Ad Hoc Networks 11 (2013) 2637–2647

Contents lists available at SciVerse ScienceDirect

Ad Hoc Networks

journal homepage: www.elsevier.com/locate/adhoc

It measures like me: An IoTs algorithm in WSNs based on heuristics behavior and clustering methods

Alessandro Di Stefano [a], Aurelio La Corte [a], Marco Leotta [a], Pietro Lió [b], Marialisa Scatá [a,*]

[a] Department of Electrical, Electronics and Computer Science Engineering, Faculty of Engineering, University of Catania, 6 A. Doria Street, 95125 Catania, Italy
[b] Computer Laboratory, Department of Computer Science, University of Cambridge (UK), 15 JJ Thomson Avenue, Cambridge CB3 0FD, United Kingdom

ARTICLE INFO

Article history:
Received 24 October 2012
Received in revised form 29 March 2013
Accepted 18 April 2013
Available online 28 April 2013

Keywords:
WSNs
IoT
Heuristics
Trustability
Clustering
Bio-inspired
Risk perception

ABSTRACT

Our work stems from the consideration that nodes of a wireless sensor network, deployed on a general topology, should follow a bio-inspired approach to respect the trustability, information load, risk and energy-saving requirements, under bounded conditions of time, knowledge and computational power. It allows to introduce a multi-agent model related to Internet of Things and heuristics models, in order to obtain a smart organized network with nodes that have both social and human cognition. Our model is based on a hierarchical clustering method and an aggregation/rejection mechanism, that follows sociological and heuristics theories. The model follows the principle of sense of community and the logic of tie for similarity. The main target is to integrate the inherent cooperation of a multi-agent system with node intelligence of Internet of Things and also with the "Satisficing" of heuristic decisions in order to get a social smart behavior of the whole network.

1. Introduction

Wireless sensor networks (WSNs) are large networks made of many autonomous low-power, low-cost, and small-sized sensor nodes. WSNs use sensors to co-operatively monitor complex physical or environmental conditions, such as motion, temperature, and sound. Such sensors are generally equipped with data processing and communication capabilities to collect data and route information back to a sink. The network must possess self-organizing capabilities since positions of individual nodes are not predetermined. Cooperation among nodes is the dominant feature of this type of network because sensor nodes use their processing abilities to locally carry out simple computations and transmit only the required and partially processed data [2]. Sensor nodes can be either thrown in mass or placed one by one in the sensor filed, hence the deployment may be deterministic or self-organizing. The future of WSNs is the integration of bio-inspired ideas, hierarchical clustering methods, and sociological models and concepts such as sense of community and the satisficing theory to form a social network model [13,9]. This will be possible using the node intelligence to allow network to self-organize itself into communities deciding how to join, through an aggregation/rejection mechanism, trying to keep the key requirements regarding the quality of service, efficiency, security, trustability and computational power. For this reason we base our model on a multi-agent system, where a single agent is an intelligent node, exploiting the Internet of Things approach. After that we introduce the heuristic model to give to the node the ability to decide about the interactions with other nodes obtaining a social smart behavior of the network. This approach is characterized by the assessment of the trustability value and the risk perception value for each node; this will rule the formation of the community and the aggregation/rejection mechanism of the nodes. Our aim is to propose an algorithm based on the models

* Corresponding author.
E-mail addresses: alessandro.distefano@dieei.unict.it (A. Di Stefano), lacorte@dieei.unict.it (A. La Corte), marco.leotta@dieei.unict.it (M. Leotta), pl219@cam.ac.uk (P. Lió), lisa.scata@dieei.unict.it (M. Scatá).

1570-8705/$ - see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.adhoc.2013.04.011

mentioned above, in order to emphasize the importance of the concept of cooperation and sense of aggregation to group or community. The model accepts and follows the natural tendency to aggregate and reject each other according to a bio-inspired and self-organized approach, following an aggregation/rejection model, applying a clustering method to a multi-agent model, based on heuristic decisions, in order to get a "satisficing" model. It allows to increase the global knowledge in a WSN with nodes characterized by bounded conditions such as limited time, limited knowledge and limited computational power. The paper is organized as follows: in the second section we explain the reasons that led us to adopt a bio-inspired approach in designing the algorithm, in the third section we give an overview of wireless sensor networks, with a brief introduction, and a dissertation about applications and the main design factors. In the fourth section we give an overview of clustering methods, underlying issues and challenges. The fifth section deals with the sense of community and the Simon's concept of satisficing. In the sixth section firstly we focus on heuristics and Internet of Things, secondly it is explained how we use these concepts in our model. In the seventh section we present and describe our proposed algorithm "It measures like me" (IMLM). The last section is dedicated to conclusion and future works.

2. Why using a bio-inspired approach?

We use a bio-inspired approach because it allows us to solve certain problems and meet specific requirements, such as reliability, information load, risk management and energy saving, under conditions of limited computational resources, time constraints and low overall knowledge. Such kind of approach has been used as a model that relates the cooperation of multi-agent systems, the intelligence of the node, according to IoT, and also the "satisficing" concept of heuristic decisions. What are the analogies between our system and a biological scenario? A biological system is characterized by the following features: high complexity; high connectivity; communication, cooperation and coordination; relation with other systems of the same nature and finally relation and communication with external environment. For this reason it is clear that a power aware WSN, that has to send aggregated information related to single clusters, is a complex system similar to a biological one. We follow the Dressler's approach, proposed in [25], composed by: identification of analogies, understanding and engineering. The identification of analogies step is summarized in the following scheme:

- High complexity → IoT intelligence node.
- High connectivity → sense of community and social behavior + aggregation model.
- Communication, cooperation and coordination → multi-agent system + heuristics + trustability model.
- Relation with other systems of the same nature → logic of similarity + heuristics + information load.
- Relation and communication with external environment − > social and human cognition.

The proposed approach tends to solve decisional issues (through heuristics), cognitive aspects (using the proposed trustability model), security problems (exploiting risk perception model), and shared knowledge management (using a controlled information load). The understanding and engineering steps will be treated in the following sections.

3. An overview of wireless sensor networks

3.1. Introduction

Sensor nodes are fitted with an on-board processor. These nodes communicate with each other, sharing data collected or other vital information to monitor a specific environment. An ideal wireless sensor networks should be networked, scalable, fault-tolerant, consume very little power, smart and software programmable, efficient, capable of fast data acquisition, reliable and accurate over long term, low cost and furthermore it should require no real maintenance [1]. The most well-known routing protocols for WSNs are [3]: flooding, gossiping, SPIN (Sensor Protocols for Information via Negotiation), directed diffusion, LEACH (Low Energy Adaptive Clustering Hierarchy), PEGASIS (Power-Efficient GAthering in Sensor Information Systems), GEAR (Geographical and Energy Aware Routing). In general, an efficient routing protocol should perform the following targets: data aggregation for power saving and in order to reduce the overall network overhead; a dynamic clustering to avoid the quick energy depletion of cluster heads and hence to increase network lifetime; a threshold for sensor nodes on data transmission and dissemination, in order to help energy-saving by reducing unnecessary transmissions; multi-path selection dissemination to improve fault-tolerance and reduce the overhead of network load; self-configuration and adaptation of the sensor nodes to changes in network topology or environmental changes; time synchronization [3].

3.2. Applications

Areas of probable usages of WSNs are [1]: military applications, such as environment monitoring, tracking and surveillance applications; environmental monitoring, such as animals tracking, forest detection and flood detection, and weather prediction and forecasting; commercial applications, such as seismic activities monitoring and prediction, and smart environment applications; health applications, such as tracking and monitoring of doctors and patients in or out the hospitals by providing them with sensors; automation and control, such as robotics control.

3.3. Design factors of WSNs

The node has communication interfaces, typically wireless links, to neighboring domains. The sensor node also often has location and positioning knowledge that is acquired through a global positioning system (GPS) or local positioning algorithm. Sensor nodes are scattered in a special domain called *sensor field*. Each of the distributed