Researches in Wireless Sensor Networks

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Outline

- Introduction to Wireless Sensor Networks (WSNs)
- Research Issues in WSNs
- Applications of WSNs
- Currently Research Results
Introduction

- A new generation of massive-scale sensor networks suitable for a range of commercial and military applications is brought forth by
  - Advances in MEMS (micro-electromechanical system technology)
  - Embedded microprocessors
Tiny, cheap sensors may deploy onto roads, walls, or machines, creating a digital skin that senses a variety of physical phenomena of interest

- Monitor pedestrian or vehicular traffic and intelligent transportation grids in human-aware environments
- Report wildlife habitat conditions for environmental conservation
- Detect forest fires to aid rapid emergency responses
- Track job flows and supply chains in smart factories
Challenges

- **Limited hardware**: Each node has limited processing, storage, and communication capabilities, and limited energy supply and bandwidth.

- **Limited support for networking**: The network is peer-to-peer, with a mesh topology and dynamic, mobile, and unreliable connectivity.

- **Limited support for software development**: The tasks are typically real-time and massively distributed, involve dynamic collaboration among nodes, and must handle multiple competing events.
Sensor Node: Mote

- Mote modules were developed by U.C. Berkeley and Crossbow Technology Inc.
- Power, size, and cost constrained
  - Slow clock cycles of microcontroller
  - Small memory
  - Small number of HW controllers
- TinyOS
Sensor Devices

- Main components:
  - Micro-processor (MCU)
  - Micro-sensor
  - Micro-radio (RF module)
  - Limited power supply
Sensor Boards for Motes

- **MTS300 Multi Sensor Board**
  - Light, Temperature
  - Microphone, Sounder
  - Tone Detection Circuit
  - Compatible with MICA, MICA2

- **MTS310 Multi Sensor Board**
  - Light, Temperature
  - Microphone, Sounder
  - Tone Detection Circuit
  - 2-Axis Accelerometer
  - 2-Axis Magnetometer
  - Compatible with MICA, MICA2
Research Issues in WSNs

- Localization and Tracking
- Time Synchronization
- Routing Protocols
- Topology Control
- Coverage Problems
- Databases, Platforms, and Tools
Localization

- For several sensor network applications, including target tracking and habitat monitoring knowing the exact location where information was collected is critical
- The value of the information collected can be enhanced if the location of the sensors where readings were made is also available
Localization

How To Get Position?

- Just assume that, don’t have any reason or,
- The placement of all nodes are regular topology or,
- All nodes equipped with GPS or,
- Inferring positional information from some constraints or condition
Localization

- GPS build nodes localize themselves within a few meter’s accuracy by listening to signals emitted by a number of satellites

- GPS’s cons
  - Expensive
  - Difficult to incorporate into every sensor node
  - Power consumption
Range-based Scheme

- Determine the distance between two different sensor nodes based on
  - Time of Arrival (TOA) or,
  - Time Difference of Arrival (TDOA) or,
  - Angle of Arrival (AOA), or
  - Received Signal Strength (RSS).
Range-Based Localization Algorithms

The position of a node can be determined when 3 beacons are within its range.
Range-Free Scheme

- Two kinds of sensor node
  - *Beacon node*: Equip GPS and can get own location information by GPS
  - *Normal node*: Don’t equip GPS
An Example of WSNs with Beacon Nodes

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Example of Connection-Imposed Proximity Constraints
The *Estimative Rectangle* (ER) of circles as a minimum rectangle that cover the intersection of these circles.

Note worthily, the four edges of ER must parallel x-axis or y-axis.
Example of ER
The Method of Location Estimation

Regard the center of the ER as the estimative location
Time Synchronization

- Since the nodes in a sensor network operate independently, their clock may not be, or stay synchronization with one another.
- This can cause difficulties when trying to integrate and interpret information sensed at different nodes.
Clock and Communication Delays

- Time differences caused by the lack of a common time origin are referred to as clock phase differences or (clock bias)
  - The clocks of different nodes may disagree on what time”0” means
  - Clock skew (drift): At real time $t$ the computer clock indicates time $C(t)$, which may or may not be the same as $t$. 

Difficulties in Time Synchronization

- In sensor network
  - No special master clocks are available
  - Connections are ephemeral
  - Communication delays are inconsistent and unpredictable
The Latency in Channel

- Send time: construct the message
  - Operating system calls
  - Context switching
  - Data access to the network interface
- Access time: access transmission channel
  - Contention
  - Collisions
- Propagation time: message across the channel to the destination node
  - Highly variable (Single hop or multi-hop)
- Receive time: this time for the network interface
  - The delay can be kept small
Routing Protocols

- Geographic, Energy-Aware Routing
- Energy-Minimizing Broadcast
- Energy-Aware Routing to a Region
- Attribute-Based Routing
- Congestion Control
- …
Topology Control Problem

- Topology control is to design power-efficient algorithms
  - maintain network connectivity
  - optimize performance metrics such as network lifetime and throughput
- Topology control determines the network topology by controlling the transmission power of sending a physical layer broadcast
Motivation

- No topology control: large transmission radius (with maximum transmission radius $R$)
- high interference
- High energy consumption
- Low throughput
Motivation

- No topology control: small transmission radius

- Network may partition
Motivation

- With topology control
  - Global network connectivity
  - Little interference
  - Low energy consumption
  - High throughput
Coverage Problem

- Find a subset of connected sensor nodes to cover an queried region.
Coverage Problem

- Each node has different sensing range and different communication range
- Nodes are sufficient to cover the sensor network and connected
- Finding a minimum number of sensing nodes $k$-covering a given region is NP-hard even $k = 1$
Recently Research Results
無線感測器硬體 Octopus I – 以AVR為基礎 (2006/3完成)

ATmega128

CC2420

LEDs

Size: 68*25 (mm)

8-bit AVR microcontroller core @8MHz
{128KB in-system programmable flash
4KB RAM
4KB EEPROM
ADC 10-bit 8 Channels}
+ IEEE 802.15.4 compliant RF transceiver
無線感測器硬體-Octopus I

Size: 68mm*25mm
無線感測器硬體-Octopus I Dock

Sensor node

Buttons

I/O connector

JTAG connector

ISP connector

RS232

Size: 100*58 (mm)
無線感測器硬體 Super Node–以MSP430為基礎

USB Connector

USB Chip

MSP430

Light Sensor

Temperature Sensor

CC2420
IEEE 802.15.4

LEDs

Size: 55*30 (mm)

16-bit MSP430 microcontroller core @8MHz
{40KB in-system programmable flash
10KB RAM
ADC 12-Bit 8 Channels}
無線感測器硬體 Super Node–
以MSP430為基礎

1MB Flash
CC2420
MSP430
Temperature Sensor
USB Connector
Resets
Connector

Size: 55*30 (mm)

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Hardware Features

- CC2420 - IEEE 802.15.4 wireless transceiver
- MSP430 - 8MHz Core microcontroller
- Expandable flash memory – up to 1 MBytes
- External oscillator – For the deep sleep mode
- A connector with 50 expansion I/O pins
- Sensors in advance
  - Two light sensors
  - One temperature-humidity sensor
Under Development Sensor Node

- WSN Simple Node
無線感測器測試平台
(Testbed)
無線感測器測試平台

- 模擬上的限制
  - 硬體的時序(Timing)和中斷(Interrupts)
  - 環境影響與即時事件
  - 難以模擬MAC層

- 實驗上的資源問題
  - 龐大數量的實驗
  - 異質性的實驗

由於有上述兩種主要的問題，因此需使用真實的實驗平台來實驗
無線感測器測試平台-實際安裝之環境與設備

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無線感測器測試平台 - 所使用之無線感測器

- 兩種自製的無線感測器

Octopus I

Octopus II

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無線感測器測試平台-無線感測器之部署位置圖

Testbed MAP

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無線感測器測試平台-3-Tier式的系統架構
結合自走車巡邏與定點監視器之遠端監控系統
目標

- 設計與實作出利用無線感測器、智慧型自走車與嵌入式作業系統，並結合智慧型視訊監控之系統，提供遠端監控之功能
- 目的應用於居家保全與即時監控
應用場景

Access Point

Server

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成果展示

- 無線導航智慧型機械人 Pioneer 3DX
  - 6具聲納感測器
  - Wireless及TCP/IP架構
  - 完整形高階C/C++程式設計環境，可用在Linux/Win32 OS
  - 可擴充各種感測器/視訊CCD/GPS/電子羅盤等

影片播放1    影片播放2

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NCU Mobile Robot (1 G)
Mobile Sensor Node with Ultrasonic (2 G)
自動避障自走車 (3 G)