Computers and Electrical Engineering 48 (2015) 312–329

Contents lists available at ScienceDirect

Computers and Electrical Engineering

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

A session protocol for wireless sensor networks. Application to oil spills monitoring ☆

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ARTICLE INFO

Article history:
Received 9 September 2014
Received in revised form 10 June 2015
Accepted 11 June 2015
Available online 27 June 2015

Keywords:
Wireless sensor networks
Session protocol
Riverbed Opnet Modeler

ABSTRACT

Wireless sensor networks may be used for the surveillance of large systems (bridges, tunnels, etc.) or in the management of disasters such as forest fires, or oil spills. In some of these applications, the topology of the network is going to be dynamic: a connected system can evolve into a clustered system that presents a break of the global connectivity. Using a collector which will regularly visit the disjoint clusters enables to restore a discreet connectivity.

A session layer protocol is proposed to reconstitute a consistent global information system. It enables the collector to reconstruct the communication context with the previously visited clusters, knowing they could have moved, merged, or have split. A node sensor model has been integrated into the Riverbed Opnet Modeler network simulation environment. Simulations show the benefits of the protocol, and particularly how it provides a better trajectory planning of the collector.

1. Introduction

In order to illustrate our work, we have chosen in this paper an application of oil spills observation. In 1972, the world program IGOSS of continuous monitoring of the pollution of the seas was initiated (Integrated Global Ocean Services System). In 1979, a report suggests to deploy sensors on the oil slicks, to study the evolution of the pollution by hydrocarbons [1]. The more recent emergence of wireless sensor networks reinforces this idea. Indeed, compared to the classical visual aerial flyover, they will allow a continuous and real time monitoring of the drift of the oil slicks, their size, their consistency, etc. From the beginning of the oil spill, many sensor nodes are randomly scattered to observe it. The major difficulty is to cope with the dynamics of the system which implies a variation of the network topology. It is primarily caused by two types of mobility which are:

- the mobility of the slicks that causes a topological change in the network which may imply a communication interruption. Indeed, at the beginning of the spill, the oil immediately tends to spread on the surface of the water into slicks, which in theory form regular circles whose diameter increases eight times in the hour following the spill, then five times before the end of the week. Then, wind, waves, and the Coriolis force (due to the rotation of the Earth) contribute to stretch, move, and fragment the slicks until their decomposition into droplets;

☆ Reviews processed and recommended for publication to the Editor-in-Chief by Associate Editor Dr. M.H. Rehmani.

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http://dx.doi.org/10.1016/j.compeleceng.2015.06.015
0045-7906/

– the mobility of the nodes themselves which are dispersed on oil slicks. Indeed, under the influence of external factors such as wind, the nodes can move randomly which may affect radio connections when they are distant from each other. Similarly, the effect of endogenous factors such as the depletion of the battery or the node failure may affect the topology of the network and cause information routing problems.

The dynamics of the network may lead to a partial or total loss of connectivity for one or several nodes, and so to the inconsistency of the global information system (non-connected communication graph). Therefore, we propose a 3-levels architecture for a coherent information system, based on the measurement, the collection and the processing of data relative to the spread of oil (Fig. 1):

– *Level 1*: the measurement (viscosity, temperature, location, etc.) is performed by each sensor and transmitted to a cluster head. This one is elected to represent several nodes, enabling to prioritize communications in order to reduce their number and locate them. Indeed, thousands of sensors may be deployed, and the system can quickly reach high dimensions. The elective process and the partitioning metric are briefly described in Section 2, to aid comprehension, even if it is not the aim of the paper;
– *Level 2*: the collection of the nodes measurements is carried out by one (or more) collector (s) (robot, airplane, etc.) which will visit (at a fixed or variable period) the cluster heads. As the clusters are evolving in location, size, number, and in representation (the head may have changed) and because we cannot have a continuum of the evolution of the slicks monitoring, we propose to implement a "session" layer with the objective of re-contextualizing each return of the collector from its previous visit. The trajectory of the collector will be defined on the basis of specific session parameters.
– *Level 3*: data processing is realized at a central level called "Information System", which is supplied with data gathered by the collector(s). In this article, we are not studying this aspect of the overall problem. It will be therefore not be discussed in detail.

So, the second level of the proposed architecture consists in a mobile sink (we call collector) that is responsible for data collection and that is based on a session layer. A particular interest of this session protocol is shown in Fig. 2: the mobile sink should move all along the monitored area in order to collect the data disseminated in the sensor nodes (upper part of Fig. 2). However, in order to increase the refreshment frequency of the global information system, it should avoid covering the whole area (especially when the distribution of the nodes is not uniform).

– Clustering is used as a first step to disseminate data from a set of nodes into a single node (and reduce yet the number of points to visit).
– The session protocol will then check that the information stored in clusters is sufficiently representative regarding the application requirements (here, regarding the size of the oil slick). If it is not the case, the related point on the trajectory will be once again removed.
– It will also contribute to improve the trajectory of the mobile sink as follows: the contextualization performed by such session layer will be used in order to predicate future nodes location and hence ensures the communication capability between the collector and the nodes. Thus, it leads to a smaller subarea to cover regardless of the trajectory strategy used. Three strategies are presented in Fig. 2: space curves (a), grid based (b), random (without session c) and controlled (our proposal d).

The next section discusses related works. Section 3 shows the clustering strategy proposed for those networks. Section 4 reminds the formalization of a session and details the session protocol. The performance of the protocol is finally analyzed in Section 5 through numerous simulations, and discussed in Section 6.

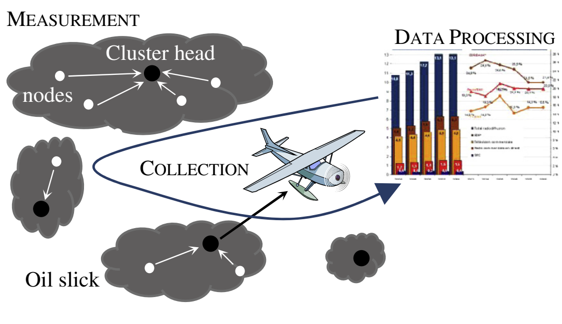

Fig. 1. The 3 levels architecture.