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Design of a generic management system for wireless sensor networks

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ABSTRACT

This paper proposes the DISON framework, a generic management system for Wireless Sensor Networks (WSNs). The first objective of the DISON framework is to allow sensor nodes to adapt autonomously to changes in application requirements and network resources. The second objective is to provide a framework that enables both the developer and the administrator of WSNs to choose what management functions to perform, what conditions should trigger sensor nodes' adaption, and how to adapt in both the development and run-time stages. To achieve these objectives, firstly we propose a multilevel management mechanism where every sensor node is empowered to participate in the management process at different levels according to its resources. Then, we explain how sensor nodes can be self adaptive by defining two data models, a context model and a policy model. We also discuss how context is validated and how it is used to trigger policies. We then present two management functions that can be applied to most applications, the monitoring function and the resource allocating function. We implement DISON in TinyOS operating system as an independent component which can interact with user applications and other network components through public interfaces. The feasibility of the resource allocating function is evaluated on a 26-node indoor testbed. The results of the experiments show that DISON can not only resolve the management problems but also improve network performance such as packet delivery rate or energy consumption. Finally, through experiments in another testbed with different number of nodes, we demonstrate the scalability of DISON.

1. Introduction

Wireless Sensor Networks (WSNs) are networks of small, light weight devices which have wireless communication and sensing physical environmental information capabilities. Everyday, there are more and more sensors integrated into our daily applications. Fig. 1(a) illustrates how WSNs are used in a smart house [1]. Sensing devices such as lighting sensors, temperature sensors and occupancy sensors are placed in rooms to help not only to reduce energy usage but also to maximize comfort. For example, the lighting sensors are used to control the intensity of bulbs in the room according to the daylight. The occupancy sensors detect if there is any person in the room to turn on/off bulbs. In the smart house, the sensor devices are inter connected to allow users to monitor the status of sensing devices and adjust the operation of sensing devices according to their needs. In addition, the sensor devices can cooperate to provide advanced services. For example, the occupancy sensors cooperate with the temperature sensors to turn off the air conditioner or change the operating mode of the air conditioner to energy saving mode when there is no person in the room.

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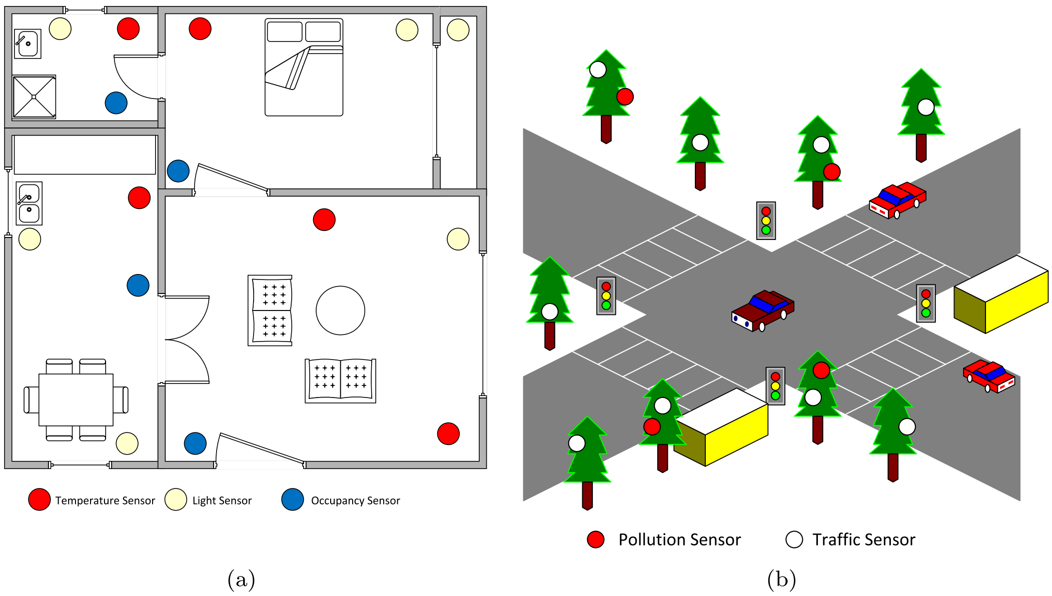

Fig. 1. WSNs applications: (a) smart house and (b) road network.

Another application of WSNs is shown in Fig. 1(b). WSNs are integrated into intelligent transportation systems to improve the driver safety. Detection obstacles and traffic sensors are installed or embedded in the road or surrounding the road (e.g., on buildings, trees, and signs). The detection obstacles detect construction sites or obstacles on the road and send information to drivers. So drivers can avoid the road which has the obstacles. The traffic sensors provide information about the presence or the passage of vehicles. This helps to detect or predict where traffic jam occurs.

However, the development and the deployment of WSNs in real life applications are extremely challenging tasks. First, sensor nodes are only equipped with a limited power source (e.g., batteries and solar cells). Therefore, sensor nodes are easy to fail or have unpredictable operations. In addition, sensor nodes can be deployed in large numbers over a large geographic area or even in hostile or harsh environment. Therefore, replacement of sensors that have run out of energy is complex or sometimes impossible.

Second, current applications of WSNs are used for a single purpose solely and assuming that their operation parameters are fixed before deployment. However, application requirements may change over time. For example, to deploy a new thief detection application in the smart house in Fig. 1(a), it would be more efficient if the new application can use existing devices in the house such as occupancy sensors rather than requiring the installation of new ones. In addition, it is convenient to have only one system which manages all the devices in the house. This helps the user to monitor and handle all the devices in the house easily. Therefore, a WSN should be able to support various types of applications or adapt to the changes in application requirements. In other words, it is expected that multiple applications will be executed concurrently over a single wireless sensor network [2,3].

Third, there has been a lot of research conducted in both hardware and networking technologies for WSNs. WSNs can use different wireless node platforms (e.g., MICAz, TelosB, IRIS, Imote2) and different network protocols (e.g., MAC protocols [4], topology control protocols [5,6] and routing schemes [7,8]). Therefore, to manage a huge amount of heterogeneous sensor nodes and their data in WSNs is extremely complex.

Fourth, there will be more and more deployed WSNs to meet different needs in future. It is possible and expected that these networks can cooperate to support each other to improve the performance or the quality of offered services. For example in Fig. 1(b), based on the traffic information from the traffic monitoring sensor network, the pollution sensor network can predict the future pollution and change the collecting data rate correspondingly.

In this article, we present DISON, a generic management system to cope with the previous stated challenges in WSNs. The first feature of DISON is that every node participates in the management process in different levels depending on its resources. This feature allows DISON to be scalable for networks of a small to a large number of nodes. The second feature of DISON is that it includes a context aware policy based mechanism. We have defined data models and reasoning mechanisms to allow sensor nodes to be aware of the changes in network resources and application requirements, as well as to allow them to react to those changes by themselves. In addition, DISON supports a resource allocating mechanism to coordinate application tasks based on network resources. This mechanism allows multiple applications to be executed concurrently in the same network and multiple WSNs to cooperate with each other. The last feature of DISON is that management