Basic Concepts of Wireless Sensor Networks

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INTRODUCTION

As with many technologies, defense applications have been a driver for research in sensor networks, which started around 1980 due to two important programs of the Defense Advanced Research Projects Agency (DARPA): the distributed sensor networks (DSN) and the sensor information technology (SensIT) (Chong & Kumar, 2003).

However, the development of sensor networks requires advances in several areas: sensing, communication, and computing. The explosive growth of the personal communications market has driven the cost of radio devices down and has increased the quality. At the same time, technological advances in wireless communications and electronic devices (such as low-cost, low-power, small, simple yet efficient wireless communication equipment) have enabled the manufacturing of sensor nodes and, consequently, the development of wireless sensor networks (WSNs).

Despite the fact that these networks have specific challenges, they represent a significant improvement over traditional sensor networks, concerning the cost, size, flexibility, distributed intelligence, errors (the combination of measures from different sensors can improve the measurements precision) and monitoring targets that otherwise would not be possible (for example, the collaboration between sensors can help monitoring low activity targets). However, the main advantage of WSNs is the possibility of being deployed anywhere, in irregular or inaccessible terrains or even in hostile environments where cable installation is not a possible solution. Furthermore, these networks require unattended operation. This means that sensor networks protocols and algorithms must possess self-organizing capabilities. The failure of sensor nodes due to lack of power, environmental interferences, or physical damage, should not affect the overall task of sensor nodes.

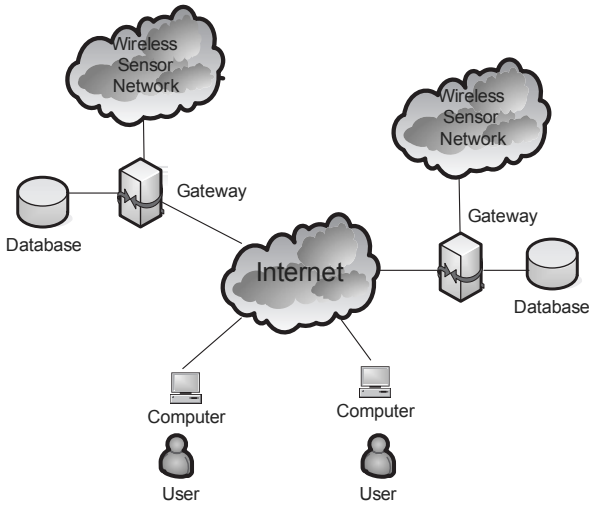
The sensor nodes have limited capabilities, which consist of sensing, signal and data processing, and radio communication. However, these networks have a unique feature: the collaborative effort of the sensor nodes in data gathering and processing, in order to accomplish more complex tasks. WSNs combine the advantages of wireless communication with some computation capabilities and detection of some physical characteristics (typically, temperature, light, vibration, sound, radiation, etc.). Thus, the application areas of WSNs are quite numerous: environmental monitoring, health (a case where deployment of sensors has to be manual), surveillance (for example, intrusion detection), security, engineering, aviation, traffic monitoring, military, home, monitoring disaster areas, industry, etc.

In this article, we present a broad survey of the communications architecture of the sensor networks, as well as the issues that influence the network design, the protocols, and algorithms proposed so far for sensor networks.

WIRELESS SENSOR NETWORKS: MAIN CHARACTERISTICS

A sensor network consists of a large number of tiny sensor nodes that are densely deployed either inside the phenomenon or very close to it. The sensors measure ambient conditions in the environment surrounding them and then transform these measurements into signals that can be processed to reveal some characteristics about the phenomenon. The data collected is routed to special nodes called sink nodes, by a multi-hop infrastructureless architecture, shown in Figure 1 (adapted from Lewis, 2004). Then the sink node sends data to the user via Internet or satellite through a gateway (also called base station, BS). The user can interact with the physical world (and, consequently, with WSNs) through the Internet. This is why some

Figure 1. Wireless sensor network structure



authors consider that a WSN "extends the Internet to the physical world" (Zhao & Guibas, 2004).

Typically, a sensor node consists of four basic components: sensing, processing, transmission, and power units (Figure 2) (Akyildiz, Su, Sankarasubramaniam, & Cayirci, 2002). Sensing units are usually composed of two subunits: sensors and analogue to digital converters (ADCs). The analogue signals produced by the sensors based on the observed phenomenon are transformed into digital signals by the ADC and then fed into the processing unit. This unit is associated with a small storage unit and allows sensor nodes to collaborate with each other to carry out the assigned sensing tasks. The transceiver unit connects the node to the network. One of the most important components of a sensor node is the power unit, which may be supported by a power-scavenging unit such as solar cells. A sensor node can also have some application-dependent additional components, such as a location finding system, a power generator and a mobilizer (Akyildiz et al., 2002).

All these subunits should fit into a module, which can be smaller than even a cubic centimeter and light enough to remain suspended in the air if necessary (Rentala, Musunuri, Gandham, & Saxena, 2002). The current generation of wireless sensors ranges from shoe-box-sized Sensoria WINS NG sensors to match-box-sized Berkely motes (Zhao et al., 2004).

Besides the size, there are some strict constraints for sensor nodes: (1) they have to consume extremely low power; (2) operate in high volumetric densities; (3) have low production cost; (4) be autonomous; (5) operate unattended, and (6) be adaptive to the environment (Rentala et al., 2002).

It is easy to conclude that one of the critical aspects of WSNs is low-power operation, but the limited transmission range (due to environmental noise and signal attenuation) is also a critical aspect. More specific challenges have to be considered (Karl & Willig, 2005) when comparing the WSNs to other traditional networks. Many protocols and algorithms have been proposed for traditional wireless ad hoc networks; however they are not well suited to the unique requirements of sensor networks.

SPECIFIC CHALLENGES OF WIRELESS SENSOR NETWORKS

WSNs share most of the ideas associated to ad hoc networks. However, the use of wireless sensors brings some new challenges (Akyildiz et al., 2002; Karl et al., 2005; Zhao et al., 2004), which are summarized next:

Figure 2. Sensor node architecture