

# Evolutionary Approaches to Gain Self-star Properties in Wireless Sensor Networks

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## ABSTRACT

Sensor technologies have significantly advanced in the past two decades, and they have been increasingly adopted in many important applications such as environmental observation, homeland security, structural health monitoring, home/office/factory automation and inventory tracking. As the unit cost of individual sensors decreases, emerging applications tend to *network* a larger number of sensors to cover larger observation areas and monitor them in higher spatial and temporal resolutions. In these applications, each network consists of sensor nodes, each of which is a low-cost computing device with sensing and communications capabilities. Each node links up with its neighboring nodes via wireless radio from the moment it is deployed and turned on. Although nodes have limited power and processing/communications capabilities, an assembly of hundreds of them can spontaneously organize into a perceptive network that is spread throughout an observation area and collaboratively perform tasks that no individual nodes could. Due to their great potential impacts on a variety of domains, *MIT Technology Review* magazine selected wireless sensor networks (WSNs) as one of ten technologies that can change the world (2003).

One of key research issues in designing and operating WSNs is to gain such self-\* properties as:

- *Self-configuration*: allows WSN applications to configure their own operational parameters (e.g., routing decision parameters and sleep period) and self-organize into desirable structures and patterns (e.g., routing structures and duty cycling patterns).
- *Self-optimization*: allows WSN applications to constantly seek improvement in their performance by adapting to network dynamics with minimal human intervention.
- *Self-healing*: allows WSN applications to autonomously detect and recover from disruptions in the network (e.g., node and link failures).

These self-\* properties are important in WSNs because they are often required to operate in unattended areas (e.g., forest and ocean), physically unreachable areas (e.g., inside a building wall) or potentially harsh/hostile areas (e.g., nuclear power plants).

This presentation describes a biologically-inspired sensor networking framework, called BiSNET, which leverages two evolutionary approaches to gain and augment self-\* properties in WSNs: (1) evolutionary multiobjective optimization and (2) accelerated evolution.

BiSNET consists of two types of software components: *agents* and *middleware platforms*, which are modeled after bees and flowers, respectively. Each application is designed as a decentralized group of agents. This is analogous to a bee colony (application) consisting of bees (agents). Agents collect sensor data on platforms (flowers) on nodes and carry the data to base stations on a hop-by-hop basis. Agents perform this data collection functionality by autonomously sensing their local and surrounding network conditions (e.g., network traffic and node/link failures) and adaptively

invoking biological behaviors such as pheromone emission, swarming, reproduction, migration and death. A middleware platform runs on each node and hosts one or more agents. It provides a series of runtime services that agents use to perform their behaviors as well as their data collection functionalities.

BiSNET implements an evolutionary multiobjective optimization algorithm for agents. Each agent possesses operational parameters, as *genes*, which govern its behavior invocation and configure its underlying nodes. BiSNET allows agents to evolve their genes (i.e., operational parameters) via genetic operations (e.g., crossover, mutation and selection) and adapt them to dynamic network conditions by seeking the optimal tradeoffs among conflicting performance objectives. This evolution process frees application designers from anticipating all possible network conditions and tuning their agents' operational parameters to the conditions at design time. Instead, agents evolve and autonomously adapt their parameters at runtime. This can significantly simplify the design and implementation of WSN applications.

BiSNET also implements the notion of *accelerated evolution* in addition to a regular evolutionary process described above. In the regular evolution, agents use their operational parameters for their data collection in the network and then adjust their parameters based on their performance results. With accelerated evolution, agents can adjust their parameters by learning dynamic network conditions and approximating their performance under the conditions without actually using the parameters in the network. This way, accelerated evolution allows agents to expedite their evolution and efficiently adapt to network dynamics and disruptions.

This presentation will overview the design of BiSNET and demonstrate a series of simulation results. Simulation results show that BiSNET allows agents to exhibit self-configuration, self-optimization and self-healing properties in dynamic WSNs by evolving and adapting their operational parameters with respect to conflicting performance objectives. Accelerated evolution allows agents to augment their self-configuration, self-optimization and self-healing abilities by gaining significant improvement in performance convergence.

## BIO

Junichi Suzuki is an associate professor of Computer Science and a member of the Research Center for Coastal Environmental Sensing Networks at the University of Massachusetts, Boston (UMass Boston). He received a Ph.D. in Computer Science from Keio University, Japan, in 2001. He was a postdoctoral research fellow at the University of California, Irvine (UCI) from 2001 to 2004. Before joining UCI, he was with Object Management Group Japan, Inc., as Technical Director. His research interests include biologically-inspired computing/networking, autonomous adaptive distributed systems and model-driven software/performance engineering. In these areas, he has authored two books, edited seven books, published one industrial standard specification and 100+ papers in international journals and conferences. He received eight best paper awards and two best poster awards at major conferences such as IEEE SPECTS 2008, IEEE SCC 2007 and IEEE CCNC 2007. He was the recipient of an UMass Boston CSM Outstanding Achievement Award for Research in 2008. He serves on the editorial boards for five international journals including Elsevier Nano Communication Networks Journal. He has guest-edited five special issues for international journals such as ACM TAAS, Elsevier NanoComNet and Springer JAIHC. He has chaired or co-chaired seven international conferences such as ICSOC 2009 and BIONETICS 2010. He has delivered keynote speeches at ACC 2011 and ICRATEMS 2011. He has served on the program committees of 100+ conferences such as IEEE CEC, ACM GECCO, IEEE SECON, IEEE AINA, ACM/IEEE BIOSIGNALS and IEEE ICCCN.