Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 20 (2013) 406 – 413

Procedia Computer Science

Complex Adaptive Systems, Publication 3
Cihan H. Dagli, Editor in Chief
Conference Organized by Missouri University of Science and Technology
2013- Baltimore, MD

AI-WSN: Adaptive and Intelligent Wireless Sensor Network

Gursel Serpen*, Jiakai Li, and Linqian Liu

Electrical Engineering and Computer Science, University of Toledo, Toledo, Ohio, USA

Abstract

This paper proposes employment of artificial neural network techniques to develop in-network "intelligent computation" and "adaptation" capability for wireless sensor networks to improve their functionality, utility and survival aspects. The goal is to introduce computational intelligence capability for the wireless sensor networks to become adaptive to changes within a variety of operational contexts and to exhibit intelligent behaviour. The characteristics of wireless sensor networks bring many challenges, such as the ultra large number of sensor nodes, dense deployment, changing topology structure, and the most importantly, the limited resources including power, computation, storage, and communication capability. All these require the applications and protocols running on wireless sensor network to be not only energy-efficient, scalable and robust, but also "adapt" to changing environment or context, and application scope and focus among others, and demonstrate intelligent behaviour. Feasibility of the proposed approach is demonstrated through a simulation-based case study which entailed a clustering of Iris data using Kohonen's self-organizing map neural network which was embedded across a wireless sensor network.

Selection and peer-review under responsibility of Missouri University of Science and Technology

Keywords: wireless sensor network; artificial neural network; adaptation, artificial intelligence; distributed system; parallel computation

1. Introduction

Wireless sensor networks (WSN) are an emerging technology due to recent advancements in very small-scale manufacturability and high-scale integration of various electronic components in a single packaging. A typical sensor node (or mote) is a standalone package of electronics necessary to hold a number of sensors, an embedded microcontroller, a power unit that has limited capacity, which may or may not be renewable, and a radio trans-receiver at its core. Typical size of a sensor node is anywhere from a matchbox to a coin, but is expected to shrink dramatically in the next decade with the exciting promise of nanotechnology manufacturing and fabrication.

Current and projected application of wireless sensor networks encompasses a wide variety of domains, which have been traditionally challenging to access due to many reasons including potential harm to humans, being at

* Corresponding author. Tel.: 1-419-530-8158; fax: 1-419-530-8146.
E-mail address: gserpen@eng.utoledo.edu.

1877-0509 © 2013 The Authors. Published by Elsevier B.V. Open access under CC BY-NC-ND license.
Selection and peer-review under responsibility of Missouri University of Science and Technology
doi:10.1016/j.procs.2013.09.294

remote sites or being distributed over very large areas, and being subject to harsh geo or meteorological circumstances among others. Monitoring environment (pollution in a lake or river), forest fires, volcanoes, battlefield troop movements, human body, monitoring structural health of high-rise buildings or bridges, smart home automation, and the last but not the least, smart renewable energy grid monitoring and control are among the countless potential applications.

Given the nature of applications for wireless sensor networks, typical deployment scenario in many cases entails scattered random placement of hundreds or thousands of such nodes in a given geographic area through either dropping aerially from a flying craft or spreading from a moving land vehicle. Resultantly, the set of sensor nodes form an ad hoc wireless computer network. Often such nodes and the network are expected to operate for a period of at least one to two years using the on-board power source depending on the nature of the application without any outside maintenance or repair access since such access may simply be not feasible or practical.

Wireless sensor networks are conceived to be deployed and expected to operate autonomously for a number of years particularly in non-hospitable environments without human involvement. Various factors including geography, climate, and human-induced intentional or non-intentional interference in the electromagnetic spectrum will adversely affect the deployed network, and hence requiring a good level of adaptability to changing circumstances. A wireless sensor network is a dynamic system in the sense that it goes through changes over time, which have important consequences on the operation and requirements of the network. Some of these changes may include revisions to mission or functionality at different scales; changes in static or dynamic node composition; energy consumption profile of nodes and the network over time; destruction or death of certain nodes; and transient effects that may temporarily hinder a node, a cluster of nodes, or a sub-network to function within its normal operating framework.

There are a set of inter-related optimization processes, i.e. minimum energy, data loss, reliability, robustness, etc., in place during the design and operation of wireless sensor networks. In the typical design and development for wireless sensor networks, a specific set of protocols for medium access, localization and positioning, time synchronization, topology control, security and routing are identified based on the current configuration of the network, the requirements of the application and the topology of their deployment. However, poor performance or unexpected behavior may be experienced for all kinds of reasons following deployment, such as sudden death of sensor nodes, unsatisfactory implementation of application logic, topology changes and mutated network conditions. For instance, it is conceivable that adaptive protocol selection or switching schemes may be developed, which might respond more optimally to changes that affect the wireless sensor network over time. This leads to the necessity of changing the software behavior at both the protocol and application layers after the network has been deployed.

The goal of the project reported in this paper is to introduce ability for "adaptation" and facilities for "computational intelligence" to the wireless sensor networks for significantly-enhanced autonomous behaviour and operation. The expectation from an adaptive and intelligent WSN is that it can readily take into consideration the changes dictated by the dynamic nature of operational and application aspects, and accordingly adapt to changing conditions, circumstances, mission, and operational demands following the deployment. The desirable adaptation capability can be introduced through embedding an artificial neural network, which can be instantiated to any specialized form such as feedforward, self-organizing or recurrent, in fully parallel and distributed mode within the wireless sensor network.

2. Proposed Design

We are proposing embedding artificial neural networks into wireless sensor networks in parallel and distributed computation mode. Wireless sensor networks (WSN) are topologically similar to artificial neural networks. A WSN is constituted from hundreds or thousands of sensor nodes or motes each of which typically has substantial computational power (through the onboard microcontroller). An artificial neural network (ANN) is composed of hundreds or thousands of (computational) nodes or neurons, each of which is assumed to possess or require only very limited computational processing capability. This topological similarity can be the basis to benefit the adaptation and operational aspects of WSNs through leveraging the existing neural network theory in its entirety for all practical purposes. Since a wireless sensor network with thousands of motes or nodes is a distributed system with parallel computing ability, a fusion with another parallel and distributed system, the artificial neural network, is a natural consequence. In fact there is one-to-one correspondence, in that, a sensor mote can act like or implement a neural network neuron or node, while wireless links among the motes are analogous to the weighted connections among neurons. Fusing WSNs with ANNs sets the stage for WSNs suddenly to possess considerably substantial