Dozer: Ultra Low Power Data Gathering in Sensor Networks

Author: Zoltán Kincses

Introduction

- Environmental monitoring
  - monitor dense temporal and spatial data, and analyze them
- WSN has large variety of favorable attributes
  - less intrusive than tethered solutions
  - temporary measurements
  - surveillance of secluded areas
  - no need for human interactions

- The energy efficiency is fundamental
- The sensor nodes equipped with a short range radio
  - this is one of the primary power consumers
  - radio should only be turned on if necessary
  - multi-hop routing techniques must be applied to transmit data from large areas
  - this is the main reason of the idle listening and overhearing

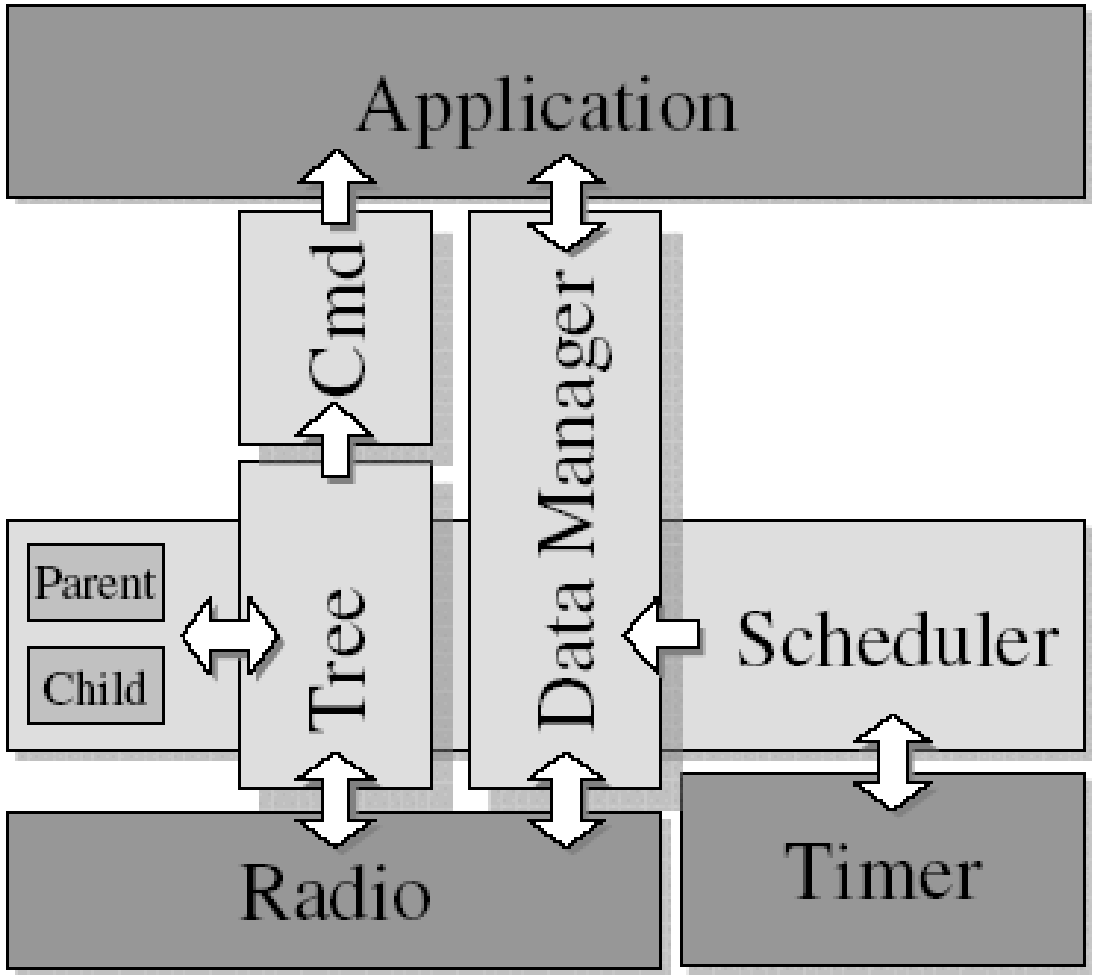
Related works

- The related works stem from generic energy-efficient MAC protocols
  - TDMA protocol
    - global schedule, each node has one or more time-slot
    - this eliminate the idle-listening and overhearing
    - hardly feasible in reality (global time synchronization)
  - contention-based protocols
    - nodes have sleep interval, awake at the same time
    - CSMA/CA used to control channel access
    - suffer from hard channel contention (T-MAC $\longrightarrow$ S-MAC)
    - low-power listening (overhearing problems)
- Most proposed protocols (TDMA + CBP)

Dozer

- Tailored for environmental monitoring and optimized for long lifetime
- Establish a tree structure on top of the physical network
- Both nodes are parent and child
- Two independent schedules for nodes
- Node as a parent decides when a child can upload data, and vice versa
- TDMA protocol, without global schedule
- Each TDMA schedule starts with a beacon message

Dozer implementation



Tree Maintance

- Node's integration in the data gathering tree
- Guarantee constant connectivity
- Energy efficient suspend mode
- There main parts
  - connection setup
  - connection recovery
  - suspend mode

Connection setup

- Upon wakeup in the bootstrap mode the nodes try to join the tree
- Starts listening for beacon messages
- Beacon messages are periodically sent by the attached nodes in the TDMA schedule
- Each beacon message is analyzed and ranked
  - distance to the sink
  - load

- The connection setup is initiated after the second beacon
  - the parent node stay receive state for a short amount of time
  - in this window accepts the incoming connections
  - on receiving a connection request parent signs a new TDMA slot for the child
  - if failing to connect, try another neighbor before retrying on the same parent

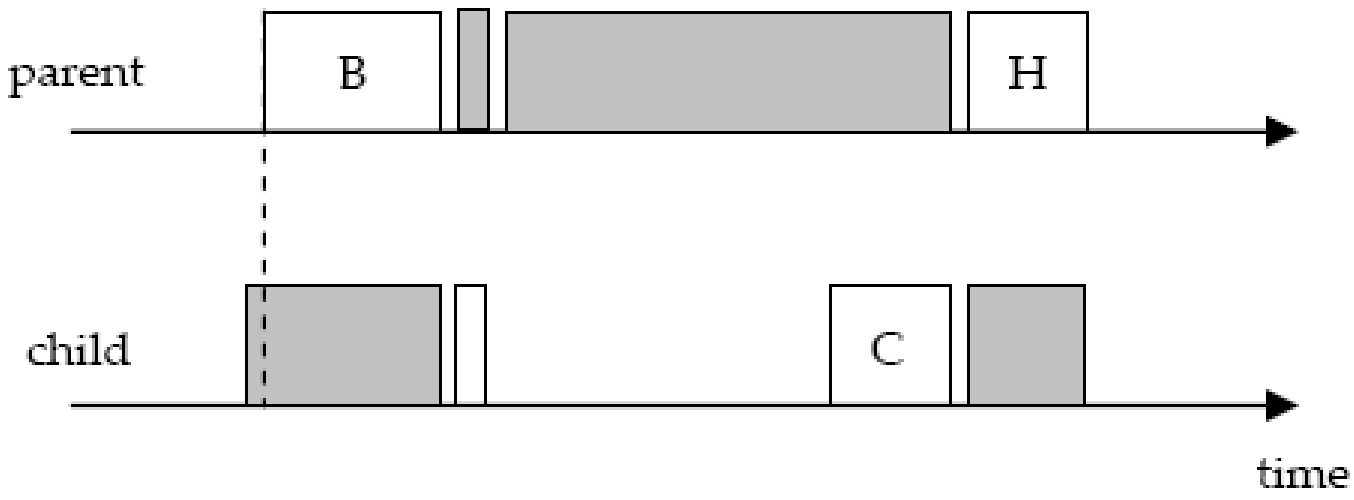


Figure 2: Connection setup – The parent node sends a beacon (B). Upon beacon reception the child sends a busy tone to activate the contention window. The child then transmits its connection request (C). A handshake (H) serves as an acknowledgment. Shaded areas denote the times a node is actually listening.

Connection recovery

- Wireless links must be excepted to break at any time
- Connection fail if multiple consecutive data transfer fail
  - try establish a new connection with the parent in its list
  - if no parent, go back bootstrap mode
  - to guarantee up-to-date list node periodically listen for beacons (not costly)
  - infrequently search for possible well suited parents

Suspend mode

- Node not connected and no beacon messages received → go suspend mode
- Periodically samples the channel
- Balance between the sleep time and rapid connection

Scheduler

- Communication between parent and children based on the TDMA protocol
- Dozer only aligns one hop per neighbors in the tree
- The nodes have to maintain two schedules
  - one provided by the parents
  - one self determined for the children
- In theory wake up times can calculate correctly, in practice clock-drift has to be considered
- In Dozer the receiver is responsible for the compensation of this drift

- The self determined TDMA schedule is fixed length
- Tree Maintance module request free slot from the Scheduler
- This slot then reserved for the new children
- No direct time synchronization, only beacons are used
- The collision is excluded, but happens infrequently and indicate the wrong alignment of two independent schedules

- Dozer extends the TDMA interval with a random time span
- The child get the seed value of the random number generation in the next beacon
- The current random number is used for the generation of the next random number

Data administration

- Data manager module features a message queue for incoming and injected packets
- As soon as the Scheduler signals this block start to send the messages
- Each messages are acknowledged and until this they stay in the queue
- With the acknowledgement the parent notifies, how many more message willing to accept
- Buffering only one data, the newer will be sent

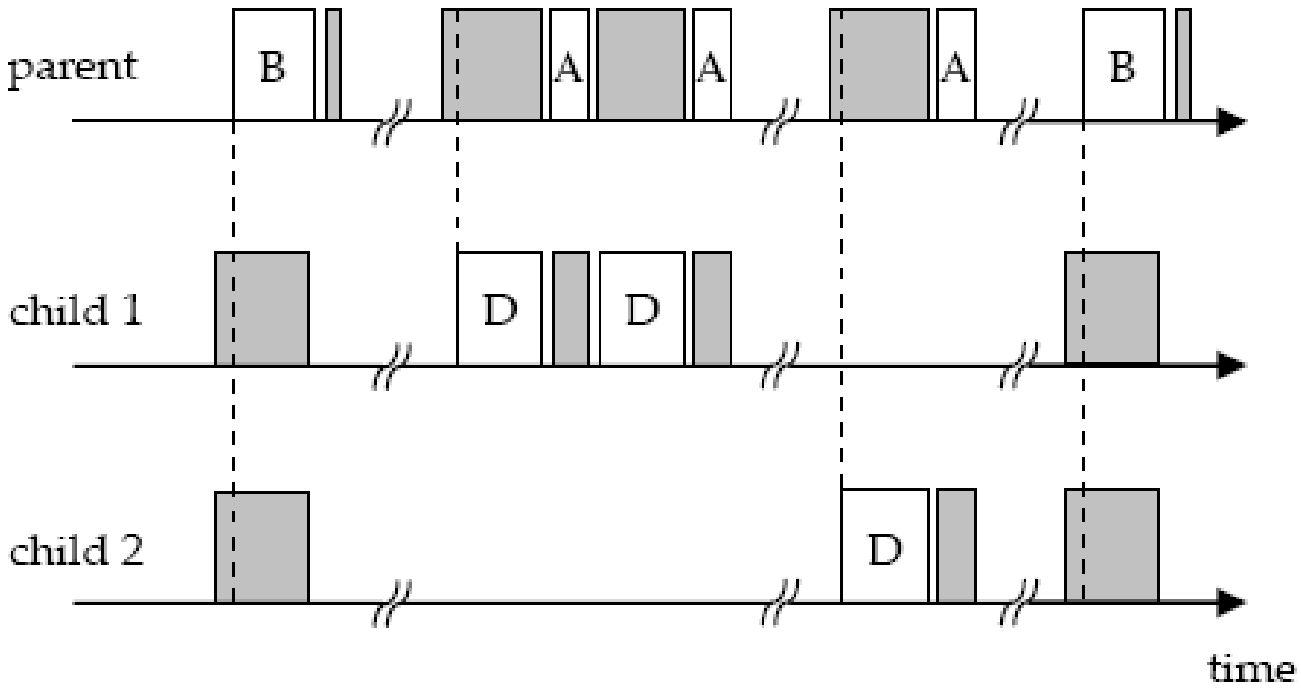


Figure 3: Message reception of a parent with two children. Upload slots are determined by parent beacon (B). All data messages (D) are explicitly acknowledged (A).

Command management

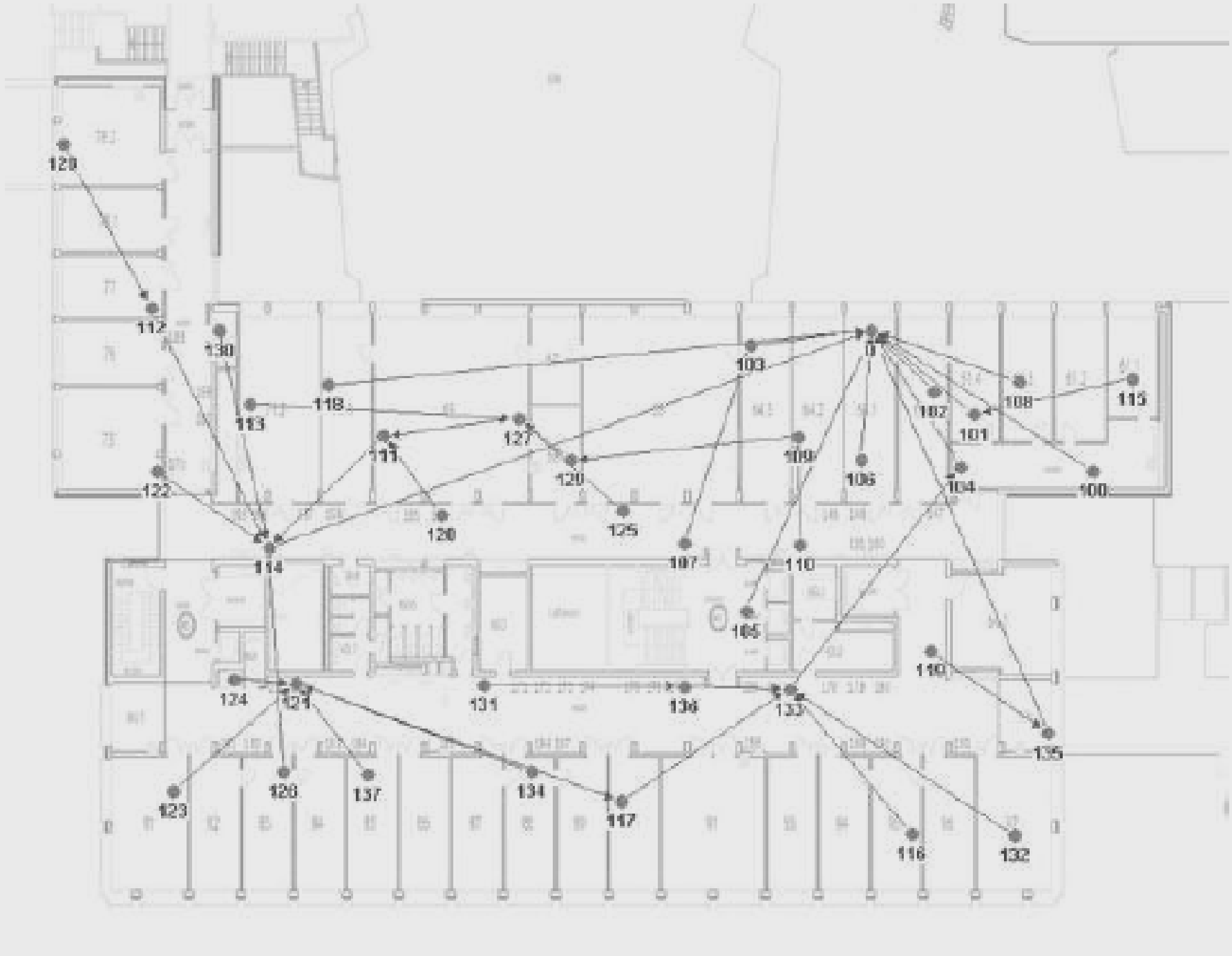
- Sink is able to send commands to the network
- Commands injected to the next beacon message
- If a beacon message received which contains a command, the Tree Management module gives it to the Command Manager

Evaluation

- Mote
  - TinyNode 584
    - MSP430
    - 10 KB RAM
    - 48 KB program memory
    - 512 KB external flash
  - Semtech XE1205 radio transceiver (135 kbit/s)
  - 868 MHz working frequency
  - 1900 mAh AA batteries
  - TinyOS 1.x operation system

Office floor experiment

- 40 TinyNode
- 70 x 37 meters area
- 80 people in office time
- Heterogeneous network structure
- 38 sensing node
- 1 base station node
- 1 node for debugging


129
112
130
113
118
111
127
120
125
122
126
114
103
0
102
108
115
101
109
106
104
100
107
110
105
119
124
121
131
136
133
135
123
128
137
134
117
116
132

Thank you for your kind attention