Chapter 3
Collaborative Sensor Networks: Taxonomy and Design Space

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ABSTRACT

Sensor networks have been widely deployed in all kinds of applications. In the near future, we expect to witness the proliferation of sensor networks with a variety of functions that requires a comprehensive collaboration mechanism among them. Specific designs are necessary to manipulate a fabric of multiple sensor networks, facilitate the collaboration among them, and support efficient data sensing, aggregation, storage, transmission, and query processing. In this chapter, through comparison and analysis of existing works, we present a new taxonomy of collaborative sensor networks based on the architectures and the methodologies of organizing different modules of a system. We find that a cross-layer design simultaneously guaranteeing the energy efficiency of underlying sensor networks and the quality of services for users is a challenging issue which has not been well studied. We also discuss the design space in this field and point out potential research directions.

1. INTRODUCTION

Sensor networks have attracted a lot of attention during the past decade. Due to the recent advances in wireless communication and micro-electronic technologies, both the price and size of sensors decrease quickly. Today's applications of sensor networks range from personal to mission critical systems including scientific observation, digital life, home automation, environment surveillance, traffic monitoring, and so on (Gao, Massey, Selavo, Welsh, & Sarrafzadeh, 2007; Li & Liu, 2007b; Szewczyk, Mainwaring, Polastre, Anderson, & Culler, 2004; Yang, Li, & Liu, 2007; Zhang, Sadler, Lyon, & Martonosi, 2004). Many of them are developed and promoted by governments, enterprises and public organizations, offering continuous collection of real-time information, satisfying the requirement of people's daily life.

DOI: 10.4018/978-1-61520-701-5.ch003

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In the foreseeable future, we expect to witness the proliferation of sensor networks with a variety of functions that requires a comprehensive collaboration mechanism among them. Specific designs are necessary to manipulate a fabric of multiple sensor networks, facilitate the collaboration among them, and support efficient data sensing, aggregation, storage, transmission, and query processing. Previous studies in sensor networks, however, mainly focus on the performance and efficiency inside a single sensor network.

In this chapter, we broaden the view into the scope of multiple sensor networks. The term "collaborative sensor networks" refers to the sensing systems with the following characteristics: first, it is an information system providing live sensing and query processing services; second, multiple heterogeneous sensor networks are integrated in; third, sensor networks in the system collaborate with each other in accomplishing the querying tasks.

We present a new taxonomy for describing and classifying infrastructures and designs of collaborative sensor networks. The taxonomy categorizes the collaborative sensor networks based on their systematical architectures and functionalities. This contributes a deep and comprehensive view to the current studies. We also discuss and summarize the challenging problems and potential issues in the community of collaborative sensor networks.

The remainder of the chapter is organized as follows. Section 2 briefly discusses the state-of-art in sensor networks. An overview of collaborative sensor networks is presented, covering all the elements from a systematical point of view. Section 3 elaborates the taxonomy of collaborative sensor networks. Challenging issues and potential research directions in this field are discussed in Section 4. We conclude this chapter in Section 5.

2. OVERVIEW

2.1 Background and Motivation

Sensor networks pose a number of unique technical challenges due to the following factors, such as Ad hoc deployment, unattended operation, untethered power supply, and dynamic changes in both connectivity and environments. Designs of sensor networks are thus emphasized to be energy-efficient and highly adaptive, which generally can be categorized into two classes: software and hardware. Research works in both classes have achieved remarkable successes in the past decade. Software focuses on algorithms, protocols, operating systems, middleware, and programming languages designed for networks of embedded sensors in various application scenarios (He, Stankovic, Lu, & Abdelzaher, 2005; Li & Liu, 2007a; Lian, Naik, Chen, Liu, & Agnew, 2007; Xiao, Chen, & Zhou, 2008). Hardware includes the work on sensor platforms, tools, implementations, measurements, and sensing devices, etc. Specifically, algorithms in sensor networks are mainly interested in energy-efficient sensing, data delivery, localization, and routing techniques. We have also seen a number of successfully applied operating systems (e.g. T-kernel (Gu & Stankovic, 2006)), sensor motes (e.g. Mica (Hill & Culler, 2002)), programming languages (e.g. nesC (*nesC: A Programming Language for Deeply Networked Systems*)), and real deployments of sensor networks (e.g. GreenOrbs (*GreenOrbs*), OceanSense (*OceanSense*, ; Yang et al., 2007)).

Most of the existing works, however, only concentrate on the issues in a single sensor network. Networked sensors are regarded to be geographically close to each other and with homogeneous functionalities, while different sensor networks are seldom considered related. For example, sensor networks in a sea-depth monitoring sensor networks are deployed in a constrained area of offing. They are uniformly equipped with acoustic sensing devices and generate homogeneous data

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