Available online at www.sciencedirect.com
ScienceDirect
Computer Networks 51 (2007) 961–994
Computer Networks
www.elsevier.com/locate/comnet

Medium access control in wireless sensor networks

Kurtis Kredo II [a], Prasant Mohapatra [b,*]

[a] Electrical and Computer Engineering Department, University of California, Davis, United States
[b] Computer Science Department, University of California, Davis, 2063 Engineering II, Davis, CA 95616, United States

Received 7 February 2006; received in revised form 15 May 2006; accepted 26 June 2006
Available online 31 July 2006

Responsible Editor: I.F. Akyildiz

Abstract

Limited energy, computational, and communication resources complicate protocol design within sensor networks and prevent the application of many techniques used within other networks. Constraints on sensor node cost further restrict which technologies sensor networks may utilize. Despite much attention in recent years, researchers have yet to achieve the goal of long term, independent operation of sensor network deployments under these constraints. One research direction considers the energy expended performing communication functionality. Medium access protocols provide the greatest influence over communication mechanisms and provide the most direct influence over the utilization of the transceiver, the largest energy consumer in most sensor nodes. We present a discussion of medium access control concepts in relation to sensor networks and examine previous wireless medium access control protocols to illustrate how they do not match the requirements and characteristics of sensor networks. We then present several protocols recently proposed in the literature specifically for sensor networks.

Keywords: Sensor network; Medium access control; Survey

1. Introduction

Sensor networks [1] consist of small, inexpensive, resource constrained devices that communicate wirelessly in a multihop network. Each device, called a sensor node, collaborates with other devices in the network to perform some operation for the end user, such as environmental monitoring or target tracking. End users typically desire to deploy sensor nodes randomly throughout the target area in large numbers—hundreds to thousands of sensor nodes; however, some special cases may require the precise deployment of a smaller network. Large sensor network deployments require sensor nodes of marginal cost to keep the overall cost within reasonable bounds, but requiring low cost places a limit on the technologies each sensor node may utilize. Therefore, each sensor node often has a simple processor and limited memory resources. Producing simple, small, and inexpensive devices also limits the energy resources available for sensor node operation. Replacing or renewing energy resources after

* Corresponding author. Tel.: +1 530 754 8380.
E-mail addresses: kbkredo@ucdavis.edu (K. Kredo II), prasant@cs.ucdavis.edu (P. Mohapatra).

1389-1286/$ - see front matter
doi:10.1016/j.comnet.2006.06.012

deployment becomes infeasible or too costly in most cases, so the protocols and applications must make judicious use of the finite energy resources. Some sensor nodes may have the capability to scavenge energy from their environment [2], such as with a solar cell, but adding such capabilities increases the sensor node cost, complicates network deployment, and current commercial devices consume too much energy to survive on ambient energy sources in most environments. Sensor nodes communicate by forming a multihop network to forward messages to the destination, which may collect data for later retrieval by the end user or transfer the data over a dedicated communications link. Sensor nodes avoid direct communication with a distant destination due to the high transmission power requirements for reliably sending messages across the deployment area, which may cover a large geographical area. Despite using multihop communication to reduce energy requirements for communication, the wireless transceiver often consumes the largest amount of energy—per time period of use—within a sensor node and, thus, provides the greatest potential for energy savings. Beyond improving the radio design, an efficient medium access control (MAC) protocol possesses the greatest capability to decrease the energy consumption of the transceiver since it directly controls transceiver operation.

A MAC protocol provides slightly different functionality depending on the network, device capability, and upper layer requirements, but several functions exist in most MAC protocols. In general, a MAC protocol provides [3]:

- Framing – Define the frame format and perform data encapsulation and decapsulation for communication between devices.
- Medium access – Control which devices participate in communication at any time. Medium access becomes a main function of wireless MAC protocols since broadcasts easily cause data corruption through collisions.
- Reliability – Ensure successful transmission between devices. Most commonly accomplished through acknowledgement (ACK) messages and retransmissions when necessary.
- Flow control – Prevent frame loss through overloaded recipient buffers.
- Error control – Use error detection or error correction codes to control the amount of errors present in frames delivered to upper layers.

Most work on sensor network MAC protocols has focused on medium access techniques since the transceiver consumes a significant amount of energy and the MAC protocol has the most direct control over its utilization. Limited energy resources provide the primary constraint for sensor network protocol design, so proposed MAC protocols primarily focus on reducing energy losses related to the wireless medium. Other design constraints, such as fairness, latency, and throughput, appear for specific applications and we present MAC protocols designed with these constraints.

Several aspects of sensor networks differentiate the MAC protocol design from MAC protocols in other networks. First, sensor nodes conserve energy by turning off unneeded hardware because most hardware, even when not active, consumes a non-negligible amount of energy. Thus, each sensor node must somehow coordinate with its neighbor to ensure both devices remain active and participate in communication. Sensor network MAC protocols most often perform—or actively participate in—this functionality so upper layers have only an abstract concept of viable links or topology information. Several techniques, such as schedule-based clustering and separate wakeup communication, exist and we mention them when used in the discussed protocols. Secondly, sensor networks produce traffic that differs from the communication patterns existing in other networks. Environmental monitoring provides a typical sensor network application. Sensor nodes monitoring a particular environmental characteristic periodically send data to a central entity for collection and analysis. These devices individually produce traffic at periodic rates with small payloads. Both the data characteristics, which may exhibit strong periodic generation and high spatial correlation, and the small payload size, which increases the impact of protocol overhead, differentiate sensor networks from other networks. Third, the limited resources available to a sensor node prevent the use of common MAC protocol techniques. Many wireless MAC protocols constantly listen to the wireless channel for activity either for reception or before transmitting. However, a transceiver that constantly senses the channel will quickly deplete the sensor node energy resources and shorten the network lifetime to unacceptable levels.

Resource limitations also complicate the implementation of common functions available in traditional networks. Security functions become difficult