Wireless Sensor Networks
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Bluetooth in WSN?

➢ There are several commercially available MAC protocol/products
  – Wi-Fi
  – Bluetooth

➢ Why not Bluetooth in WSN?
  – The need to constantly have a master node
  – Limited number of active slaves per piconet
  – Active slave must always be switched on
  – Passive slave has to apply at master to be active slave
  – Complexity
  – Tight synchronization among nodes in piconet
However…

- **Strong points:**
  - Spread Spectrum radio
  - Mass production: ensures robustness and reduces cost

- **Dual-radio BTnodes (research at ETH Zürich):**
  - Bluetooth subsystem
  - Low-power radio
  - Scatternets with max. 4 Piconets
Understanding Bluetooth

- Bluetooth Characteristics
- Protocol Stack
- Architecture:
  - Piconets
  - Scatternets
- Radio Specifications
- Baseband Specifications
  - FHSS and TDD
- Packet Formats
- Error Correction
Characteristics

- Initial goal: Cable replacement
- Operates in the unlicensed ISM 2.4 GHz range, using FHSS
- Short communication range

<table>
<thead>
<tr>
<th>Class</th>
<th>Maximum Permitted Power (mW)</th>
<th>Maximum Permitted Power (dBm)</th>
<th>Range (approximate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1</td>
<td>100 mW</td>
<td>20 dBm</td>
<td>~100 meters</td>
</tr>
<tr>
<td>Class 2</td>
<td>2.5 mW</td>
<td>4 dBm</td>
<td>~10 meters</td>
</tr>
<tr>
<td>Class 3</td>
<td>1 mW</td>
<td>0 dBm</td>
<td>~1 meter</td>
</tr>
</tbody>
</table>

- Asynchronous (data) and synchronous (voice) service supported
- Data rate
- No need for infrastructure
- Low power consumption
Lower Layer Protocols

Applications

Logical Link Control and Adaptation Protocol (L2CAP)

Higher Layers

Link Manager Protocol (LMP)

Baseband

Radio

Bluetooth Module

Host Controller Interface (HCI)
Network Topologies

- Conventional ad hoc network

- Bluetooth
An FH Bluetooth channel is associated with a piconet.

Star Topology
- 1 Master, up to 7 active slaves
- Unlimited number of passive slaves

Master:
- determines hopping scheme and timing
- Administers piconet (polling)

Logical Channels
- Asynchronous, packet oriented
- Synchronous, connection-oriented (voice, slot reservation)
Scatternet

- Scatternet – intersecting piconets.
  - Devices can be slave in both or master in one and slave in other.

- Piconets with overlapping coverage use different hopping sequences
  - Collisions may occur when multiple piconets use the same carrier frequency at the same time

- Devices can participate in multiple piconets simultaneously, creating a scatternet
  - A device can only be the master of one piconet at a time
  - A device may serve as master in one piconet and slave in another
  - A device may serve as slave in multiple piconets

M=Master  SB=Standby  P=Parked  S=Slave
Radio & Baseband Specification

- Operates in 2.4 GHz ISM:
  - Divided into 79 hop frequencies: \( f = 2402 + k \) MHz, \( k = 0,..78 \) (but 23 in Spain, France, Japan), spaced 1 MHz apart.

- Restriction of ISM band for FH system:
  - Signal bandwidth is limited to 1 MHz
  - Data rates is limited to 1 Mb/s per channel

- GFSK:
  - Binary ‘1’: sent as positive freq deviation from RF channel center freq
  - Binary ‘0’: sent as negative freq deviation from the channel center freq

- Bluetooth radio is based on FHSS and TDD:
  - In time domain, RF channel is divided into time slot of 625 micro secs on different frequency

- Terminology:
  - Frame = a complete transmit/receive cycle
  - Slot = a 625 microsecond segment within a frame
Frequency Hopping &
Time Division Duplexing

Complete packet transmission occurs during a Slot
Frequency hops from Slot to Slot to Slot
Frames define matched Master / Slave Slot transmissions
Multi-Slave Transmission

- The Bluetooth master interleaves traffic between multiple simultaneously active slaves.
- Each Master can support up to 7 simultaneously active slaves.
Multi-Slot Packets ⇒ Reduced Overhead

625 µs

f(k) f(k+1) f(k+2) f(k+3) f(k+4) f(k+5) f(k+6)

Tx Rx

Single-slot

3-slot

5-slot

Wireless Sensor Networks
Point to Multi-Point Transmission

- The Bluetooth Master can also simultaneously transmit to all of its active Slaves at one time.
- In such transmissions there can be no reverse traffic from the Slaves.
FHSS in Piconet

Active Piconets: 1  Total Transmission Slots: 100  Transmission Slots Hit: 0  Transmission Efficiency: ~100%

Wireless Sensor Networks
Bluetooth Piconets Degrade Gracefully with Density...

- Ten active piconets
- 1000 transmission slots
- 56 collisions
- 112 slots corrupted
- ~89% net efficiency

Active Piconets: 10  Total Transmission Slots: 1000  Transmission Slots Hit: 112  Transmission Efficiency: ~89%
Packet Format:

- **Access Code:** timing synchronization, offset compensation, paging and inquiry.

- **Packet Header:**
  - Target device address
  - Type code
  - Information for packet acknowledgement, sequencing, flow control, CRC

- **Payload:** voice field, data field or both.
Fast ARQ is implemented
   – To minimize complexity, overhead, and wasteful retransmission
   – Sender is notified of packet reception in Rx slot after Tx
Thank you