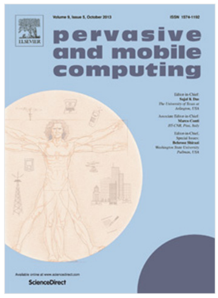

An evolutionary cluster-game approach for Wireless Sensor Networks in non-collaborative settings

Ketema Adere Gemeda, Gabriele Gianini, Mulugeta Libsie

PII: S1574-1192(17)30030-5
DOI: https://doi.org/10.1016/j.pmcj.2017.10.008
Reference: PMCJ 902

To appear in: *Pervasive and Mobile Computing*

Received date : 5 May 2017
Revised date : 30 September 2017
Accepted date : 13 October 2017

Please cite this article as: K.A. Gemeda, G. Gianini, M. Libsie, An evolutionary cluster-game approach for Wireless Sensor Networks in non-collaborative settings, *Pervasive and Mobile Computing* (2017), https://doi.org/10.1016/j.pmcj.2017.10.008

An Evolutionary Cluster-Game Approach for Wireless Sensor Networks in Non-collaborative Settings

Ketema Adere Gemeda[a], Gabriele Gianini[b,*], Mulugeta Libsie[a]

[a]*Computer Science Department, Addis Ababa University, Ethiopia*
[b]*Computer Science Department, Universita degli Studi di Milano,Italy*

Abstract

Wireless Sensor Networks typically consist of a large number of sensor nodes with constrained resources. Cluster-based routing algorithms for WSNs try to preserve battery power by grouping nodes into multiple clusters: a single node in each cluster, the Cluster Head (CH), communicates with a Base Station on behalf of the others. In an ideal collaborative setting, sensor nodes should alternate in the role of CH. However, the cooperation of nodes is not granted in WSNs with more than one governing authority, where sensor nodes can behave selfishly, in order to save their own resources. In this paper, we propose a novel evolutionary cluster-head determination algorithm called GREET, based on an Evolutionary Game Theory (EGT) approach. In the proposed algorithm, individual nodes adapt their strategies on the basis of the outcomes of the interactions with other nodes and converge to an Evolutionary Stable Strategy (ESS) equilibrium. We show that this ESS corresponds to one of the desired behavioral outcomes. This outcome is obtained without the support of external cooperation enforcement mechanisms. In the study, we use an analytic model of the population evolution, based on the so-called *replicator dynamics*, as a guide in the choice of the mechanisms, then we adapt the approach to realistic more scenarios. We show, by means of a systematic simulation study, that the algorithm extends the network lifetime and provides a better packet throughput, w.r.t other standard WSN algorithms, such as LEACH and CROSS.

Keywords: Wireless Sensor Networks, Cluster-based Routing, Evolutionary Game Theory, Snow Drift Game

1. Introduction

Wireless Sensor Networks (WSNs) can consist of hundreds of sensor nodes distributed over a geographical area. Sensor nodes are capable of observing physical phenomena, of processing data, and sometimes of taking appropriate actions [1, 2, 3]. WSNs are typically used for tracking and monitoring. Monitoring applications include environmental monitoring, health monitoring, inventory location monitoring and structural monitoring. These applications are often made possible by the fact that a WSN has a short system setup time and sensor nodes can be deployed with acceptable cost. The versatility of WSNs and their broad range of applications are increasingly attracting the interest by the industry and by the research community.

Sensor nodes are low-power devices equipped with one or more units devoted to sensing and processing, a memory unit, a power supply unit and a communication unit. They can be either stationary or mobile [4]. The hardware of a sensor node may also have additional application-dependent components such as a location finding system, a power generator or a mobilizer.

Sensor nodes collect and route information about the observed physical phenomena – possibly through multiple hops – to a central node, called *sink* or *base station* (BS), for further processing and decision-making. The BS has a dedicated power supply and a higher processing capability and can be connected to other networks, like the Internet. The WSN deployment can be either structured or unstructured [2]. In an *unstructured* WSN, nodes are deployed in an ad-hoc manner (for instance dropped from a plane or randomly placed in a field) and then left unattended to perform its monitoring and reporting functions. In a *structured* WSN, all or some of the nodes are deployed in a pre-planned manner, which results in lower network management and maintenance cost. The latter modality has a higher initial cost and it is not always feasible.
In general, WSNs are characterized by the following features [2]: (1) sensor nodes are highly constrained in power, computation, and storage capabilities; (2) sensor nodes have a modest and sometimes non-renewable battery power; (3) in most sensor network applications, the sensed data flow from multiple source sensor nodes to a particular sink (a many-to-one traffic pattern) or to few sinks; (4) sensor nodes are densely deployed in a region of interest and collaborate to accomplish a common sensing task; (5) due to the large number of sensor nodes deployed, it is usually not possible to build a global addressing scheme for a sensor network. Due to those peculiarities, designing resource efficient routing algorithms is challenging.

An effective approach to routing – able to preserve

*Corresponding author. Now at EBTIC (Emirates ICT Innovation Centre), Khalifa University, P.O. Box 127788, Abu Dhabi, United Arab Emirates.