Energy-Efficient Data Collection for Bluetooth-Based Sensor Networks

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Take Home Message

DCP: • **Data Collection Protocol** – a communication protocol for sensor networks
  - Optimized for BT-equipped sensor nodes
  - Builds a tree of clusters and collects data to a central base station
  - Not affected by piconet or scatternet restrictions
Outline

• Problem Statement
• BT and Sensor Networks
• Data Collection Protocol (DCP)
  – Set-Up Phase
  – Steady-State Phase
• Simulation Results
Problem Statement

- How to collect sensor data from a network with BT-equipped sensor nodes?
  - scalable
  - robust
  - energy-efficient

Scenario: Flood Prevention
BT and Sensor Networks

• ... a contradiction?
  – delay
  – energy consumption
  – network layer constraints
• ... but
  – cheap
  – available (!)
  – medium access

Thesis: Bluetooth is a qualified for prototyping sensor network applications!
Data Collection Protocol

• Term „Data Collection“

• Cooperation Strategy: **Clustering**
  – Cluster Head, Cluster Member

• Periodic Cluster **Reorganization**
  – Energy consumption
  – Topology changes

• PFA = Packet Forward Address

• DCP does not maintain connections during steady-state (unlike scatternets!)
Data Collection Protocol – 2 Phases

- Cluster Head Selection
- Cluster Formation
- PFA Delivery

Collection of Sensor Data
DCP – Set-Up-Phase (I)

1. Cluster Head Selection
   - randomly determined

2. Base Station Inquiry
   - detect CH and 1-hop-CM

3. Base Station transmits PFA
   - first CMs (1,3,4), then CHs (2)

4. Discovered nodes turn off inquiry scan
   - „invisible“ mode

5. 1-hop-distant CH inquiry
   - CM and CH discov. by BS are not detected due to disabled inq. scan

6. 1-hop-distant CH transmit PFA
   - first CMs (6), then CHs (5,7)

Abbreviations:
- BS = Base Station
- CM = Cluster Member
- CH = Cluster Head
- PFA = Packet Forward Address
DCP – Steady-State-Phase

- CM transfer sensor data to CH
- CH preprocess sensor data (data compression/fusion)
- CH forward aggregated data to PFA/BS

Nodes disconnect immediately (unlike scatternets)
- clusters are not limited to piconet size
- energy savings for low data rates
- reduced interference
  (How many Bluetooth piconets fit into a room?)
Simulation Results (I)

legend: [node density; node's transmission range]

2 simulation set-ups:
- 100m*100m with 100 nodes (node density 0.01)
- 50m*50m with 100 nodes (node density 0.04)

Unconnected Nodes

Number of Nodes Depending on a Cluster Head
Simulation Results (II)

Average Number of Hops to BS

Max. Number of Hops to BS

Cluster Head Probability
Take Home Message

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Thank You!
DCP – Set-Up-Phase (II)

- Synchronization of inquiry scans
  - Waiting time of cluster heads before inquiry

\[ T_c = T_b \cdot r \]

- \( T_c \) = waiting time
- \( T_b \) = basic time
- \( r \) = # of discovered CH not yet connected

<table>
<thead>
<tr>
<th>Bluetooth-USB-Module (chip set)</th>
<th>Allnet 1572 (Broadcom)</th>
<th>Epox BT-DG02 (CSR)</th>
<th>Aiptek BT-USB (Transilica)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( T_g ) (s)</td>
<td>4.40</td>
<td>4.46</td>
<td>4.47</td>
</tr>
<tr>
<td>ready after 6s</td>
<td>99 %</td>
<td>100 %</td>
<td>97 %</td>
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Basic Time
Outlook and Implementation