Department of Electrical and Computer Engineering
University of Rochester, Rochester, NY
Ph.D. Public Defense

Tuesday, April 7, 2015
2:00 PM
Hopeman Engineering Building, Room 335

Increasing Coverage and Improving Efficiency for RFID Systems and Wireless Sensor Networks

Li Chen

Supervised by
Professor Wendi Heinzelman

Abstract: Radio-frequency identification (RFID), which uses radio-frequency electromagnetic fields to transfer data between an RFID reader and RFID tags in order to identify and track objects, has been widely deployed in recent years. RFID systems have the advantages of low cost, easy deployment and high design flexibility, and hence are used for access control, commercial tracking, toll collection and asset management. Compared to other identification methods such as bar codes and QR codes, RFID tags can be accessed without a line of sight, which increases the flexibility of ID tracking.

One of the key limitations for RFID technology is coverage. An RFID system with better coverage can access more tags in a larger area with fewer RFID readers, which leads to lower cost, less access delay and higher tag access efficiency. My research begins with an investigation of the coverage problem for passive RFID tags. Due to the limitations of the transmission power, the coverage is limited. I developed and implemented a range extension approach for passive RFID tags using devices called EDGE devices. With the help of EDGE devices, the coverage of a single RFID reader can be doubled. Also, multiple EDGE devices can work cooperatively to further extend the coverage area.

Another challenge in RFID system design is the MAC protocol. Due to some hardware limitations, most RFID systems are designed to use a contention based MAC protocol, which leads to high collisions, low fairness and low scalability. I proposed a token based RFID MAC protocol called Token-MAC to address these issues. Token-MAC can achieve a higher tag rate than contention based protocols. Also, Token-MAC can provide higher fairness performance, and it increases the scalability of the RFID system as well. I implemented the Token-MAC protocol in a programmable RFID tag and evaluated the performance of Token-MAC. I also compared the performance of Token-MAC with a TDMA approach and the standard RFID protocol called C1G2 in experiments and through simulations.

As passive RFID tags can be powered by an electromagnetic field, it is possible to use these devices to build a wake-up radio for Wireless Sensor Networks (WSNs). Passive wake-up radios can greatly increase the operational lifetime for a wireless sensor node by eliminating idle listening, when the node is awake but not transmitting or receiving data. However, due to the limited amount of energy harvested by an RFID tag, the limited wake-up range is a problem for passive wake-up radio sensor nodes. Most passive wake-up radio receivers can only work with a wake-up distance much shorter than the communication range. In this the- sis, I present a passive wake-up radio design for Wireless Sensor Networks with extended wake-up range. This wake-up radio utilizes a high efficiency power harvesting receiver, a low power wake-up trigger circuit, and a wireless sensor node to build a passive wake-up sensor node called a REACH-Mote.

Furthermore, due the high efficiency power harvesting receiver and the com- pact RFID transmitter, it is possible to build a sensor node that operates using the energy obtained from the power harvester rather than from a battery and utilizes the harvested energy to transmit energy to nodes further away, waking up a second level of nodes. This potential network topology may lead to a new design in wireless sensor networks.

In summary, I have developed 1) an RFID range extension method using EDGE devices that improves the coverage of RFID systems; 2) Token-MAC, an RFID MAC protocol that improves the performance of the RFID system; 3) passive wake-up radio sensor nodes called REACH-Mote and REACH^2-Mote designed for wireless sensor networks; and 4) a multi-hop passive radio wake-up sensor node. These designs improve the performance of RFID systems and wire- less sensor networks, enhancing the network stability, throughput and lifetime and enabling new applications of RFID systems and wireless sensor networks.