BTnodes

Architecture and Applications

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Initial Projects

Smart everyday objects
by attaching sensor nodes:
– self aware
– context sensitive
– cooperative
– integration into computing environment

Ad hoc networking scenarios
– integrated application protocols
– scalable multi-hop routing

Wearable Computing
Bluetooth Piconets

Communication organized in piconets
- controlled by one master
- up to 7 active slaves
- 255 inactive (parked) slaves

Master-Slave
- implements centralized control
- synchronization of all slaves
- only master-slave communication

Multiple piconets
- separate channels
- no coordination
Bluetooth Connections

Managed by the host controller

Statemachine for each connection

Link Layer Control & Adaptation (L2CAP)
- connection-oriented
- connectionless data
- protocol multiplexing for a single “air interface”
- packet segmentation and reassembly
- channel abstraction
- encryption
- Security
- …
Hardware Requirements

Autonomous wireless communication and computing platform based on a Bluetooth radio module and a microcontroller.

Requirements

- small form factor, low component count
- standardized wireless interface
- flexible and cost effective deployment of large quantities of networking nodes
Power Consumption Details

Sensor Network Example: 10% duty cycle

<table>
<thead>
<tr>
<th>Operation</th>
<th>Power consumption [mW]</th>
<th>Lifetime [h]*</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 sec sensing</td>
<td>12</td>
<td>252</td>
</tr>
<tr>
<td>2 sec communication</td>
<td>160</td>
<td>19</td>
</tr>
<tr>
<td>54 sec idle</td>
<td>0.5</td>
<td>6048</td>
</tr>
</tbody>
</table>

Total duty cycle        ~ 6.5 mW  421

*on 840 mAh Li-ion
System Software

**Lightweight OS**
- event-driven application model
- cooperative multithreading
- device drivers (UART, RTC, ADC, ...)

**Programming**
- standard C language
- high-level Bluetooth interface
- system software available as library
- emulation environment on Linux
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Multiple Drivers and the Dispatcher

```c
void handler(/* ... */) {}
void main()
{
    btn_disp_ev_reg(RECEIVE_EV, handler, 0);
    btn_disp_run();
}
```

Diagram:
- **Application**
  - `handler()`
  - `read()`
- **Driver**
  - `read_buffer`
  - `received_irq()`
- **Dispatcher**
  - `btn_disp_run()`
  - `event_buffer`
  - `RECEIVE_EV`
  - `EVENT, handler func RECEIVE_EV, handler()`
  - `OTHER_EV, func2()`
Bluetooth enabled Appliances

Communication with other Bluetooth enabled devices
  – standard Bluetooth profiles for SMS, object push and RFCOMM

BTnode enabled Egg Carton

SMS from Egg Carton

Interactive Dialog
XHOP/R-DSR Multihop Network

Bluetooth multihop source routing prototype
- integrated scalable application protocol
- based on Dynamic Source Routing (CMU)
- routing across piconet borders to support >8 nodes

Remote topology discovery
- script like command language in the payload

Performance
- 1-2 sec per hop, depending on inquiries
Cool sights at MobiSys 2003


K. Römer: *The Lighthouse Location System for Smart-Dust*, ETH Zürich

C. Carter, R. Kravets and J. Tourrilhes: *Contact Networking: A Localized Mobility System*, U of Illinois and HP labs

K. Barr and K. Asanovic: *Energy Aware Lossless Data Compression*, MIT

M. Balazinska and P. Castro: *Characterizing Mobility and Network Usage in a Corporate WLAN*, MIT and IBM TJ Watson

All papers are available in the Wearable Repository.
Hardware Details

**Integrated PIFA Antenna**

**Communication**
- Ericsson Bluetooth Module

**LEDs, Reset, Clocks**

**Memory**
- 128 kB Flash
- 244 kB SRAM
- 4 kB EEPROM

**Generic Sensor Interfaces**

**UART and I2C Data Interfaces**

**CPU**
- Atmel ATmega 128L MCU
  - 8-Bit RISC (max. 8 MHz ~8MIPS)

**Power Management**

Dimensions:
- 61 mm
- 40 mm
- 40 mm
Designing for Power Aware Operation

Features

– optional switchable power supply for Bluetooth module
– MCU with 6 power down modes
– frequency scaling: 7.3 MHz - 57 kHz
– low idle/sleep current

– single power supply (3.6 – 16 V), single internal voltage (3.3 V)
– battery charge indicator
– direct current access shunts for all components
– internal Vcc available at every connector to power external sensor modules

Power consumption @ 3.3V, 7.3 MHz [mW] max. typ. Lifetime [h]*

– Bluetooth Connected/CPU On 250 160 12-19
– Bluetooth Idle/CPU On 95 67 32-45
– Bluetooth Off/CPU Idle 15 12 202-252
– Bluetooth Off/CPU Sleep 6 <0.5 504-6048

*on 840 mAh Li-ion