Algorithms for Radio Networks

WSN: Data Aggregation II
Data Aggregation

Minimal temperature: 17°C

\[ \text{Minimal temperature: } 17°C \]
Routing Models for Data Aggregation

- **Address Centric Protocol**
  - each sensor sends independently towards the sink
  - not suitable for (real) aggregation

- **Data Centric Protocol**
  - Forwarding nodes can read and change messages

- **Literature**
  - Krishnamachari, Estrin, Wicker The Impact of Data Aggregation in Wireless Sensor Networks, Proc. of the 2nd Int. Conf. on Distributed Computing Systems Workshops (ICDCSW’02)
Energy Optimal Tree Structure

- **Given:**
  - set of data sources and a sink
  - communication graph $G$

- **Compute:**
  - Steiner tree $T$
    - sub-graph of $G$
    - connects all sources and sinks
    - number of edges is minimal

- **Alternative:**
  - edges have an (energy) weight
  - minimize the sum of edge weights
Steiner Tree Problem

Steiner point

Dienstag, 17. Januar 12
Theoretical Bounds

- Costs for address based Routing $N_A$
  \[ N_A = \sum_i d_i \]
  - $d_i$: shortest distance from source $i$ to sink $s$

- Cost for optimal data centric routing $N_D = \text{weight of Steiner-tree}$
  \[ N_D \leq (k - 1)X + \min_i \{d_i\} \]
  - $X$: maximal shortest path between sources
  - $k$: number of sources

  \[ N_D \geq \min_i \{d_i\} + k - 1 \]
Theoretical Bounds

- For fixed $X$ and $k$ and growing $\min_i \{d_i\}$

\[
\lim_{d \to \infty} \frac{N_D}{N_A} = \frac{1}{k}
\]
Theoretical Bounds

- **Theorem**
  - If the subgraph induced by the sources is connected, then the optimal routing can be computed in polynomial time.

- **Proof sketch**
  - Compute MST $T$ for the sources.
  - Compute the shortest path from $T$ to the sink.
Approximation Algorithm

- The Steiner tree approximation algorithm (of the last lecture) cannot be implemented efficiently in a WSN.
Suboptimal Aggregation

- Center at Nearest Source (CNS)
  - Data source closest to the sink collects all information
  - All other sources send the information on the shortest path to this source (center)
Suboptimal Aggregation

- Shortest Paths Trees (SPT)
  - Set of all shortest paths from the sources to the sink
Suboptimal Aggregation

- **Greedy Incremental Tree (GIT)**
  - Select the shortest path between the data source, closest to the sink, and the sink
  - Select successively the closest node to the tree and the shortest path to any of the tree nodes
Energy Saving by Data Aggregation

Number of Sources = 9

Krishnamachari, Estrin, Wicker The Impact of Data Aggregation in Wireless Sensor Networks, Proceedings of the 22nd International Conference on Distributed Computing Systems Workshops (ICDCSW'02)
Energy Saving by Data Aggregation

Communication Radius = 0.3

Average Number of Transmissions vs. Number of Sources

AC, CNSDC, SPTDC, GITDC, lower bound

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