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Algorithms for Radio Networks

WSN: Data Aggregation II

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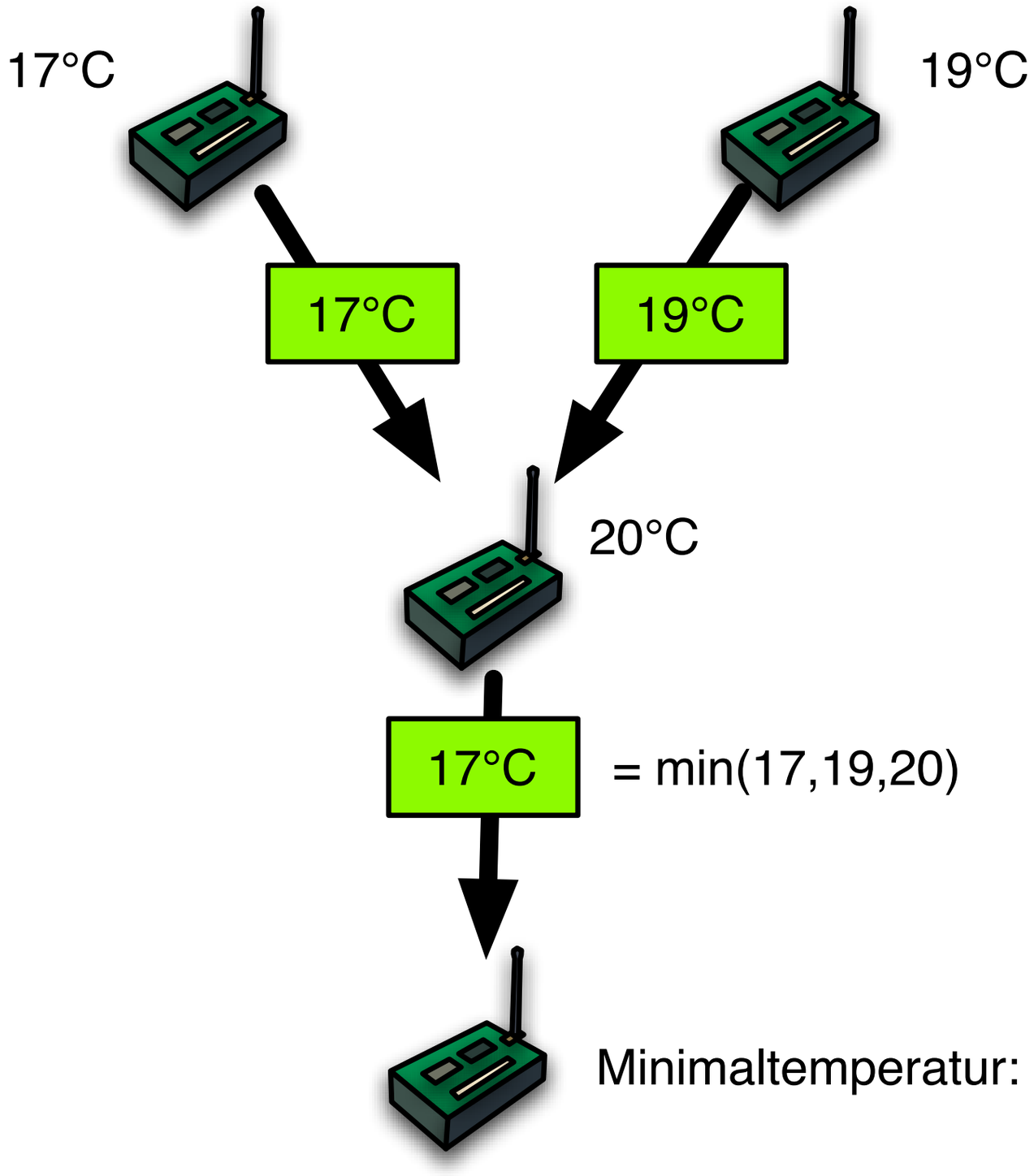
Data Aggregation



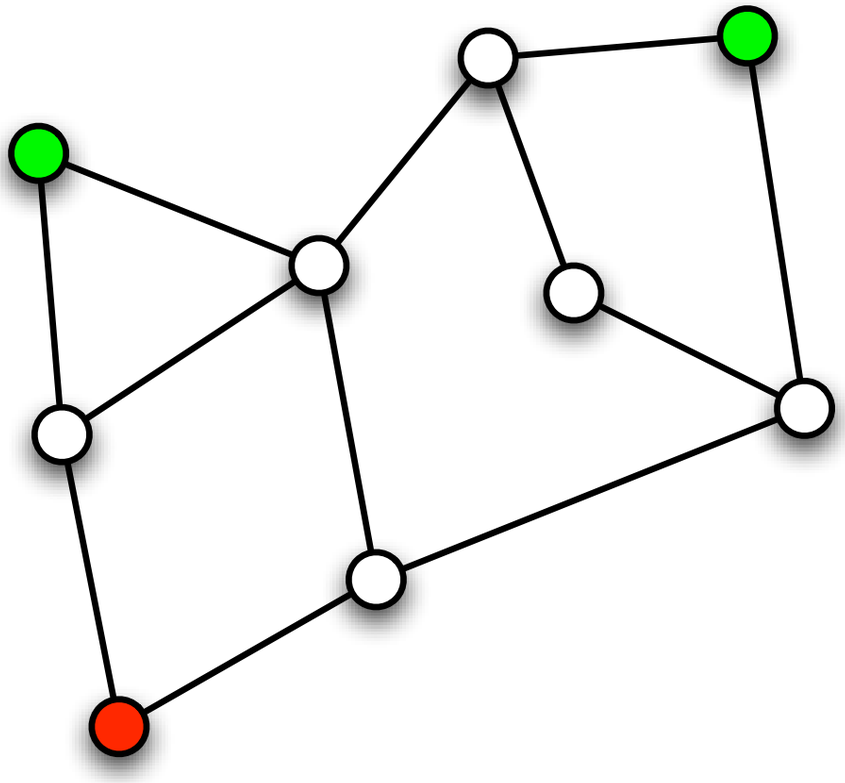
Routing Models for Data Aggregation

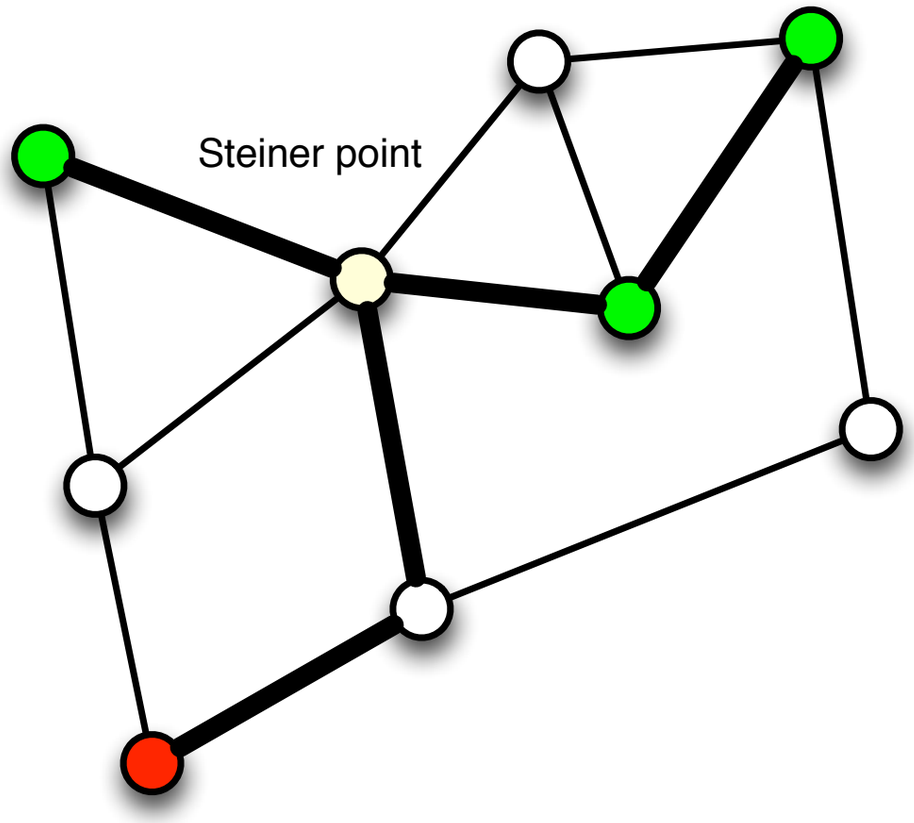
- **Address Centric Protocol**
  - each sensor sends independently towards the sink
  - not suitable for (real) aggregation
- **Data Centric Protocol**
  - Forwarding nodes can read and change messages
- **Literature**
  - Krishnamachari, Estrin, Wicker The Impact of Data Aggregation in Wireless Sensor 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





Theoretical Bounds

- **Costs for address based Routing N_A**

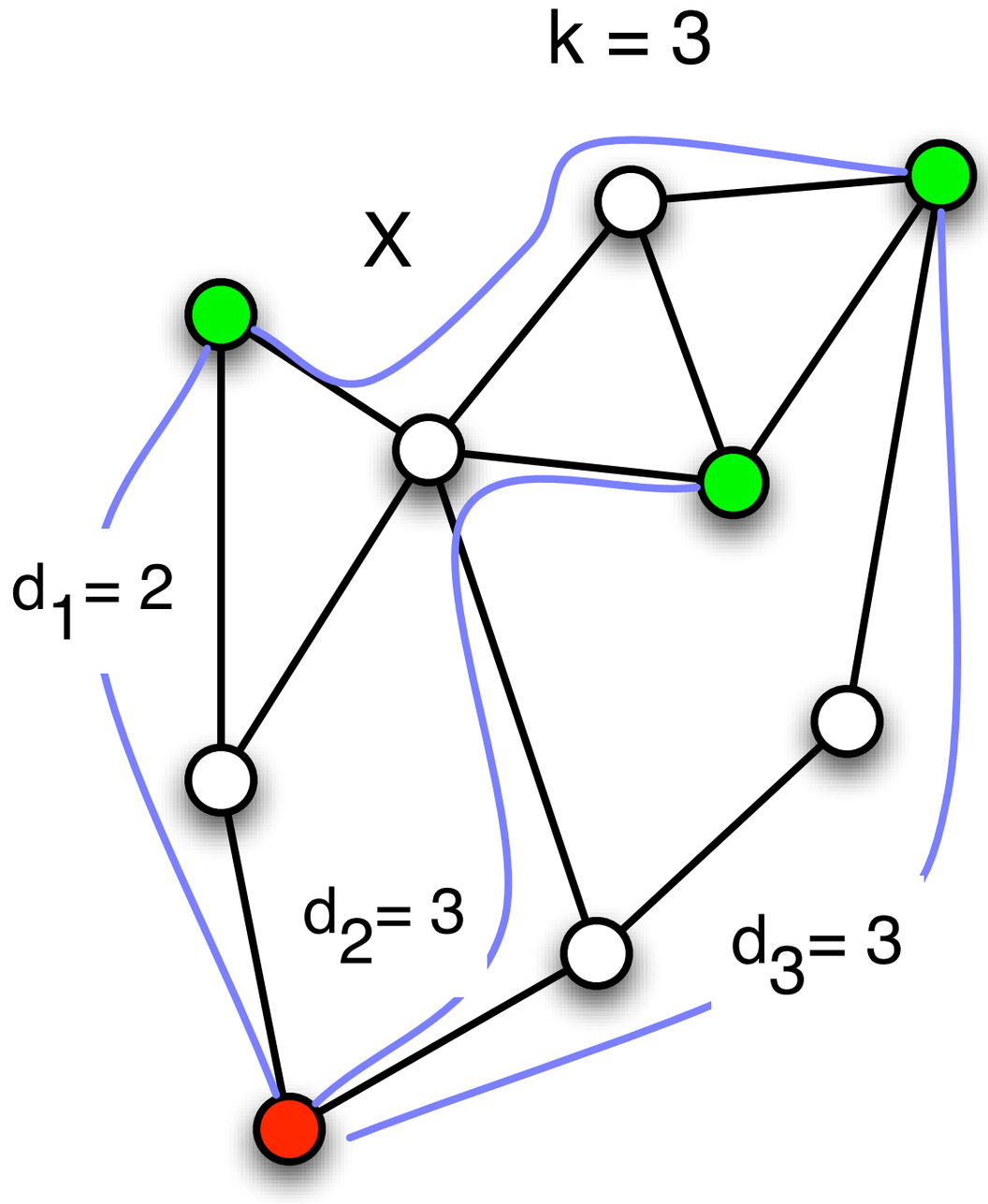
$$N_A = \sum_i d_i$$

  - d_i: shortest distance form source i to sink s
- **Cost for optimal data centric routing N_D = weight of Steiner-tree**

$$N_D \leq (k-1)X + \min_i\{d_i\}$$

- X: maximal shortest path between sources
- k: number of sources

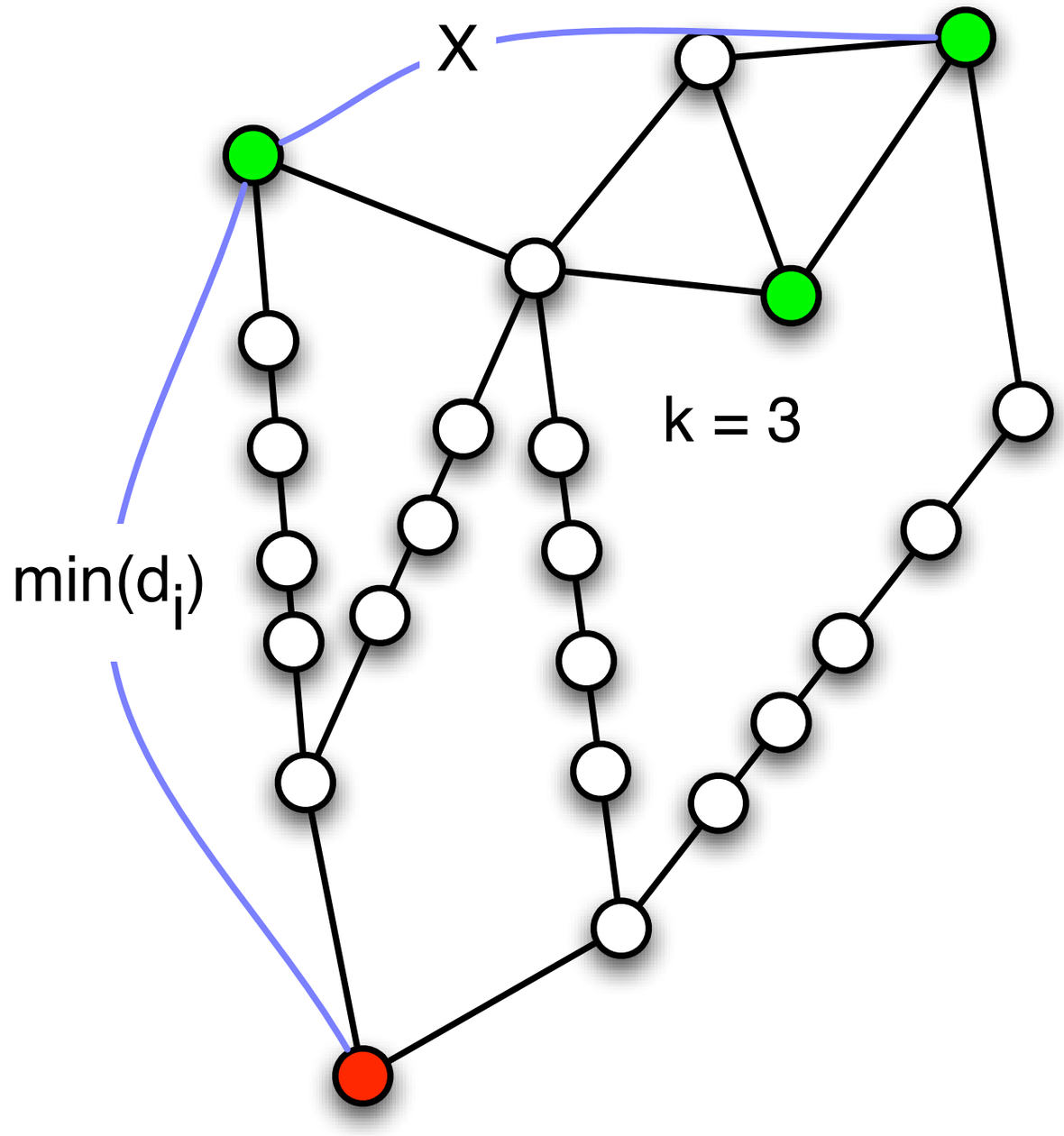
$$N_D \geq \min_i\{d_i\} + k - 1$$



Theoretical Bounds

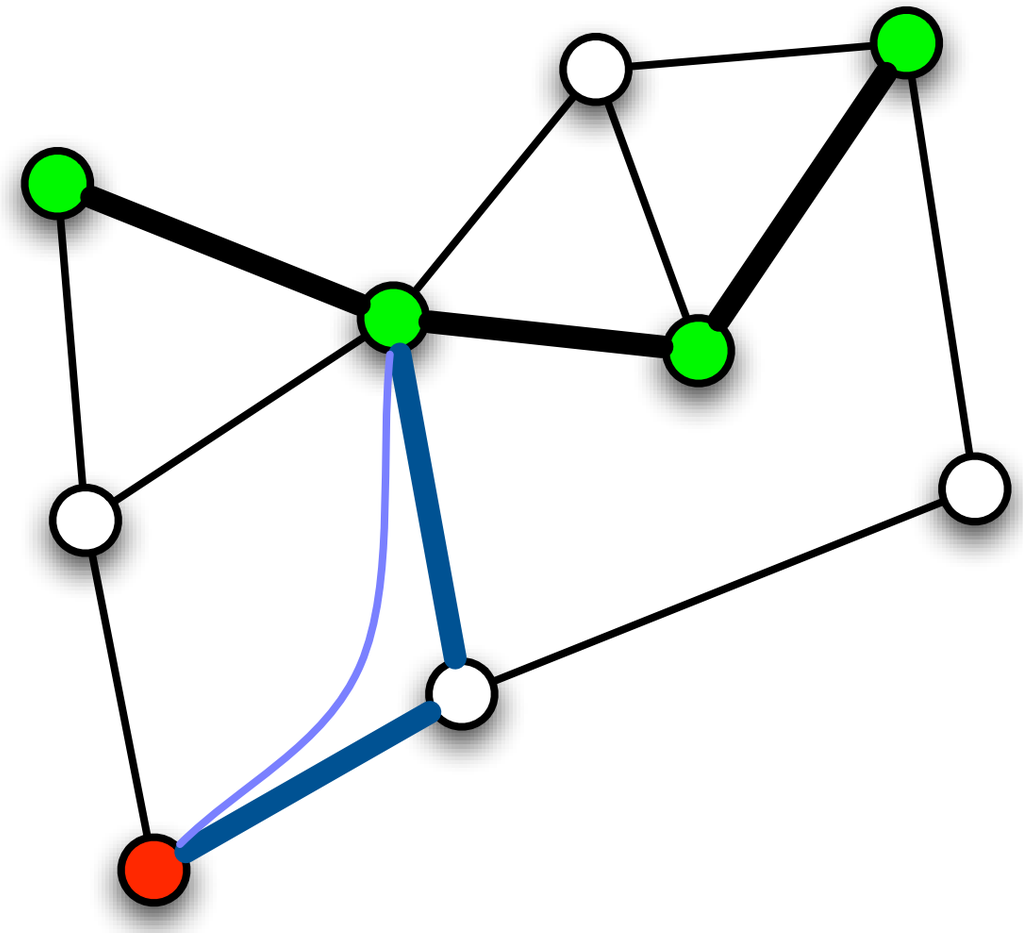
- **For fixed X and k and growing $\min_i\{d_i\}$**

$$\lim_{d\to\infty} \frac{N_D}{N_A} = \frac{1}{k}$$



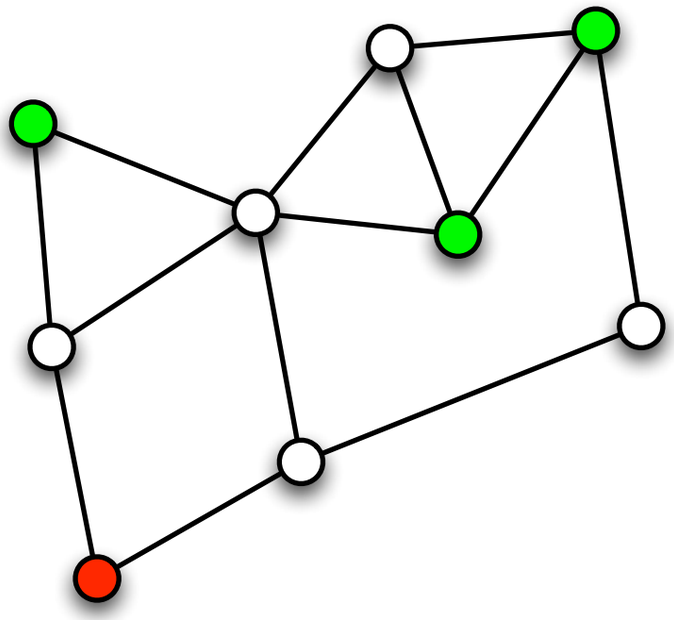
Theoretical Bounds

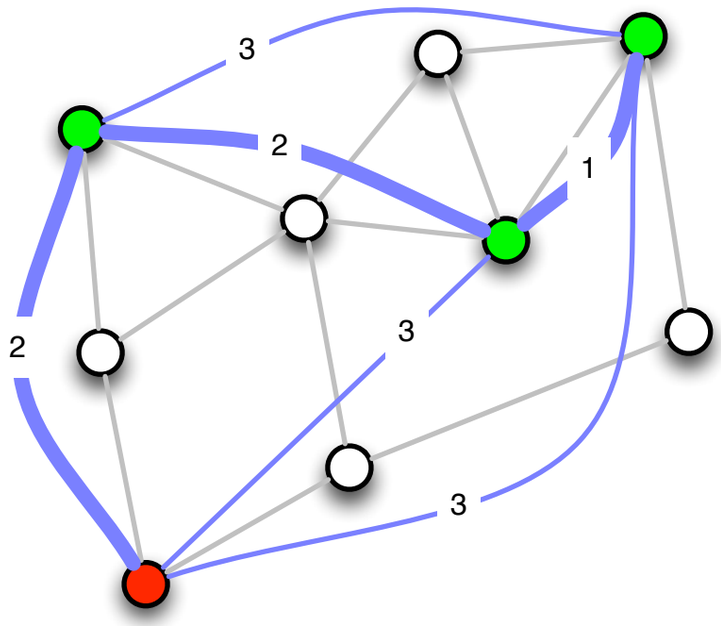
- **Theorem**
  - If the subgraph induced by the sources is connected, then the optimal routing can be computed in polynomial time
- **Proof sketch**
  - Compute MST T for the sources
  - Compute the shortest path from T to the sink

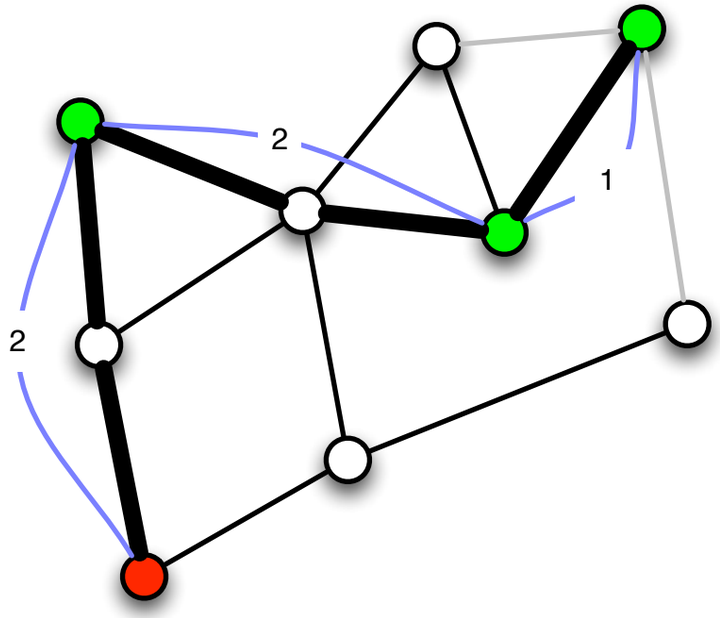


Approximation Algorithm

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

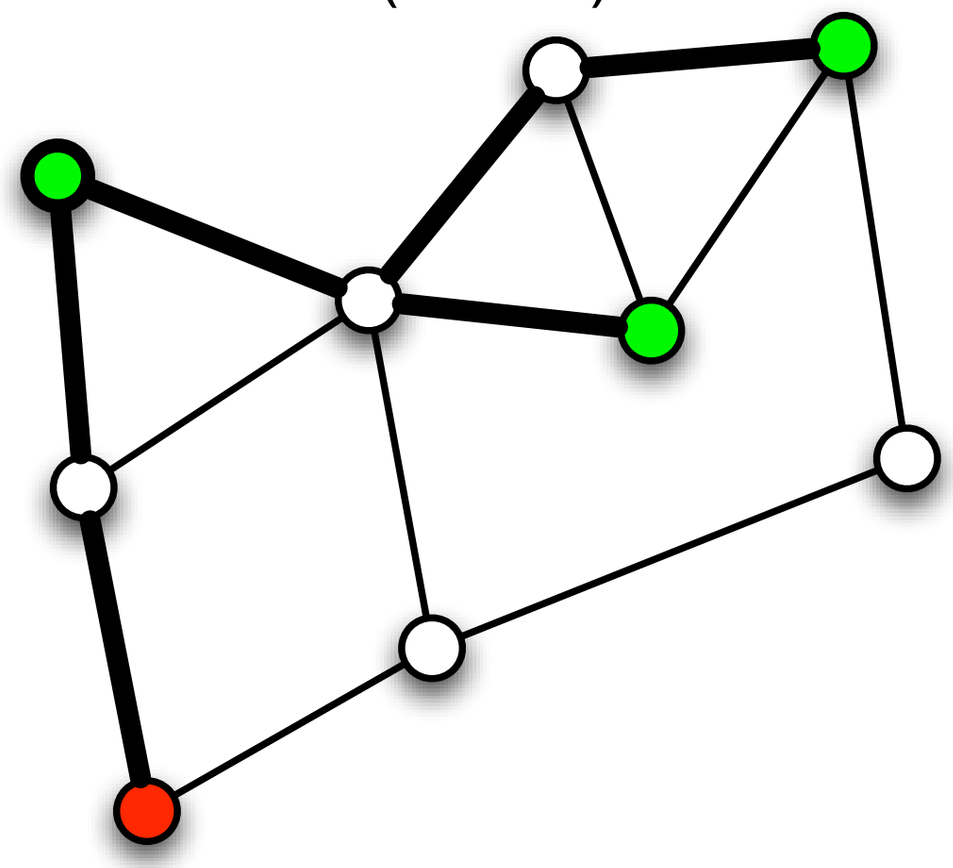






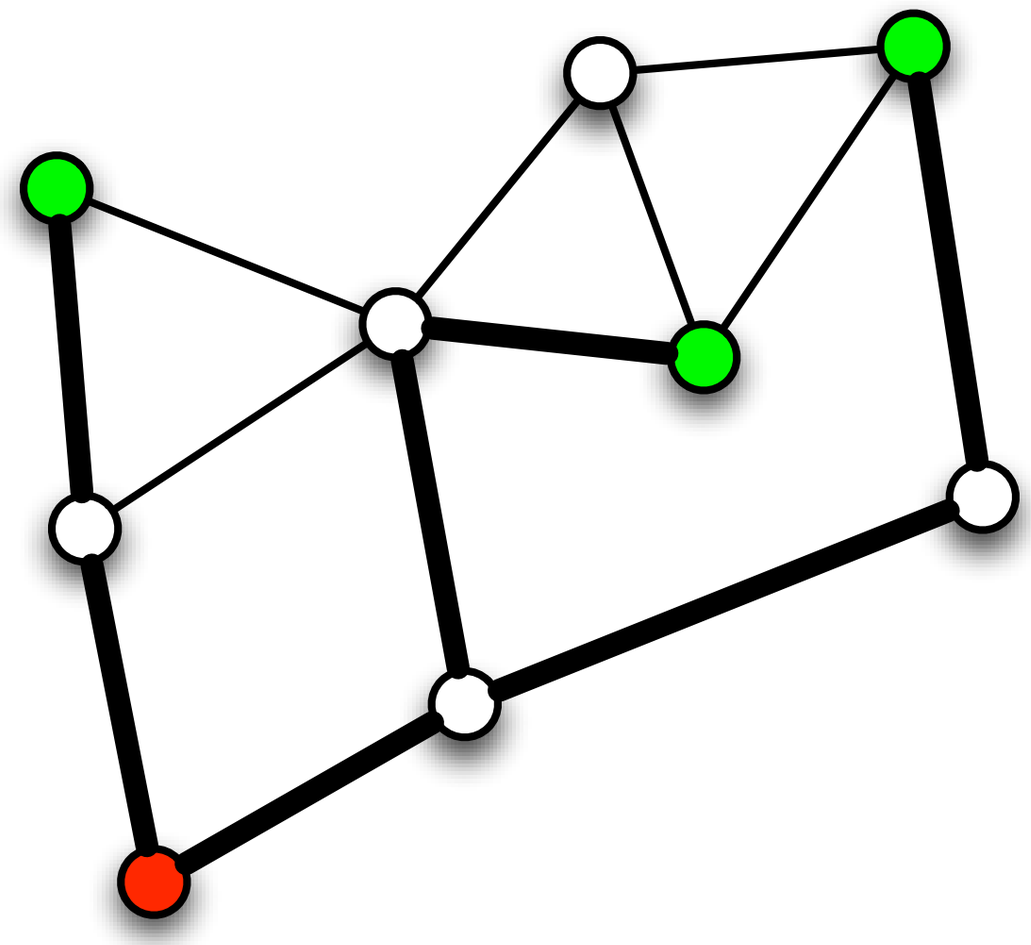
Suboptimal Aggregation

- **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)



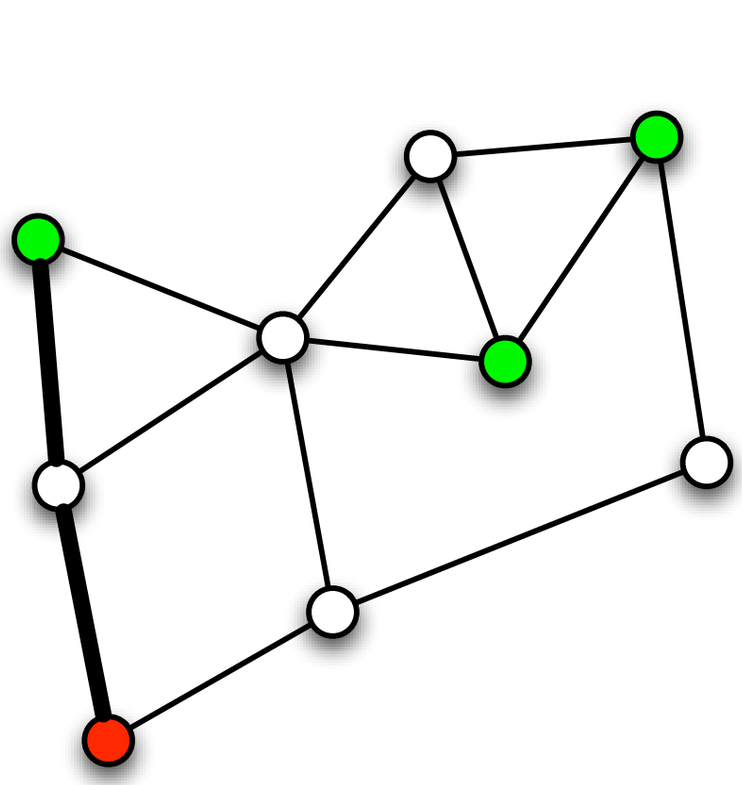
Suboptimal Aggregation

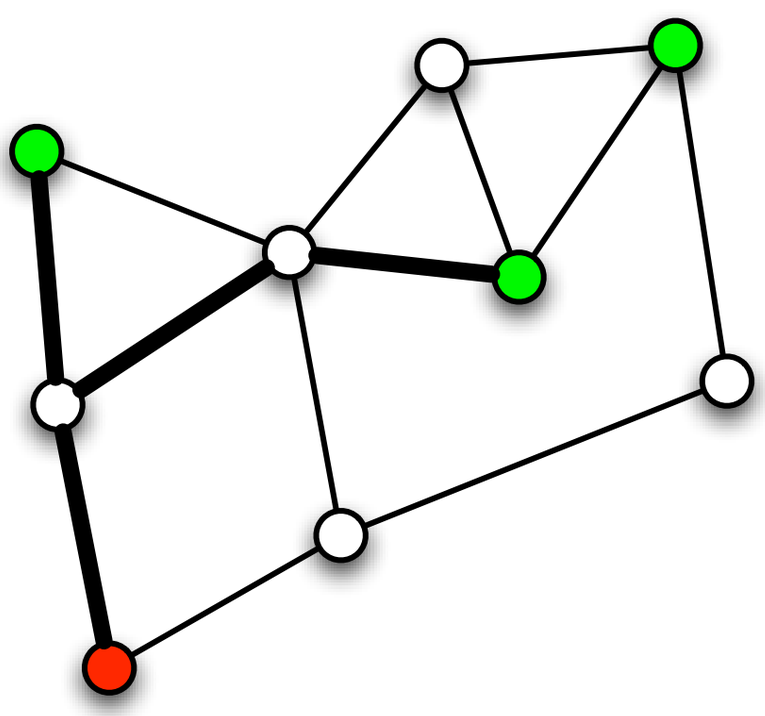
- **Shortest Paths Trees (SPT)**
  - Set of all shortest paths from the sources to the sink

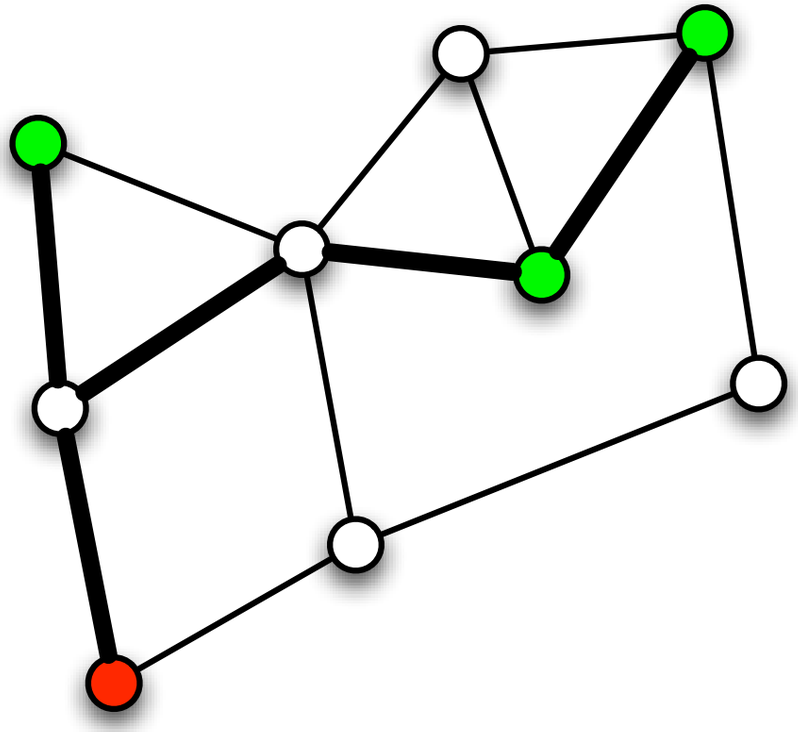


Suboptimal Aggregation

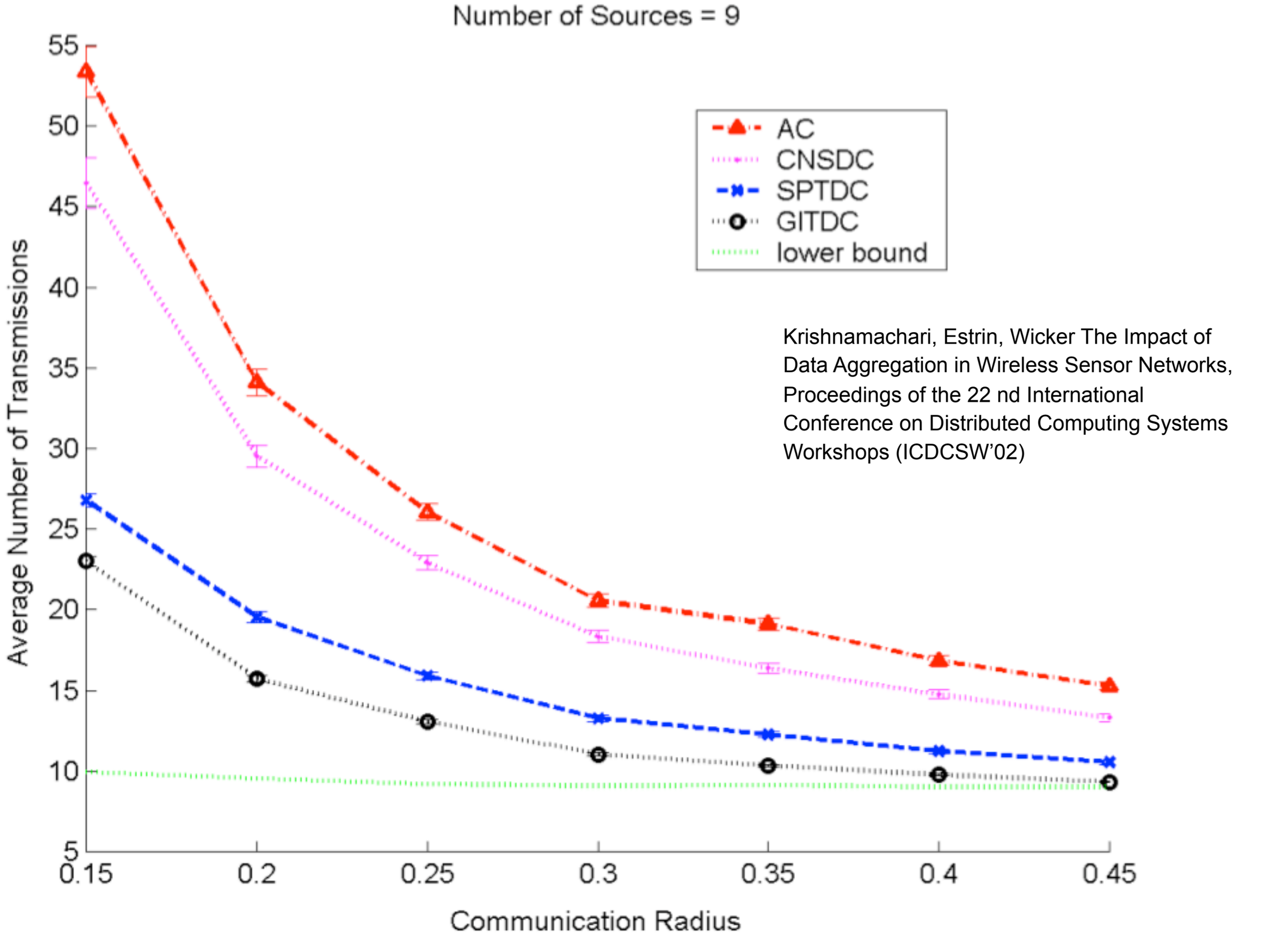
- **Greedy Incremental Tree (GIT)**
  - Select the shortest path between the data source, closest to the sink, and the sink
  - Select successively the closest node to the tree and the shortest path to any of the tree nodes







Energy Saving by Data Aggregation



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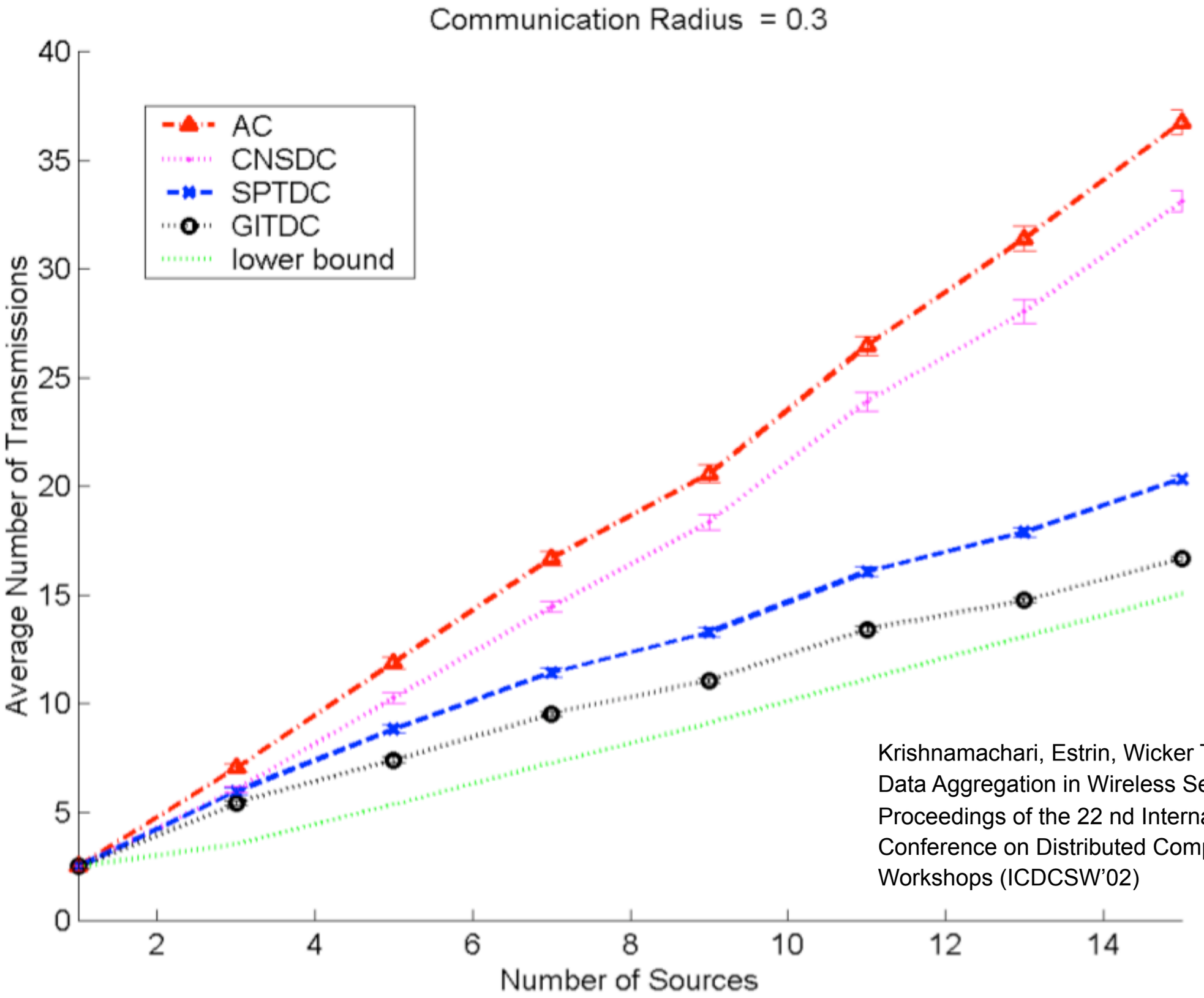

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