A MODEL FOR WIRELESS SENSOR NETWORKS SUPPORTED COOPERATIVE WORK

Lina M. Pestana Leão de Brito[1] and Laura M. Rodríguez Peralta[1, 2]
[1]*Mathematics and Engineering Department, University of Madeira (UMa)*
Campus da Penteada, 9000-390 Funchal, Madeira, Portugal

[2] *Centre for Informatics and Systems of the University of Coimbra (CISUC), Pólo II, 3030-290 Coimbra, Portugal*

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Abstract: Collaboration is essential to Wireless Sensor Networks due to the typical resource limitations of the sensor nodes. In fact, the main functions of the network cannot be accomplished without collaboration among sensor nodes. Most of the work found in literature only focuses a specific type of collaboration, associated with the accomplishment of a certain task, such as signal processing, computing, routing, etc. In this paper, we present a graph-based model of cooperative work for WSNS. This model is called Wireless Sensor Networks Supported Cooperative Work (WSNSCW) and considers the specific requirements of the WSNS.

1 INTRODUCTION

Combining the advantages of wireless communications with some computational capability, Wireless Sensor Networks (WSNS) allow for a wide range of applications: environmental monitoring, health, surveillance, traffic monitoring, security, military, industry, agriculture, etc.

Nowadays, wireless sensor nodes are intended to be small and cheap. Consequently, these nodes are typically resource limited (Akyildiz et al., 2002) They have reduced memory and limited processing capacity. Battery is, also, restricted. Moreover, due to short transmission range (caused by restrained transmission power), nodes can only communicate locally, with a certain number of local neighbours. For these reasons, it is perfectly natural that nodes need to collaborate among themselves in order to accomplish their tasks. Collaboration enhances the scalability of the network and facilitates mission completion (Gracanin et al., 2006).

It is also worth mentioning that, according to (Ramanathan et al., 2002), WSNS originated a new collaboration concept. In traditional networks, collaboration exists within the same group of nodes, even though they move (node-centric collaboration). In WSNs, collaboration occurs among nodes located in a certain region, which means that the group of nodes may not be the same (location-centric collaboration). For instance, if a node leaves a predefined region, it stops collaborating with other nodes. However, besides localization-based collaboration, it is possible to identify other ways to collaborate, based whether in monitoring a certain phenomenon or in the hardware characteristics of the nodes themselves (Ranjan et al., 2005),(Medidi et al., 2006), (Hussain et al., 2004), (Zhou et al., 2006).

At the moment, there are several works concerning collaboration in WSNS. However, most of them only focus a specific type of collaboration, associated with the accomplishment of a certain task (signal processing, routing, task scheduling, etc.). Usually, these collaborations simply intend to improve some parameters of the network (energy costs, coverage, transmission costs, processing costs, delay, etc.).

Until now, the only work that presents a model for cooperative work in sensor networks has been proposed by Liu et al. (Liu et al., 2006). This model was created for sensor networks; however, it does not consider the specific requirements of the WSNS.

In this paper, we present a graph-based model of cooperative work for the specific case of the WSNS, named Wireless Sensor Networks Supported Cooperative Work (WSNSCW), which considers the specific requirements of the WSNS. Our model allows for not only the modelling of the cooperative work, but also for the modelling of the entire WSN and all its components.

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This paper is organized as follows. In section 2, we briefly describe the related work. In section 3, the model for WSNSCW is presented and exemplified. Section 4 provides some conclusions and perspectives of future work.

2 RELATED WORK

Most of the works concerning collaboration in WSNS only focus a specific type of collaboration, which is associated with the accomplishment of a certain task, such as: sensing (Gracanin et al., 2006), (Krohn et al., 2005), (Wang and Ramanathan, 2005), (Reich, 2002), signal processing (Sheng and Yu, 2003), (Ramanathan et al., 2002), (Bergamo et al., 2004), (Li and Yu, 2003), (Broxton et al., 2005), (Asis and Kai, 2006), (D'Costa and Saveed, 2003), (Wang and Wang, 2007), computing (Al-Omari and Weisong, 2006), (Iftode et al., 2004), (Singh and Prasanna, 2003), transmission (Yang et al., 2006), (Krohn et al., 2006), (Krohn et al., 2006), (Yang and Tong, 2005), (Yang and Tong, 2005), routing (Chen et al., 2006), (Yang and Tong, 2005),(Fang et al., 2004) localization (Sheng and Hu, 2003), (Reghelin and Fröhlich, 2006), (Bergamo et al., 2004), (Dardari and Conti, 2004), (Li and Hu, 2003), (Broxton et al., 2005), security (Chadha et al., 2005), task scheduling (Sanli et al., 2005), calibration (Reghelin and Fröhlich, 2006), (Bychkovskiy et al., 2003), heuristics (Reghelin and Fröhlich, 2006), target tracking (Onel et al., 2006), (Wang and Wang, 2007), resource allocation (Giannecchini et al., 2004), time synchronization (Hu and Servetto, 2005), knowledge building (for smart sensors) (Bove and Mallet, 2004), etc. There are also works concerning the collaboration between wireless sensor nodes and other kind of devices (heterogeneous groupware collaboration) to support some specific applications (eg. collaboration between sensor nodes and PDAs, in a fire fighting scenario) (Cheng et al., 2004), (Chassot et al., 2006), (Chaczko et al., 2005).

Until now, the only work that presents a model for cooperative work in sensor networks has been proposed by Liu et al. (Liu et al., 2006). It is the SNSCW (Sensor Networks Supported Cooperative Work) model.

The hierarchical SNSCW model divides the cooperation in a sensor networks in two layers. The first one relates to the cooperation between humans and sensor nodes (user-executor relationship, being initiated either by the user or by the sensor node), and the other layer relates to the cooperation between the sensor nodes (represented by an activity-task-cooperation layered abstract model; considering two main subtypes of cooperation: peer-to-peer and master-to-slave).

This model was designed for sensor networks. However, it does not consider the specific requirements of the WSNs, for instance, its scale, its auto-configuration requirements, the resource limitations of wireless sensor nodes, etc (Akyildiz and Su, 2002). Also, it only allows for modelling of collaboration itself.

3 WSNSCW MODEL

In this paper, we present a model of cooperative work for the specific case of WSNS, named Wireless Sensor Networks Supported Cooperative Work (WSNSCW). As WSNSCW is a model of cooperative work created specifically to WSNS, it considers the particular requirements of WSNS. It is a graph-based model; nevertheless, it includes other objects in order to make possible the modelling of all the components of a WSN.

The SNSCW model, proposed in (Liu et al., 2006), only focuses cooperation in WSNs, more precisely, the different types of cooperation that can occur in a WSN. Our model not only allows for the modelling of cooperation within the network, but also for the modelling of the entire WSN and all its components (different types of nodes, clusters, base stations, etc.). In what concerns to collaboration, both the model and the example presented in this paper only include the concepts of session and relationships among nodes. However, we intend to improve our model, including other concepts related to CSCW (Computer Supported Cooperative Work) (Vin and Rangan, 1992), (Mills, 2003).

WSNSCW is also a heterogeneous model, in the sense that it can be applied to any type of wireless sensor regardless its size, its hardware characteristics, types of signals it can measure, etc. It can also be applied to any WSN despite of the specific application. However, in this paper we are going to illustrate the use of this model, applying it to the case of an environmental monitoring application.

3.1 Definitions

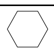
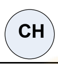
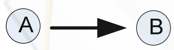
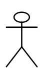
In this section, the entities of our model are defined. The entities are all the components than might exist in a WSN. Table 1 shows the symbol, the concept and the description of all the entities included in the model.

A WSN can be composed by different types of nodes: ordinary wireless sensor nodes (which can be in one of two possible states, in order to save energy: active or inactive – sleep mode), anchor nodes (which support the other sensor nodes in the localization process), one or more sink nodes (also known by base stations, which are responsible for sending data to the gateway) and a gateway (responsible to send data to the user, through the Internet). If nodes are grouped in clusters, one of the cluster members become the cluster head; and all the wireless sensor nodes have to send data to the cluster head (usually, the more powerful node of the cluster, responsible for sensing data to the sink node).

There is a relationship between nodes that collaborate with each other. A relationship can be established based on: localization of the nodes, existence of clusters, phenomenon to monitor, hardware characteristics of the sensor node, etc. Associated with this relationship there is always an exchange of data (data flow entity), which may be of several different types (light, sound, temperature, image, acceleration, etc.). It is also relevant to identify the type of signal that was used by the sensor node to collect this data (radio frequency, ultrasound, acoustical or light).

There can be established several collaborative sessions when monitoring a WSN, and they can exist simultaneously or not. A session may be established based on the objective of the WSN (type of phenomenon to monitor, geographical area to monitor, on monitoring time, etc.)

Table 1: Definition of the entities that can constitute a Wireless Sensor Network.

Symbol	Concept	Description
	Sensor node	Wireless sensor nodes, typically with limited resources. They can be stationary or mobile.
	Sink node/ Base Station	Node to which data collected by ordinary nodes is sent; being responsible to send data to the gateway.
	Gateway	Node responsible to send the data to the user, through the Internet.
	Anchor node	Node with known localization.
	Active sensor node	Node which is in the active state.
	Inactive sensor node	Node which is in the sleep mode, in order to save energy.
	Cluster	Group of nodes, created according to: geographical area, type of sensor, type of phenomenon, task, etc.
	Cluster Head	Sensor node to whom all sensor nodes in the cluster send the collected data; it is responsible for sending the received data to the Sink node.
	Data flow	This label identifies both the type of signal being used (radio frequency, ultrasound, acoustical or light) and the type of data being transmitted between nodes (temperature, humidity, light, sound, video, internal voltage, etc.).
	Relationship	The arrow represents a relationship between nodes A and B. Node A transmits data to node B; so, node B consumes information from node A. A relationship can be established based on: localization, phenomenon, type of sensor node, etc.
	Session	In a certain moment, there may be several collaborative sessions in a WSN. A session can be established based on the objective (type of phenomenon to monitor, geographical area to monitor) of the WSN.
	Battery	It represents the remaining battery of the sensor node.
	User	Person that interacts with the WSN, querying the network, visualizing data, etc. The user customizes the work of the sensor nodes; the data collected by sensor nodes is used by the users' application.

As the battery is the most critical resource of a sensor node, it is really important that the user knows the state of the battery of each sensor. That is why the battery is also an entity of our model.
Finally, the user is the entity who interacts with the WSN, defining the application, querying the network, visualizing data, customizing the work of the sensor nodes, etc.

3.2 Example Scenario

In this section, we exemplify the use of our model, by applying it to the specific case of an environmental monitoring application.

Let's consider a forest monitoring WSN with a total of 45 nodes. Among these nodes there are 3 sink nodes, 5 anchor nodes and 37 wireless sensor nodes. The nodes were deployed in an ad hoc manner, in two different geographical areas of a forest.

The user works in a place, which is far away from the forest being monitored. So, he monitors the WSN through the Internet. As shown in Fig. 1, in this example there are three simultaneous collaborative sessions. These sessions where initiated by the user, after he defined three different objectives: to monitor the temperature of area A1 (session CS1), to monitor the humidity of area A2 (session CS2), and to monitor the light of the same area (session CS3).

Within each area, clusters have been created according to the geographical localization of sensor nodes, being based in the proximity between nodes. The cluster head was chosen, among nodes in the cluster, as the node with more battery. In this case, 5 clusters have been created and, hence, there are 5 cluster heads. The nodes in the cluster automatically start to collaborate to collect data and send it to the cluster head. Also, the cluster head starts sending data to the sink node, which, in turn, send it to the user, through the gateway. Only the nodes of the cluster need to be in the active state, as they need to monitor the phenomenon and also need to send the data to the cluster head. The remaining nodes are in the sleep mode, in order to save energy. Nodes can also become inactive if their batteries end.

As this scenario relates to an environmental monitoring application, it is very important to be able to correlate collected data in time. So, anchor nodes had to be deployed in the WSN. As the localization of anchor nodes is known, they can help the cluster heads (as well as the remaining nodes of the cluster, if needed) in determining their own position.

As the battery is the most critical resource of a sensor node, it is really important that the user knows the state of the battery of each node. This way, the user gets to know when he has to go to the field in order to change the batteries of the sensor nodes.

Any changes that might occur on this scenario (new collaborative sessions, new clusters, nodes changing from sleep mode to the active state or vice versa, etc.) can be represented by a succession of figures analogous to Fig. 1.

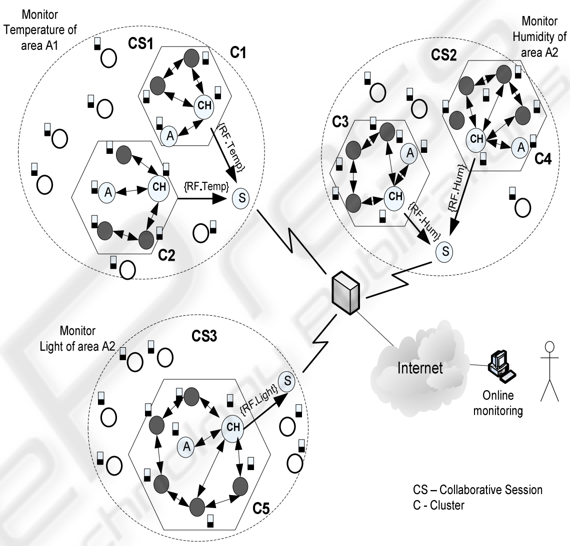


Figure 1: Applying the WSNSCW model to a WSN, considering the specific case of forest environmental monitoring.

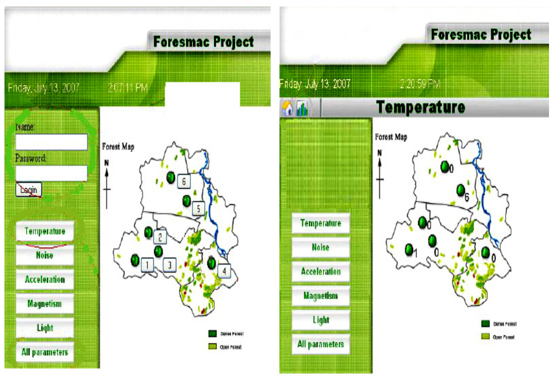


Figure 2: Screenshots of the implementation of the web-based 2D visualization tool.

Fig. 2 shows a prototype of a web-based visualization tool. This tool was created to visualize some of the components of a forest environmental monitoring WSN. At the moment, it only shows one type of nodes and one of the parameters they can measure (temperature, noise, acceleration, magnetism, light and the battery level), at a time (according to the user selection). However, this tool should be based in the WSNSCW model. Consequently, it should show all the entities defined in the model: different types of nodes, relationships between them, different clusters, data flows, etc.

In this initial phase, it is still a 2D visualization tool. However, we intend to develop it into a 3D visualization tool, since it is more appropriated for representing a WSN deployed in different types of terrains. In the specific a forest environment, for instance, we can have different types of terrains (flat, mountainous, etc.), which might interfere with the collaboration established between nodes.

4 CONCLUSIONS AND FUTURE WORK

WSNSCW is a model of cooperative work specifically designed to WSNs. It is a graph-based model that can be applied to a heterogeneous network, in the sense that it can be applied to any type of sensors and any type of application. The great advantage of this model lies in the fact that, besides modelling the cooperation of the network, it also allows for modelling the whole network and all its components. In this paper, we applied this model to the specific case of a forest environmental monitoring application.

In the near future, we intend to include more concepts of CSCW in the WSNSCW model. We also intend to formalize this model using graph theory as well as to use the model to create a web-based visualization tool for WSNs in a 3D environment. As in a forest environment, we can have different types of terrains (flat, mountainous, etc.), it is important that the visualization tool allows for the 3D visualisation of the whole network, including all its components, as they are the deployed in the forest terrain. For instance, it will be possible to visualize all the nodes in their real position, and also where they are deployed considering all the terrain irregularities and obstacles that might exist. This will lead to a more realistic view of the network.

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