Power-efficient and Reliable MAC for Routing in Wireless Sensor Networks

MSc DCNDS - Group C - Executive Summary

Ioannis Daskalopoulos   Hamadoun Diall

Kishore Raja

. . .

Supervisors: Stephen Hailes (UCL) and George Roussos (Birkbeck College)

. . .

University College London

Department of Computer Science

MSc Data Communications, Networks and Distributed Systems

. . .

Gower Street, London WC1E 6BT, UK

September 2005

Contents

1 Overview

Recent technological advances are enabling the continuous miniaturisation of components necessary to develop tiny and inexpensive sensor devices capable of communicating wirelessly over short distances. These devices, loaded with appropriate software, can be networked in an *ad hoc* manner to form wireless sensor networks that ultimately empower us to perform ubiquitous, untethered monitoring of the environments we work/live in at resolutions previously unattainable and in ways yet unimaginable. The range of potential applications is simply daunting...

Wireless sensor networks pose, however, unique challenges: small size and low cost requirements impose harsh resource constraints on sensor nodes in terms of of processing power, memory, network bandwidth and, above all, energy. The significance of these limitations lies in the fact that the paradigms established for resource-rich and well-connected systems simply cannot be applied. Currently, and for the foreseeable future, energy awareness and efficiency is the single most important metric in the design of algorithms for data collection, processing and communication.

2 Objectives

In this project we initially intended to look at multi-hop network routing issues within wireless sensor networks, taking energy consumption considerations into account. We also had access to a modular prototype sensor platform developed by IMEC -- a world-class, high-tech microelectronics research centre in Belgium. As their system, based on T.I. MSP430 micro-controller and a Nordic nRF2401 radio chip, lacked a proper operating system or general-enough abstractions for a networking stack, we were required to build or port some of this basic software.

In our quest to provide software support for this sensor platform we came across a number of issues, exacerbated by a very steep learning curve for all the hardware and software involved. The pace of our progress was hampered to a degree that forced us to redefine our goals and concentrate mainly on link-layer aspects of the radio networking stack.

3 Related Work

Wireless sensor networks form a relatively new and very active area of scientific investigation of electronic engineering and computer science, that keeps attracting increasing amounts of attention from research communities worldwide. Nonetheless, numerous questions still remain open in almost all aspects: hardware design, software paradigms, networking algorithms, etc. The aforementioned resource limitations imply that solutions tend to be very application-specific, therefore no single protocol can address all scenarios optimally.

As we aimed to port an operating system onto the IMEC sensor platform, we looked at two solutions: TinyOS and Contiki. We selected the former for being more mature, with a wider user community and having better support for the MSP430. Furthermore, we surveyed a significant number of energy efficient protocols devised specifically for wireless sensor networks, both for medium access control (or MAC) and data routing, and even integrated link-layer/routing approaches.

We also came across a sensor platform -- D-Systems, developed at Cork University, Ireland -- that featured the same nRF2401 radio but a different micro-controller. As there was TinyOS software available, we it as base for developing support for our platform.

4 Achievements

Due to unforseen issues and time constraints we were unable to fully explore our ambitious, initial objectives. However, we successfully met our revised goals:

- First TinyOS port to a platform combining an MSP430 micro-controller and an nRF2401 radio chip.
- TinyOS support of all relevant subsystems of IMEC's prototype -- most of MSP430's features and peripherals, nRF2401 radio chip, and all sensing devices on-board.
- Development of a simple, yet reliable and energy efficient, MAC protocol tailored for the specific characteristics and limitations of the radio unit present on IMEC's prototype platform.
- Empirical evaluation suggests a high packet delivery ratio (above 95%) with relatively low radio duty cycles (25% active), particularly for applications generating regular traffic patterns.
- The above results translate into significant energy savings, if we consider that the radio subsystem accounts for an overwhelming slice of the sensor node's power budget (˜23 mA with radio turned on vs. almost nil when off).
- MAC algorithm implementation extended to support simulation under TOSSIM, TinyOS' integrated wireless sensor network simulator.
- Multi-hop routing protocols bundled with TinyOS work on top of the developed radio stack, which was tested experimentally and in simulation.
- Software prepared for release, including user-level and technical documentation.

5 Conclusions

Despite the many challenges encountered along the way, the project has been a very rewarding learning process about wireless sensor networks for all the team members. It is expected that the deliverables produced will be of interest to IMEC -- the project's primary stakeholder --, also UCL where hands-on courses on wireless sensor network are planned for next year, and probably even the wider reserach community...