Guest Editorial
Bio-Inspired Networking

Technology is taking us to a world where myriads of heavily networked devices interact with the physical world in multiple ways, and at multiple scales, from the global Internet scale down to micro- and nano-devices. Many of these devices are highly mobile and autonomous, and must adapt to the surrounding environment in a totally distributed and unsupervised way. fundamental research challenge is the design of robust decentralized computing systems, which are capable of operating under changing environments, and yet exhibit the desired behavior and response time, under unpredictable operating constraints, such as traffic demand, energy consumption, size, and processing power. These systems should be able to adapt and learn how to react to unforeseen scenarios, as well as to display desired emergent properties.

Biological systems are able to handle such challenges with an efficiency far beyond current human artifacts. Based on this observation, recently a number of approaches inspired by biological mechanisms and phenomena have been proposed as a strategy to handle the complexity of massively distributed systems such as the Internet, or wireless ad hoc and sensor networks. The goal of such bio-inspired approaches is to discover and to enhance methods for engineering technical solutions presenting a similar high stability and efficiency as biological entities often have.

In the last few years, especially the networking and communication areas benefited from bio-inspired research solutions. As the existing research shows, bio-inspired approaches are a fruitful direction in networking and communications. This JSAC special issue highlights the latest achievements in this new research domain, emphasizing different approaches as learned from the biological world and applied to the development of human artifacts. In particular, this special issue focuses on methodologies used to identify relevant biological mechanisms, the modeling of these mechanisms, and their application to artificial technical solutions.

In the context of this JSAC special issue, we considered all techniques with direct biological background including animal learning strategies, self-organizing methods as observed from swarms down to nano-structures observed and analyzed in molecular biology. In response to our call for papers, we received papers studying a wide variety of problems in networking based on biologically-inspired solutions. In particular, the following areas have been investigated: epidemics, ant colony optimization and swarm intelligence, pulse coupled oscillators, population dynamics, and nano-communication.

In the paper "Modeling Broadcasting Using Omnidirectional and Directional Antenna in Delay Tolerant Networks as an Epidemic Dynamic," the authors study broadcasting of information in a system of moving agents equipped with omnidirectional as well as directional antennas. The agent communication protocol is inspired by the epidemics dynamics.

Ant colony optimization is used in the paper "Routing and Wavelength Assignment with Crankback Re-Routing Extensions by Means of Ant Colony Optimization." In particular, it is shown that crankback re-routing extensions can offer significant improvements in the successful setup of Label Switched Paths (LSPs) by allowing new retries on alternate paths that circumvent blocked links or nodes. Exploiting concepts of ant colony optimization, these extensions can be incorporated into a fully-distributed algorithm.

Again focusing on optical networks, the paper "An Ant-Based Algorithm for Distributed Routing and Wavelength Assignment in Dynamic Optical Networks" proposes the use of an ant colony optimization algorithm to solve the intrinsic problem of routing and wavelength assignment on wavelength continuity constraint optical networks. The main advantage of the protocol is its distributed nature, which provides higher survivability to network failures or traffic congestion.

In the paper "Phero-Trail: A Bio-Inspired Location Service for Mobile Underwater Sensor Networks," the authors propose a bio-inspired location service called a Phero-Trail location service protocol for application in a SEA Swarm (Sensor Equipped Aquatic Swarm). A SEA Swarm is a collection of mobile underwater sensors that moves as a group with water current and enables monitoring of local underwater events such as contaminants and intruders. In Phero-Trail, location information is stored in a SEA Swarm, and a mobile sink uses its trajectory like a pheromone trail of ants.

The concept of pulse coupled oscillators has been used in the paper "Bio-Inspired Algorithms for Decentralized Round-Robin and Proportional Fair Scheduling." The authors consider the development of decentralized scheduling in a small network of self-organizing devices that are modeled as pulse-coupled oscillators. By appropriately designing the dynamics of the oscillators, the network of devices can converge to a desynchronous state where the nodes naturally separate their transmissions in time.

Population dynamics have been studied in "A Population Based Approach to Model the Lifetime and Energy Distribution in Battery Constrained Wireless Sensor Networks." The authors present a general framework to model the availability of power at sensor nodes as a function of time, based on models for population dynamics in biological studies.

In the paper "Dynamic Conjectures in Random Access Networks Using Bio-Inspired Learning," the authors consider a distributed learning approach that enables autonomous nodes to independently optimize their transmission probabilities in random access networks.

Finally, the field of nano-communication has been studied. In the paper "A Physical Channel End-to-End Model for

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Molecular Communication in Nanonetworks," molecular communication is addressed as one of the most promising paradigms for nanonetworks. The objective of this paper is the development of a physical channel model for molecular communication. The nanonetwork physical channel model is studied as the composition of three subsequent modules, namely, the transmitter, the signal propagation and the receiver.

In the paper "A New NanoNetwork Architecture using Flagellated Bacteria and Catalytic Nanomotors," molecular communication is investigated, where the information is encoded as molecules that are transported between nano-scale devices within different distances. Two new communication techniques, flagellated bacteria and catalytic nanomotors, are proposed to cover medium range communication. Both techniques are based on the transport of DNA encoded information between emitters and receivers by means of a physical carrier.

We are content that the selected papers highlight some of the best and most innovative ideas in the upcoming field of bio-inspired networking. They can be seen as excellent starting points for future research in this emerging area in networking.

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Dr. Dressler is an Editor for journals such as Elsevier Ad Hoc Networks and ACM/Springer Wireless Networks (WINET). He was guest editor of special issues on self-organization, autonomic networking, and bio-inspired computing and communication for IEEE Journal on Selected Areas in Communications (JSAC), Elsevier Ad Hoc Networks, and Springer Transactions on Computational Systems Biology (TCSB). Dr. Dressler was general chair of the 2nd IEEE/ACM International Conference on Bio-Inspired Models of Network, Information, and Computing Systems (BIONETICS 2007). Besides chairing a number of workshops associated to high-level conferences, he regularly acts in the TPC of leading networking conferences such as IEEE INFOCOM, IEEE ICC, IEEE Globecom, IEEE MASS, IFIP Networking and others. Dr. Dressler published two books including Self-Organization in Sensor and Actor Networks, published by Wiley in 2007.

Dr. Dressler is a Senior Member of the IEEE (Communications Society, Computer Society, Vehicular Technology Society) as well as a Senior Member of ACM (SIGMOBILE), and member of GI (KuVS, Real-time). He is actively participating in several working groups of the IETF. His research activities are focused on self-organizing networks addressing issues in wireless ad hoc and sensor networks, inter-vehicular communication systems, bio-inspired networking, and adaptive network security techniques.

Tatsuya Suda received the B.E., M.E., and Dr.E. degrees in applied mathematics and physics from Kyoto University, Kyoto, Japan, in 1977, 1979, and 1982, respectively.

From 1982 to 1984, he was with the Department of Computer Science, Columbia University, New York, as a Postdoctoral Research Associate. Since 1984, he has been with the Department of Computer Science, Information and Computer Science, University of California, Irvine, where he is currently a Professor. He has also served as a program director of the Networking Research Program at the National Science Foundation from Oct. '96 through Jan., '99. He received an IBM postdoctoral fellowship in 1983. He was the Conference Coordinator from 1989 to 1991, the Secretary and Treasurer from 1991 to 1993, the Vice Chairman from 1993 to 1995, and the Chairman from 1995 to 1997 of the IEEE Technical Committee on Computer Communications. He was also the director of the U.S. Society Relations of the IEEE Communications Society from 1997 to 1999. He is an editor of the IEEE/ACM Transaction on Networking, a senior technical consultant to the IEEE Transaction on Communications, a former Editor of the IEEE Transaction on Communications and is an Area Editor of the International Journal of Computer and Software Engineering. He is a member of the Editorial Board of the Encyclopedia of Electrical and Electronics Engineering, Wiley and Sons. He was the Chair of the 8th IEEE Workshop on Computer Communications and the TPC co-chair of the

IEEE Infocom 97. He was a visiting associate professor at the University of California, San Diego, a Hitachi Professor at the Osaka University, a NTT Research Professor, and currently is a NTT Docomo Research Professor.

Dr. Suda has been engaged in research in the fields of computer communications and networks, high speed networks, multimedia systems, ubiquitous networks, distributed systems, object oriented communication systems, network applications, performance modeling and evaluation, and application of biological concepts to networks and network applications. Dr. Suda's recent research includes molecular communication, a new paradigm for nano scale communication among biological nanomachines.

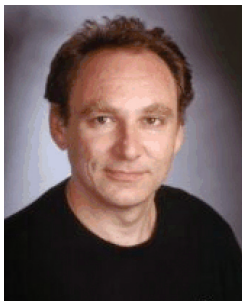
Dr. Suda is a Fellow of IEEE and a member of ACM.

Iacopo Carreras is a senior researcher, leading the technical group on Mobile Computing at the Pervasive and Secure Computing Environments, CREATE-NET research center.

Dr. Carreras received his M.Sc degree (summa cum laude) in Telecommunications Engineering from the University of Pisa, Italy, in 2001. He received his Ph.D. degree in Computer Science from the Department of Information Engineering of the University of Pisa, Italy. From 2000 to 2001, he worked at Telecommunications Networks Group, Berlin University of Technology. From 2001 to 2003 he worked as software engineer at Netikos (Telecom Italia Group). Since 2003 he is with the Pervasive and Secure Computing Environments at CREATE-NET research center, Italy.

He co-authored several peer reviewed research papers in international conferences and journals. Dr. Carreras was Technical Program co-chair of the 4th International Conference on Bio-Inspired Models of Network, Information, and Computing Systems (BIONETICS 2009). He served as chair and PC member for the MSAN and BIONETICS conferences, and as a peer reviewer for various international conferences and journals. He is participating to several international European research projects. He is a member of IEEE, IEEE Computer Society, and IEEE Computational Intelligence Society. His research interests span the areas of pervasive and mobile computing, wireless communications, autonomic networking with a specific focus in the areas of performance evaluation, biologically-inspired paradigms, large-scale networks and complex systems.

Masayuki Murata received the M.E. and D.E. degrees in Information and Computer Sciences from Osaka University, Japan, in 1984 and 1988, respectively. In April 1984, he joined IBM Japan's Tokyo Research Laboratory, as a Researcher. From September 1987 to January 1989, he was an Assistant Professor with the Computation Center, Osaka University. In February 1989, he moved to the Department of Information and Computer Sciences, Faculty of Engineering Science, Osaka University. In April 1999, he became a Professor of Osaka University, and since April 2004, he has been with the Graduate School of Information Science and Technology, Osaka University. He has contributed more than four hundred and fifty papers to international and domestic journals and conferences. His research interests include computer communication networks and performance modeling and evaluation. He is an IEICE Fellow. He is a member of IEEE, ACM, and IEICE.



Jon Crowcroft is the Marconi Professor of Networked Systems in the Computer Laboratory at the University of Cambridge. Prior to this, he was professor of networked systems at UCL in the Computer Science Department. He is a Fellow of the ACM, a Fellow of the British Computer Society, a Fellow of the IEE and a Fellow of the Royal Academy of Engineering, as well as a Fellow of the IEEE. He was a member of the IAB; was general chair for the ACM SIGCOMM 95-99. He is on the editorial team for the Internet Protocol Journal and ACM CCR, and has regularly been a program committee member for MobiHoc, ACM SIGCOMM and IEEE INFOCOMM. He has published 5 books - the latest is the Linux TCP/IP Implementation, published by Wiley in 2001 as well as numerous papers.

Prof. Crowcroft has 3 main projects at the present. The EPSRC Wines II Programme funded TINA, which is a large research project to design an integrated communications system for future intelligent airports. The EU Haggle project is a radical research programme of work into delay tolerant networking (DTNs) for smart mobile phones and related devices, to allow applications and systems to be built easily that tolerate frequent disconnection, and to use social networking concepts to optimise the dissemination of information (news, context, social relationships) amongst such devices. Prof Crowcroft also leads the Cambridge part of the ITA, which is a very large joint US-UK programme of work in fundamentals of next generation wireless networks. This latter work currently entails research into inter-domain mobile ad hoc networks, robust optimisation of coding, transmission and routing, and into network coding. Prof. Crowcroft is one of the team that put together the UK research challenge in Ubiquitous Computing. Most recently he has been a CNRS visiting scholar at the University of Paris VI, working on the Wireless Internet for Paris project, as well as visiting with Thomson research, where he has been contributing to modelling the theoretical scaling properties of file swarming and of DTNs. Crowcroft is on the advisory board for Microsoft Research, Cambridge, and just finished 2 years as a member of DoCoMo Lab's research advisory board.