Chapter 5
Infrastructure for Testing Nodes of a Wireless Sensor Network

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ABSTRACT
Maintaining reliable networks of low cost, low energy wireless sensor network (WSN) nodes is a major concern. One way to maintain a reliable network is to perform in-field testing on nodes throughout their lifetimes, identifying failing nodes so that they can be repaired or replaced. This chapter explores the requirements for a wireless test access mechanism, and introduces a method for remote execution of software-based self-test (SBST) programs. In an effort to minimize overall test energy consumption, an SBST method is derived that takes the least amount of microcontroller cycles, and is compatible with system-level optimizations such as concurrent test execution. To further reduce test energy, compression algorithms compatible with WSN nodes are explored for use on test programs. The efficacy of all proposed methods is evaluated experimentally, using current measurement circuitry applied to a WSN node.

INTRODUCTION
Wireless sensor networks (WSN) have become available for use in various industrial control, environmental monitoring, and military applications. Typical WSN applications require that the network be reliable and maintainable in order to be useful. Such constraints necessitate a unique approach to the design and testing of WSN nodes. It may seem counter-intuitive that reliable networks can be built with what are often inexpensive nodes that are individually unreliable. In fact, one way to maintain a reliable network is to test nodes throughout their lifetimes in order to identify failing nodes so that they can be repaired or replaced. This is especially vital when nodes are deployed in inhospitable environments that accelerate their failure rate. This work is aimed at addressing the aggregation of
Quality issues in the operation of WSNs: correct operation, reliability, availability, and operation under strict energy constraints.

While much work has been dedicated to the manufacturer testing of embedded systems such as WSN nodes, this chapter addresses the in-field testing of nodes in a deployed WSN. There are several obstacles in realizing this type of testing scenario, starting with the lack of a testing infrastructure. Such as infrastructure needs to define how testing is carried out at a network-level and how test programs and test responses are stored and communicated. There is also a need for test programs that achieve an adequate test quality, or fault coverage, of individual node components and of the node as a whole. All the while, nodes must operate while using as little energy as possible. This poses significant challenges in maintaining wireless signal quality, and consequently, reliable network operation. It means that the overhead of performing testing must be kept to a minimum, so as not to severely impact the operational life of the node. These obstacles are addressed in this chapter, and the approach used is briefly introduced in the following subsections.

**TESTING INFRASTRUCTURE**

To achieve a reliable WSN, one requires an infrastructure for performing remote node tests. Until recently, the most efficient and often only in-field self-testing involved using built-in self-test (BIST) hardware within wireless nodes. Since this is often not possible due to the performance, area, and energy overheads (Krstic, Lai, Cheng, Chen, & Dey, 2002), a promising type of software-based testing is introduced as an effective alternative. These software-based self-test (SBST) programs work by using an existing microcontroller unit (MCU) instruction set to perform self-testing of all digital and mixed-signal components on a WSN node. The SBST programs allow an equivalent test quality to be achieved while minimizing energy consumption.

An infrastructure is presented that allows a basestations to distribute SBST programs to nodes in the network, remotely execute the SBST programs, and return test results back to the basestation. A method is also presented that harnesses regular network nodes as helper nodes in characterizing the wireless links that they can establish with their neighbors. The resulting testing infrastructure allows detection of failed node and even prediction of failing nodes to be achieved.

To ensure that nodes are properly tested, any test that is employed must meet an acceptable coverage of modeled faults (fault coverage). The SBST programs that are used must then be built to test the entire node, and must cover every testable component on-board the node. Testable components include the MCU, memory, RF module, and sensors, as these are the primary components of any WSN node. A known-good test result for each test must also be calculated and stored separately. The result can then be compared with actual results remitted by nodes.

**ENERGY EFFICIENCY**

Since nodes are power-sensitive devices whose power sources are often on-board batteries, network quality can suffer if some or all nodes exhaust their energy reserves prematurely. Any overhead energy consumption must be minimized, such as the running of self-test programs. To do this, several energy-saving techniques are introduced which can reduce test energy consumption and test time:

-**Test optimization**: Test time is decreased by selecting the most efficient set of instructions to achieve the same test quality.
-**Test combination**: There is an inherent overlap in testing separate systems on the same node. The coverage of each test is analyzed and redundancy eliminated.
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