Fire Sensor Network Demonstrator

Master’s Thesis

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Overview

- **Context**
  - Motivation
  - Related Work

- **Tools/Hardware**
  - TinyOS2.0
  - Tmote Sky
  - DSN and Adapter for Tmote Sky (Bootloader)

- **Cluster heartbeat**
  - Concept
  - Implementation
  - Results
Motivation

- Implementation of a robust reporting system on a wireless sensor network
  - Requirements
    - Detection of node failures < 100 seconds
    - Robust against temporary loss of links
    - Low power consumption

- Developing using the JAWS Deployment Support Network
  - Testing
  - Optimisation
  - Profiling
Related Work, Positioning of this Thesis

- MAC Protocols for WSN (Lowpower)
  - Strategies for saving power
    - Avoid collisions
    - Avoid overhearing
    - Minimise idle listening
    - Minimise protocol overhead
  - Contention based (random access)
    - B-MAC, S-MAC, WiseMAC ..
  - Schedule based
    - Sink based, Clusters [Arisha]
    - Rotating duties, Clusters [PACT, BMA (LEACH)]
    - Static scheduling, regular topologies [SS-TDMA]
    - Partitioned scheduling [EMACs, LMAC]
Related Work, Positioning of this Thesis

- Failure Detection in WSN

  - **General**
    - [Szu-Chi Wang, Sy-Yen Kuo, DSN‘03]
      - Heartbeat, Gossipping (Random, Coordinated)
      - Local broadcast
      - Simulation
      - No linklayer lowpower considerations

  - **Cluster based**
    - [Ann T. Tai, Kam S. Tso, William H. Sanders]
      - Cluster = 1-hop neighbourhood
      - Heartbeat
      - Relies on inherent redundancy of radio transmissions
      - No implementation
      - No linklayer lowpower considerations

(a) Intra-cluster

(b) Inter-cluster
Tools/Hardware

-Hardware: Tmote Sky
  -TI MSP430 microcontroller
  -250kbps 2.4GHz wireless transceiver (CC2420)
  -Ultra low power
  -Fast wakeup from sleep (<6μs)
  -Commercial

-Software: TinyOS 2.0
  -Framework for wireless sensor network applications
  -Modular composition
  -NesC-Language
  -Final release pending
  -By default no lowpower MAC protocol implementation
DSN Connection for Tmote Sky

Interfaces of the Tmote

**USB Interface**
- Convenient way for programming
- Communication for logs is simple
  - Needs a USB master circuit

**JTAG Interface**
- Standard programming interface
- Needs additional implementation of the JTAG protocol for the BTnode
- No normal communication possible (logs)

**Pins of UART0**
- Easy communication
  - Not standard port for bootstrap loader
    - Requires a new bootstrap loader
DSN Connection for Tmote Sky

Hardware

Software (Based on TinyOS)

- Bootstrap Loader
  TI MSP Bootstraploader protocol over UART0

- DSN Component
  Communication with DSN
  Logmessage buffering
  Generates target command events

User Program
Cluster Heartbeat: Operation Concept

- **Approach**
  - Coordinated heartbeat
  - Crosslayer optimisation (TDMA, special slot assignment)
  - Redundancy through mesh topology
    - Local broadcasts
    - Local aggregation of alive-information (Bitmask)
  - Acknowledged messaging on application layer
  - Bounded network size (Cluster)

1. Reporting Wave to sink
2. Acknowledge Wave from sink
Information Flow in the Cluster, Reporting Wave

- Reporting wave towards clusterhead
  - Nodes
    - Wake up
    - Aggregate bitmask
    - Broadcast bitmask in their slot
  - Only one packet sent by each node
  - Promiscuous listening increases robustness

Flow of alive-information
- Clusterhead
- 1-hop node
- 2-hop node
Information Flow in the Cluster, Acknowledge Wave

- Initiated from the clusterhead
  - Send order is reversed
  - Node action when receiving packet
    - Synchronize to clusterhead
    - Update schedule
    - Rebroadcast ACK-wave in their slot
  - Only one packet sent by each node
  - Promiscuous listening increases robustness

Flow of alive-information:
- Clusterhead
- 1-hop node
- 2-hop node
Retransmissions, Short Wave Rounds

Faultless case

Shortwaves in error cases
Nodes missing

Schedule missing
TDMA Scheme

- Report wave
- Acknowledge wave
- Sleep

Slot

- TLOAD
- TRXTX
- TTRANSMIT
- TXRX

Guardtime \( \geq T_{LOAD} + T_{RXTX} \)

Processing time \( \geq T_{TXRX} \)
Guardtime for Reporting Wave

Slot synchronisation

Interval for transmission start

Maximal clock drift over one period

Slot ..

1 2 3 4 5

Node 1
Node 2
Node 3
Node 4
Node 5

Guardtime avoids overlapping slots

Slot synchronisation
Clock drift (20ppm)

Interval for transmission start

Maximal clock drift over one period

Guardtime avoids overlapping slots

Slot ..

1 2 3 4 5

Node 1
Node 2
Node 3
Node 4
Node 5

Guardtime avoids overlapping slots
Slot Calculations and Measurements

<table>
<thead>
<tr>
<th>Description</th>
<th>Calculated based on datasheet</th>
<th>measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>(T_{LOAD})</td>
<td>-</td>
<td>1.1 ms</td>
</tr>
<tr>
<td>(T_{RXTX} + T_{SFD})</td>
<td>352(\mu)s</td>
<td>360(\mu)s</td>
</tr>
<tr>
<td>(T_{TXRX})</td>
<td>192(\mu)s</td>
<td>-</td>
</tr>
<tr>
<td>(T_{TX}) (29 Bytes)</td>
<td>928(\mu)s</td>
<td>1020(\mu)s</td>
</tr>
<tr>
<td>(T_{TX}) (n Bytes)</td>
<td>n * 32(\mu)s</td>
<td>-</td>
</tr>
<tr>
<td>(T_{GUARD_REPORT}) (100s period)</td>
<td>4 ms</td>
<td>-</td>
</tr>
<tr>
<td>(T_{PROCCESS_GUARD,MAX})</td>
<td>-</td>
<td>224(\mu)s</td>
</tr>
<tr>
<td>(T_{PROCCESS_ACK,MAX})</td>
<td>-</td>
<td>264(\mu)s</td>
</tr>
</tbody>
</table>
Slot Calculations and Measurements (cont.)

\[ T_{\text{GUARD REPORT}} = 4\text{ms} \geq T_{\text{LOAD}} + T_{\text{RXTX}} \]
\[ T_{\text{PROCESS REPORT}} = 224\mu\text{s} \geq T_{\text{TXRX}} \]
\[ T_{\text{SLOT REPORT,MIN}} = T_{\text{GUARD REPORT}} + T_{\text{TRANSMIT}} + T_{\text{PROCESS REPORT}} = 5.120\text{ms} \]

\[ T_{\text{GUARD ACK}} = T_{\text{LOAD}} + T_{\text{RXTX}} \]
\[ T_{\text{PROCESS ACK}} = 264\mu\text{s} \geq T_{\text{TXRX}} \]
\[ T_{\text{SLOT ACK,MIN}} = T_{\text{GUARD ACK}} + T_{\text{TRANSMIT}} + T_{\text{PROCESS ACK}} = 2.940\text{ms} \]

Guardtime is negligible

**Minimal active Time:**

\[ 16 \times (T_{\text{SLOT REPORT,MIN}} + T_{\text{SLOT ACK,MIN}}) = 128.96\text{ms} \]

At a period of 100 seconds

**Dutycycle of 1.3 %**
Robustness Analysis for Communication Faults

- Total Communication fault
- Link failures
- Channel fault
Robustness Analysis for Communication Faults

- Total Communication fault
  - Duration < Wave round
  - Separation > T_{PERIOD}
  - 3 cases

- Part of reporting wave fails
  - Sink recognises missing nodes and initiates a retry wave

- Part of reporting wave and start of ACK wave fails
  - Sink recognises missing nodes
  - First retry wave does not succeed
  - A second one is started

- Part of ACK wave fails
  - In next report wave Sink recognises missing nodes
  - For this reason a second wave round is started then
Contribution (Summary)

- DSN-Adapter for Tmote Sky
- Implementation of a reliable heartbeat-style failure detector
- Testing Implementation, Profiling with DSN
End of the Presentation

Questions?