communication without shared secrets. Uncoordinated spread spectrum techniques can handle an unlimited amount of (malicious) receivers. Finally, the authors discuss the applications of these techniques to anti-jamming navigation broadcast, bootstrapping of coordinated spread spectrum communication, and anti-jamming emergency alerts.

Category III: Configuration and Data Collection Issues: The first paper by I. Kulkarni and D. Pompili [8] studies the problem of task allocation for autonomous underwater vehicles for MCN. In their model, there are two different types of autonomous underwater vehicles (AUVs): gliders and propeller driven vehicles (PDV). The energy consumed by gliders is less than that of PDV but PDVs can move faster than gliders. This presents a speed-energy trdeoff. The paper presents a framework that allows forming an optimal team of vehicles based on task allocation. The framework forms an optimization problem that aims at (i) maximizing the available energy of the team of AUVs after the mission, (ii) minimizing the energy required by the team of AUVs to complete the mission, (iii) maximizing the minimum available energy of AUVs in the mission, all with a bound on the total mission time.

In the second paper, H. Shiang and M. Schaar [9] study how to optimize the transmission decisions of autonomic nodes for supporting mission-critical applications. Autonomic nodes individually sense the environment, learn the dynamic network changes based on their local information, and adapt their transmission actions in an autonomous manner to optimize the utility of the applications. The paper provides a Markov decision process (MDP) framework for optimizing nodes' cross-layer transmission actions and minimizing the delays of the mission-critical applications, while considering the spatio-temporal dependencies among their actions. Furthermore, the paper proposes an online model-based reinforcement learning approach for agents to solve the distributed MDP at runtime.

In the third paper, S. Lee, and M. Younis [10] addresses the problem of relay node deployment to join federated segments in WSNs. The deployment area is modeled as a grid with equal-sized cells and the optimization problem is mapped to selecting the fewest count of cells to populate relay nodes such that all segments are connected. The paper shows that the problem of finding the optimal number and positions of relay nodes with respect to length between segments is NP-hard and a heuristic algorithm is presented and evaluated to show the its perfroamcne in terms of connectivity and traffic balance.

The final paper of this group by A. Navarra, C. Pinotti, V. Ravelomanana, F. Sorbelli, and R. Ciotti [11] propose a new distributed training protocol for coarse-grain localization purposes in high density wireless sensor-actor network environments. The authors exploit the high density features in the context of anonymous, asynchronous and randomly distributed sensors deployed along with a few actors, which are more powerful than sensors in terms of energy and transmission capabilities. The proposed protocol auto-organizes the sensors with respect to a virtual infrastructure centered at actors and constituted of concentric rings divided into sectors. Analytical study as well as experiments on the proposed algorithm are provided. The obtained results show under which theoretical and practical settings the training process can be performed in a fast and high quality way respect to the granularity of the required localization and the energy consumption.

We conclude this editorial by thanking the numerous reviewers and the J-SAC Editorial Board for their effort and time. It is because of their diligent support and rigorous review that this issue on the timely topical area of Mission-Critical Networking has come to fruition. We hope that you enjoy reading this collection of papers at the cutting edge of MCN research.

MOHAMED ELTOWEISSY, *Guest Editor*
Pacific Northwest National Laboratory, USA

DAVID H.C. DU, *Guest Editor*
University of Minnesota, USA

MARIO GERLA, *Guest Editor*
University of California — Los Angeles, USA

SILVIA GIORDANO, *Guest Editor*
University of Applied Sciences, Switzerland

MOHAMED GOUDA, *Guest Editor*
University of Texas and National Science Foundation, USA

HENNING SCHULZRINNE, *Guest Editor*
Columbia University, USA

MOUSTAFA YOUSSEF, *Guest Editor*
Nile University and Alexandria University, Egypt

Don Towsley, *J-SAC Board Representative*

Mohamed Eltoweissy is a Chief Scientist of Cyber Security Research Pacific Northwest National Laboratory. Before joining PNNL, Eltoweissy was an associate professor in The Bradley Department of Electrical and Computer Engineering at Virginia Tech where he also held a courtesy appointment in the Department of Computer Science at Virginia Tech. His current research interests crosscuts the areas of computational trust, networking architecture and protocols, and distributed systems for large-scale ubiquitous cyber-physical systems. Eltoweissy's recent contributions include elastic shared sensor-actuator networks, concern-oriented reference model and bio-inspired architecture for trustworthy networks, dynamic key management for sensor and ad-hoc networks, and reputation management in ad hoc networks and service environments. Eltoweissy received his Ph.D. in Computer Science from Old Dominion University in 1993 and his M.S. and B.S in Computer Engineering from Alexandria University, Egypt in 1989 and 1986, respectively. Eltoweissy also holds a certificate in Leadership and Management from the University of Notre Dame. He has numerous publications in archival journals and respected books and conference proceedings. He also has an extensive funding record (over $10M). Eltoweissy serves on the editorial board of IEEE Transactions on Computers (the flagship and oldest Transactions of the IEEE Computer Society). Eltoweissy has and continues to participate in the leadership and organization of numerous conferences and workshops. He is also active as an invited speaker at both the national and international levels. Eltoweissy is a senior member of IEEE and a senior member of ACM. Eltoweissy received the nomination for the Virginia SCHEV Outstanding Faculty Awards, the highest honor for faculty in Virginia.

David H.C. Du received the B.S. degree in mathematics from National Tsing-Hua University, Taiwan, R.O.C. in 1974, and the M.S. and Ph.D. degrees in computer science from the University of Washington, Seattle, in 1980 and 1981, respectively. He is currently the Qwest Chair Professor at the Computer Science and Engineering Department, University of Minnesota, Minneapolis. His research interests include cyber security, sensor networks, multimedia computing, storage systems, high-speed networking, high-performance computing over clusters of workstations, database design and CAD for VLSI circuits. He has authored and co-authored more than 210 technical papers, including 100 referred journal publications in his research areas. He has also graduated 49 Ph.D. and 80 M.S. students. Dr. Du is an IEEE Fellow and a Fellow of Minnesota Supercomputer Institute. He is currently served on a number of journal editorial boards. He has also served as guest editors for a number of journals including IEEE Computer, IEEE and Communications of ACM. He has also served as Conference Chair and Program Committee Chair to several conferences in multimedia, database and networking areas. Most recently, he is the General Chair for IEEE Security and Privacy Symposium (Oakland, California) 2009 and Program Committee Co-Chair for International Conference on Parallel Processing 2009.

Mario Gerla is a Professor in the Computer Science at UCLA. He holds an Engineering degree from Politecnico di Milano, Italy and the Ph.D. degree from UCLA. He became IEEE Fellow in 2002. At UCLA, he was part of the team that developed the early ARPANET protocols under the guidance of Prof. Leonard Kleinrock. He joined the UCLA Faculty in 1976. At UCLA he has designed and implemented network protocols including ad hoc wireless clustering, multicast (ODMRP and CODECast) and Internet transport (TCP Westwood). He has lead the $12M, 6 year ONR MINUTEMAN project, designing the next generation scalable airborne Internet for tactical and homeland defense scenarios. He is now leading two advanced wireless network projects under ARMY and IBM funding. His team is developing a Vehicular Testbed for safe navigation, urban sensing and intelligent transport. A parallel research activity explores personal communications for cooperative, networked

medical monitoring (see www.cs.ucla.edu/NRL for recent publications).

Silvia Giordano holds a PhD. from EPFL, Switzerland. She is currently the head of the Networking Lab (NetLab) in the Institute of System for Informatics and Networking (ISIN), and direction member of ISIN, at the University of Applied Science - SUPSI in Ticino, Switzerland. She is teaching several courses in the area of: Networking, Wireless and Mobile Networking, Quality of Services and Networks Applications. She is co-editor of the book "Mobile Ad Hoc Networking" (IEEE-Wiley 2004). She has published extensively on journals, magazines and conferences in the areas of quality of services, traffic control, wireless and mobile ad hoc networks. She has participated in several European ACTS/IST projects and European Science Foundation (ESF) activities. She is series editor of the Series on Ad Hoc And Sensor Networks of the IEEE Communication Magazine. She is area editor of Computer Communications journal by Elsevier, Ad Hoc & Sensor Wireless Networks journal, Ocpscience, Journal of Ubiquitous Computing and Intelligence (JUCI) and Journal of Autonomic and Trusted Computing (JoATC) both by American Scientific Publishers (ASP), and Mediterranean Journal of Computer and Networks, SoftMotor. She was already co-editor of several special issues of IEEE Communications Magazine and Baltzer MONET and Cluster Computing on mobile ad hoc networking and QoS networking. She was general chair of WoWMoM 2009, program co-chair of IEEE PERCOM 2009, program co-chair of IEEE VTC-Fall 2008, IEEE MASS 2007, workshop chair of IEEE WOWMoM 2007, tutorial chair of MobiHoc 2006, general chair of IEEE WONS 2005, co-founder of IEEE Persens workshop, IEEE AOC workshop and ACM Mobihoc SANET workshop and is/was on the executive committee and TCP of several international conferences, and serves as reviewer on transactions and journals, as well as for several important conferences. Silvia Giordano is a senior member of IEEE Computer Society, ACM and IFIP WG 6.8. She is Awards Co-Chairs of the ACM N2Women. Silvia Giordano acts as evaluator and expert to EU Framework Program and NSF Program, as well as for other several national Programs. Her current research interests include wireless and mobile ad hoc networks, QoS and traffic control.

Mohamed Gouda holds the Mike A. Myers Centennial Professorship in Computer Sciences at the University of Texas at Austin. Currently, he is serving as program director at The national Science Foundation. His research areas are distributed and concurrent computing and network protocols. In these areas, he has been working on abstraction, formality, correctness, nondeterminism, atomicity, reliability, security, convergence, and stabilization. He has published over fifteen book chapters, over sixty journal papers, and over ninety conference and workshop papers. Gouda is the author of the textbook "Elements of Network Protocol Design", published by John-Wiley & Sons in 1998. This is the first ever textbook where network protocols are presented in an abstract and formal setting. He coauthored, with Tommy M. McGuire, the monograph "The Austin Protocol Compiler", published by Springer in 2005. He also coauthored, with Chin-Tser Huang, the monograph "Hop Integrity in the Internet", published by Springer in 2006. He is the 1993 winner of the Kuwait Award in Basic Sciences. He is also the recipient of an IBM Faculty Partnership Award for the academic year 2000 - 2001 and again for the academic year 2001 - 2002 and became a Fellow of the IBM Center for Advanced Studies in Austin in 2002. He won the 2001 IEEE Communication Society William R. Bennet Best Paper Award for his paper "Secure Group Communications Using Key Graphs", coauthored with C. K. Wong and S. S. Lam and published in the February 2000 issue of the IEEE/ACM Transactions on Networking (Volume 8, Number 1, Pages 16-30). In 2004, his paper "Diverse Firewall Design", coauthored with Alex X. Liu and published in the proceedings of the International Conference on Dependable Systems and Networks, won the William C. Carter Award.

Henning Schulzrinne received his undergraduate degree in economics and electrical engineering from the Technische Hochschule in Darmstadt, Germany, in 1984, his MSEE degree as a Fulbright scholar from the University of Cincinnati, Ohio and his Ph.D. degree from the University of Massachusetts in Amherst, Massachusetts in 1987 and 1992, respectively. From 1992 to 1994, he was a member of technical staff at AT&T Bell Laboratories, Murray Hill. From 1994-1996, he was associate department head at GMD-Fokus (Berlin), before joining the Computer Science and Electrical Engineering departments at Columbia University, New York. His research interests encompass real-time, multimedia network services in the Internet and modeling and performance evaluation. He is an editor of the Journal of Communications and Networks, the IEEE Transactions on Image Processing and IEEE Communications Society editor of the IEEE Internet Computing Magazine. He co-chairs the IEEE Communications Society Internet Technical Committee and is chair of the IEEE Communications Society Technical Committee on Computer Communications. He is also technical co-chair of Infocom 2000. He is currently serving as a member of the IAB (Internet Architecture Board). Protocols co-developed by him are now Internet standards, used by almost all Internet telephony and multimedia applications.

Moustafa Youssef received the B.S. and M.Sc. degrees in Computer Engineering from Alexandria University, Egypt, in 1997 and 1999, respectively, and the Ph.D. degree in Computer Science from the University of Maryland at College Park, USA, in 2004. From 2004 to 2007 he was a Research Associate in the University of Maryland Institute for Advanced Computer Studies, the University of Maryland. Since 2007, he has a joint appointment with Alexandria University, Egypt and Nile University, Egypt, where he is now an Assistant Professor. He is a recipient of the of the 2003 University of Maryland Invention of the Year award for his Horus location determination technology and the 1999 Taha Hussien Medal of Honor from Egyptian Ministry of Education. He is also an elected member for the honor society Phi Kappa Phi and a life member for the Egyptian Society for Talented. He served as a co-chair for the Second IEEE International Workshop on Intelligent Pervasive Devices (PerDev09), co-located with Percom 2009, program co-chair for The IEEE International Workshop on Mission Critical Networks (MCN 2008), co-located with Infocom 2008, program co-chair for The First IEEE International Workshop on Power-Aware Pervasive Devices (PerDev2008), co-located with Percom 2008, and program co- chair for the IEEE First International Workshop on Research Challenges in Next Generation Networks for First Responders and Critical Infrastructures (NetCri 2007). Dr. Youssef's research interests are in mobile wireless networks, location determination systems, and pervasive computing.