Chapter 3


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ABSTRACT

Resource constrained Wireless Sensor Networks (WSNs) require an automated firmware updating protocol for adding new features or error fixes. Reprogramming nodes manually is often impractical or even impossible. Current update protocols require a large external memory or external WSN transport protocol. This paper presents the design, implementation, and experiments of a Program Image Dissemination Protocol (PIDP) for autonomous WSNs. It is reliable, lightweight and it supports multi-hopping. PIDP does not require external memory, is independent of the WSN implementation, transfers firmware, and reprograms the whole program image. It was implemented on a node platform with an 8-bit microcontroller and a 2.4 GHz radio. Implementation requires 22 bytes of data memory and less than 7 kilobytes of program memory. PIDP updates 178 nodes within 5 hours. One update consumes under 1‰ of the energy of two AA batteries.

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INTRODUCTION

A Wireless Sensor Network (WSN) consists of autonomous sensor nodes (Akyildiz, Weilian, Sankarasubramaniam, & Cayirci, 2002). The goal of sensor node hardware development is to create tiny battery-powered low-cost disposable nodes. Increasing the performance or memory capacity increases the physical size, energy consumption and manufacturing costs. Thus, nodes are limited in computation, storage, communication and energy resources. These limitations must be addressed when designing and implementing protocols in WSNs.

It is not always possible to physically access the nodes in the field once they are deployed. Yet, adding new features, applications and program error fixes necessitates updating the program image that contains the software and protocols running on a node. The solution is a WSN reprogramming protocol, which is used to inject new software into a WSN.

Five general challenges affecting reprogramming in WSNs can be identified (Wang, Zhu, & Cheng, 2006). First, large program images must be transferred reliably through an error prone medium. Thus, the receiver should be able to detect errors and request the corrupted segments again. Second, processing speed and memory capacity in nodes set limits to the time and space complexity of designed protocols. Third, battery powered WSN nodes inherently require the reprogramming protocols to be energy efficient. Fourth, the reprogramming protocol must be scalable enough to handle WSNs that consist of hundreds or thousands of nodes deployed in varying densities. And fifth, the operating system, which is used in nodes, can set limits on the program image format and the reprogramming protocol.

Several protocols (Wang, Zhu, & Cheng, 2006) have been proposed for reprogramming a WSN. A common approach is to equip each node with external memory storage where the new program image is stored. Once the image has been received and verified, a dedicated image transfer program copies the new program image over the old image. This approach allows uninterrupted operation as the new image is transferred in the background. However, the additional memory increases hardware price and takes place on the circuit board, therefore necessitating expensive or energy consuming platforms that prohibit the vision of long term, disposable nodes. Furthermore, many protocols (Hui & Culler, 2004; Levis, Patel, Culler, & Shenker, 2004; Levis & Culler, 2002) support a particular operating system only.

In this paper we present the design, implementation and experimental results of a Program Image Dissemination Protocol (PIDP) for autonomous adhoc multihop WSNs. PIDP consists of firmware version handshakes between nodes, periodic firmware version advertisements and a reliable program image transfer, as shown in Figure 1. Firmware version advertisements are used between neighboring nodes to advertise and compare firmware versions and check for compatibility. The reliable image transfer is used to transfer program images between nodes and to rewrite the program memory. A small bootloader program locates and executes the loaded program image. PIDP is lightweight, energy efficient, reliable and, unlike other reprogramming protocols, does not require external memory for temporary storage of program images. A PIDP update in one part of the WSN does not disturb the whole network, thus, allowing a continuous operation of the non-affected nodes. Furthermore, PIDP is not restricted to a particular operating system or WSN protocol.

PIDP was evaluated using the TUTWSN prototype (Kuorilehto, Kohvakka, Suhonen, Hämäläinen, Hännikäinen, & Hämäläinen, 2007). TUTWSN is a state of the art adhoc multihop WSN technology for resource-constrained WSNs developed by Department of Computer Systems at Tampere University of Technology. TUTWSN features an energy efficient medium access control (MAC), which uses time-division multiple