Sensor Networks

Presented by
Kihwan Kim

Overview

- A Survey on Sensor Networks
- SPIN Protocol
- LEACH Protocol
- Directed Diffusion
- TTDD

A Survey on Sensor Networks

Ian F. Akyildiz, Weilian Su,
Y. Sankarasubramaniam, and E Cayirci
(Georgia Institute of Technology)
IEEE Communications Magazine, August, 2002

Sensor

- What is a sensor?
  - A device responses to stimulus such as
    - Heat, light, sound, pressure, motion flow
  - A device produce measurable corresponding electrical signal
    - ^{o}F, Lux, db etc
  - A device has functions
    - sensing, computing, communication

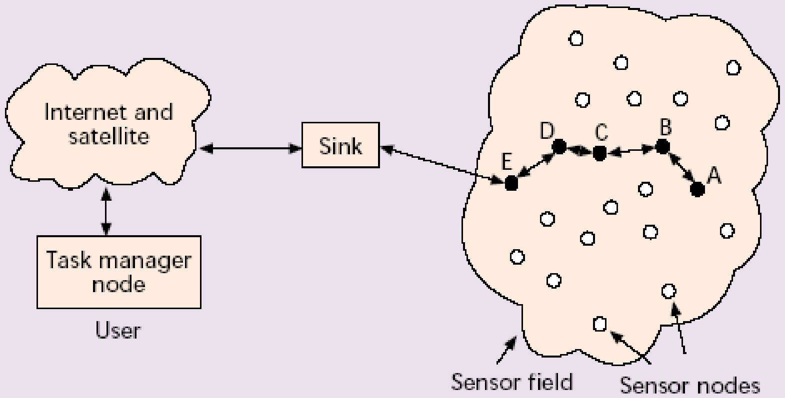
Introduction

- Sensor networks
  - Compose of large number of sensor nodes
    - Low cost, low power
  - Sensors are deployed in very large ad-hoc manner
  - Sensor networks perform remote monitoring and event detection in a geographically large region or in an hospitable area

Application of Sensor Network

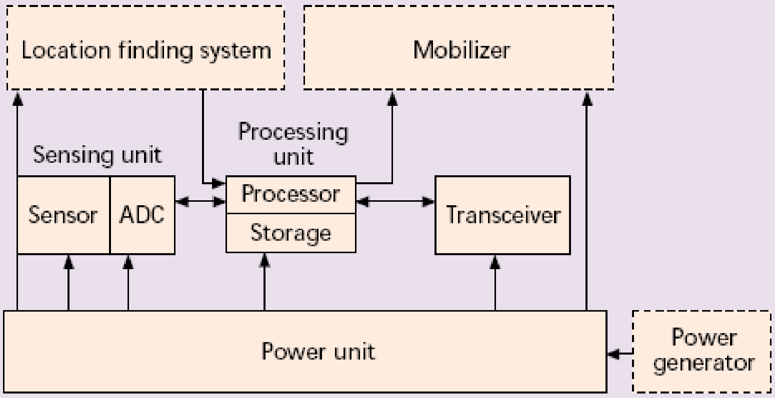
- Military
  - Detecting enemies
- Health
  - Monitoring patients
  - Assisting disabled patients
- Commercial
  - Monitoring product quality
  - Monitoring disaster areas.

Sensor Network Architecture



Source: original paper

Component of Sensor Node

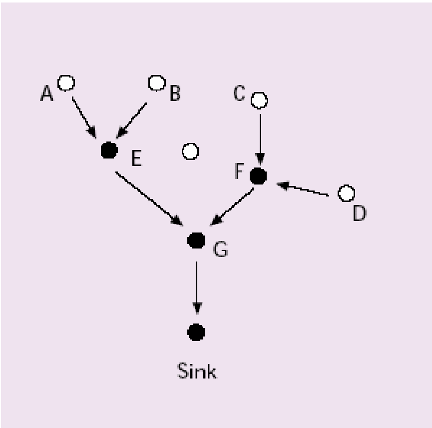


Source: original paper

Data Centric Approach

- Attributed based naming
  - Querying an attribute of the phenomenon
    - Ex: the areas where the temperature is over 70ºF
- Interest dissemination
  - Sinks broadcast the interest (Direct diffusion)
  - Sensors broadcast advertisement for data(SPIN)

Data Aggregation



- Node aggregates data from other nodes
- More process power
- Less transmission power
- Solving implosion and overlap

Several Schemes for Network Layer

- SPIN
  - Broadcast with minimum energy
- Directed diffusion
  - A Scalable and Robust Communication Paradigm for Sensor Networks
- LEACH
  - Clustering with minimum energy

Research Topic

- Fault Tolerance
- Scalability
- Costs
- Topology
- Deployment
- Environment
- Power Consumption

SPIN
Sensor Protocol for Information via Network

Title : Adaptive Protocols for Information Dissemination in Wireless Sensor Network

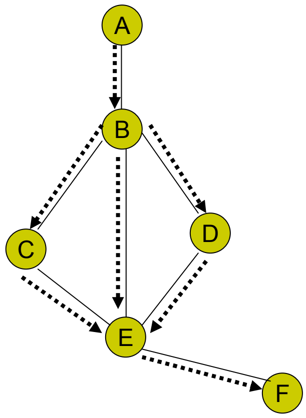
Authors: W. R. Heinzelman, J. Kulik, and H. Balakrishnan (***M.I.T)***

Published: Mobicom ‘99

Motivation

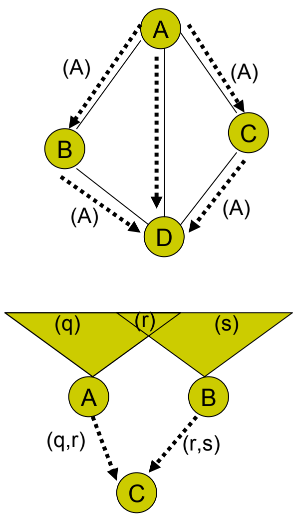
- Data dissemination
  - All node can share information with other nodes
- Energy concerning
  - In whole network point of view, minimum energy is used for delivering data
- Goal
  - Broadcast with minimum energy

Simple Solution - Flooding



- Send a data to all its neighbors
- If a node received a duplicated packet, ignore it
- Some routing algorithm uses flooding for updating table

Problem of Flooding



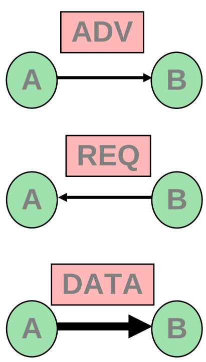
- Implosion
  - A node receives duplicated data from different nodes
- Overlap
  - Redundant information
- Consuming Energy

Two basic ideas

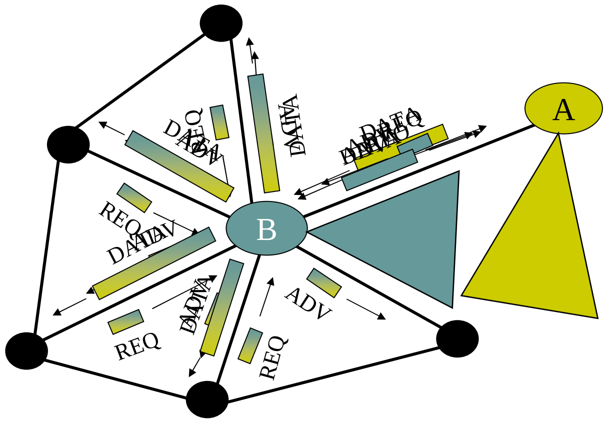
- Exchanging sensor data may be expensive, but exchanging data about sensor data may not be.
- Nodes need to monitor and adapt to changes in their own energy resources

SPIN Mechanism

- SPIN messages
  - ADV- advertise data
  - REQ- request specific data
  - DATA- requested data
- Resource management



SPIN-PP Example



Conclusion & Problem

- SPIN solves implosion and overlap problems
- SPIN improve resource consuming
- Delay is worse than simple flooding
- SPIN is still based on channel forwarding
  - In real world, any node within a sender’s transmission range can receives data

LEACH

Title : Energy-Efcient Communication
Protocol for Wireless Microsensor
Networks

Authors: W. R. Heinzelman, A. Chandrakasan,
H. Balakrishnan(MIT)

Published: Hawaaian Int’l Conf. on System Science
January 2000

Motivation

- Motivation
  - Long system life time with limited battery and bandwidth
  - Direct transmission to sink, previous minimum energy routing is not optimal
- Goal
  - Efficient routing with clustering technique

Basic Idea

- Only cluster headers are involved in data forwarding to outside of cluster
- Other nodes in the cluster just send data to its cluster head
- Cluster headers are randomly choose
- Cluster headers are roatated

Cluster Head Selection

- Each sensor node chooses a number s
  - 0 < s < 1
- If s < T(n) then it will be a header
  - T(n) threshold

$$T(n) = \begin{cases} \dfrac{P}{1 - P * [r \bmod (1/P)]} & \text{if } n \in G \\ 0 & \text{otherwise,} \end{cases}$$

P : desired percentage of cluster head

G: set of nodes that have not been a cluster head in the last 1/P round

r: current round

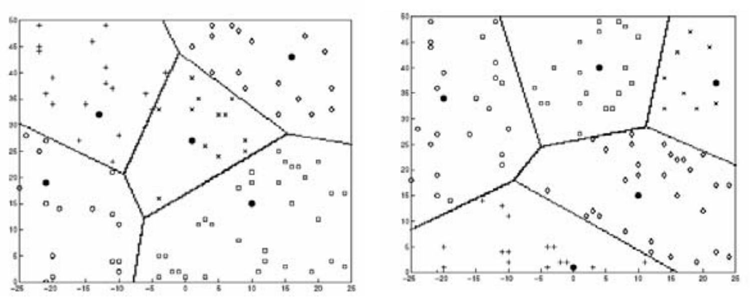
r is increased → T(n) is increased

Communication

- Each cluster header advertise itself to other nodes
- Each non cluster header node chooses one header based on signal strength
- Cluster head assigns times to other nodes with TDMA manner
- Non cluster header node sends its data with its time slot
- Cluster header aggregates data from other nodes then sends data to sinks

Cluster Header Rotation

- After assigned time expired running cluster header selection program again
- New cluster headers are selected



Directed Diffusion

Title : Directed Diffusion : A Scalable and Robust Communication Paradigm for Sensor Network

Authors: C. Intanagonwiwat, R. Govindan, D. Estrin(USC*)*

Published: Mobicom '2000

Motivation & Example

- How many pedestrians do you observe in the geographical region X?
- Tell me in what direction ;that vehicle in region Y is moving?
- Goal
  - Robust, scaling and energy efficient communication paradigm in senor network

Basic Idea

- Data centric manner
  - Data aggregation
  - Attribute naming
  - caching
- Distributed algorithm for communication
- Application level communication
  - Attribute naming

Elements of diffusion

- Naming
  - Data is named using attribute-value pairs
- Interests
  - A node (sink) requests data by sending interests with named data
- Gradients
  - Gradients is set up to “draw” events
  - data matching the interest.
- Data Propagation
- Reinforcement
  - Sink reinforces particular neighbors to draw higher quality (higher data rate) events

Naming

- Task naming
  - Tasks are named by a list of attribute – value Pairs
  - Task description specifies an interest for data matching the attributes

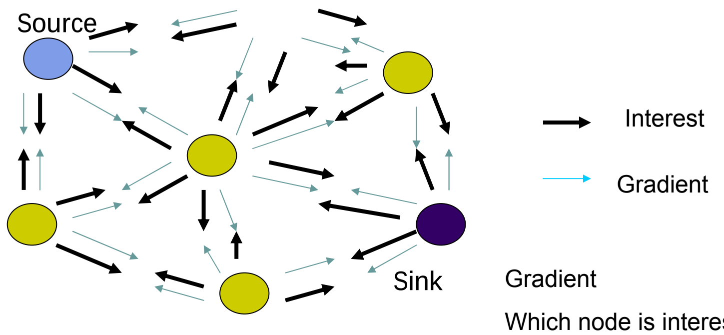
Request (interest)
Type = four-legged animal
Interval = 20 ms
Duration = 1 minute
Location = [-100, -100; 200, 400]

Reply
Type =four-legged animal
Instance = elephant
Location = [125, 220]
Confidence = 0.85
Time = 02:10:35

Interest

- The sink periodically broadcasts interest messages to each of its neighbors
- Every node maintains an interest cache
  - Each item corresponds to a distinct interest
  - No information about the sink
  - Interest aggregation : identical type, completely overlap rectangle attributes
- Each entry in the cache has several fields
  - Timestamp: last received matching interest
  - Several gradients: data rate, duration, direction

Gradient



Gradient

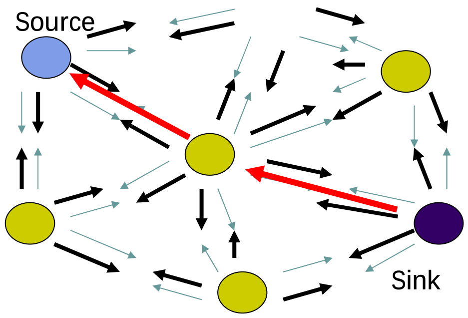
Which node is interested

Data rate, Duration

Data Propagation

- Sensor node computes the highest requested event rate among all its outgoing gradients
- When a node receives a data:
  - Find a matching interest entry in its cache
    - Examine the gradient list, send out data by rate
  - Cache keeps track of recent seen data items
  - Data message is unicast individually to the relevant neighbors (different from multicast)

Reinforcement



The neighbor reinforces a path:
1. Choose the one from whom
it first received the latest event (low delay)
2. Choose all neighbors from which
new events were recently received

- Finding Path
  - Sink sends interest with low rate
  - Sink receives low data
  - Sink chooses one node and sends interest with high late
- Reinforcement means increasing interest

Distributed Algorithm

- Interests sending (Dissemination)
  - Flooding
  - Using GPS or other techniques
- Setting gradient
  - Node only concerns its neighbors
  - Probabilistic or energy concerned gradient
- Data Propagation
  - Single path
  - Multi path
- Reinforcement
  - Least delay

Conclusion & Problem

- Achieve data centric manner
- Achieve distributed manner communication
- Need to compare to other techniques
  - Only compare to flooding
- Scalability
  - Simulation only use 5 nodes
  - Can a node contain many interest with many gradient?

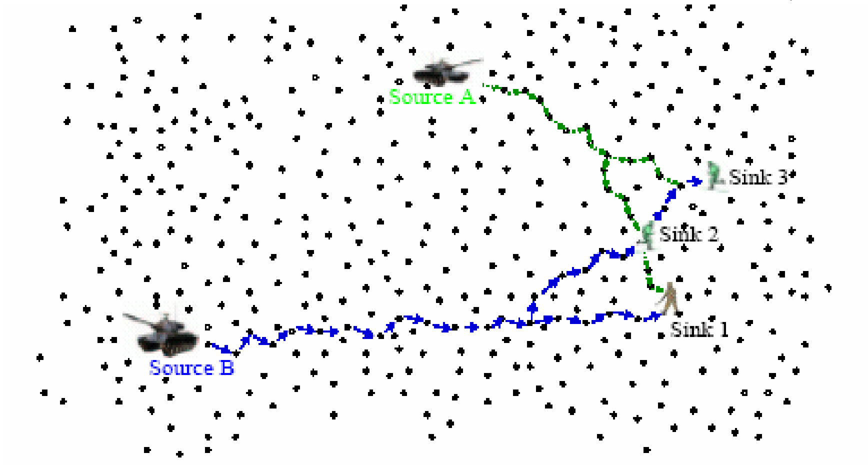
TTDD

Title : A Two-Tier Data Dissemination Model for Large-Scale Wireless Sensor Network

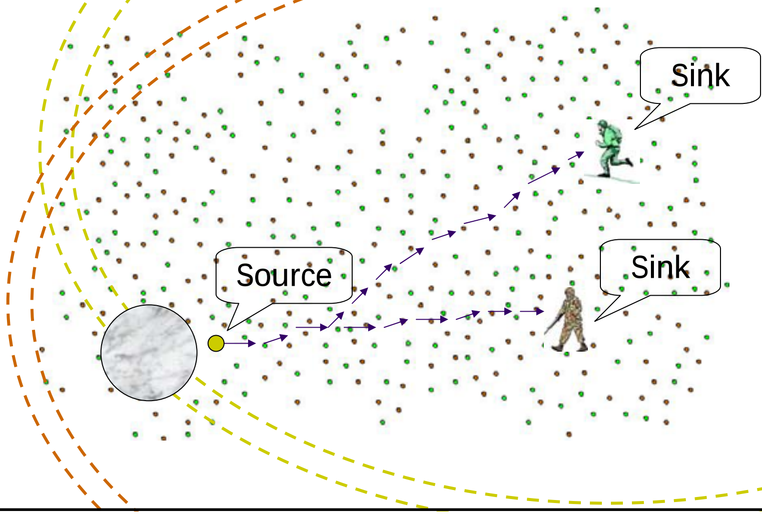
Authors: H. Luo, F. Ye, J. Cheng, S. Lu, L. Zhang (UCLA)

Published: Mobicom ‘2002

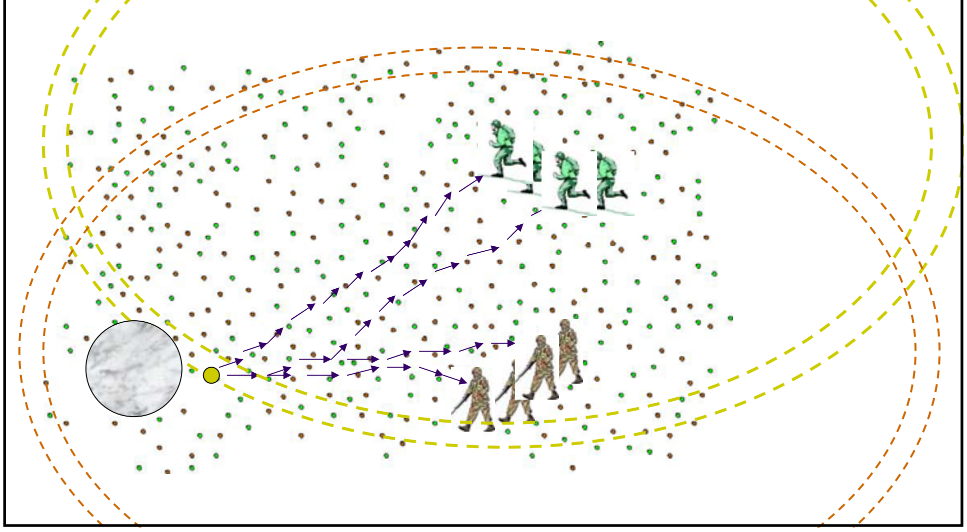
Sensor Network Example



Application Scenario



Application Scenario



Assumption & Motivation

- Assumption
  - Sensors densely applied in large field
  - Sensor is fixed (source is fixed)
  - Sinks can moves
  - Sensor generates data when it detects a target
- Motivation
  - How can a moving sink receive data continually
- Goal
  - Efficient data dissemination from multiple source to multiple mobile sinks

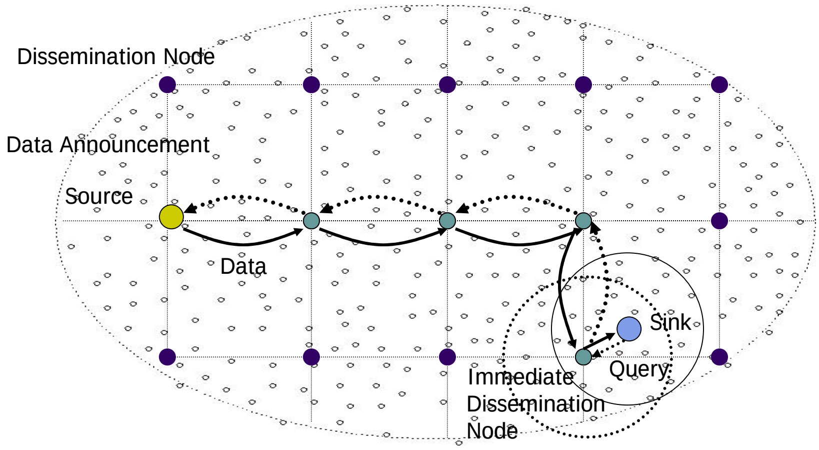
Basic Idea

- Two-Tier System
  - Dissemination node
    - Involved in data forwarding
  - Common node
    - Sensing
- Grid Approach
  - Source makes grid structure to propagate data

Grid Approach

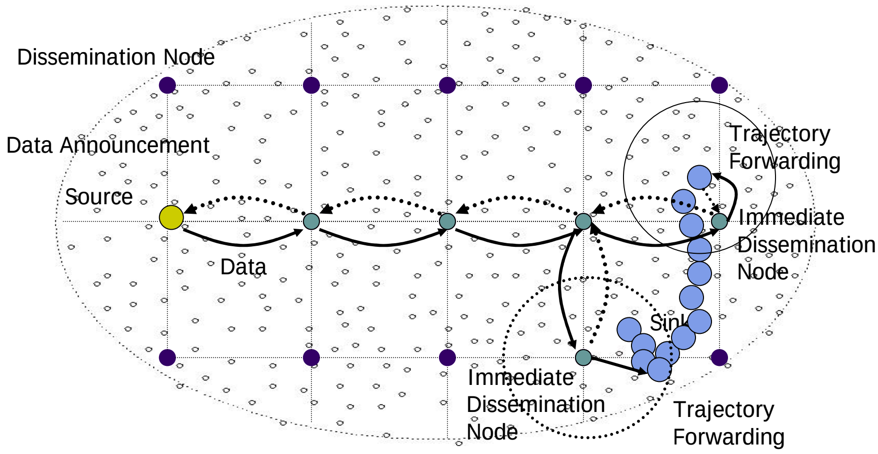
- Source divides the plane into αXα square cells, with itself at one of the ***crossing point*** of the grid.
- The source calculates the locations of its four neighboring *dissemination points*
- The source sends a data-announcement message to reach these neighbors using *greedy geographical forwarding*
- The node serving the point called *dissemination node*

TTDD Basic Concept



Ref:http://www-net.cs.umass.edu/cs781_sensornets/342,50,TTDD Basics

TTDD Mobile Sinks



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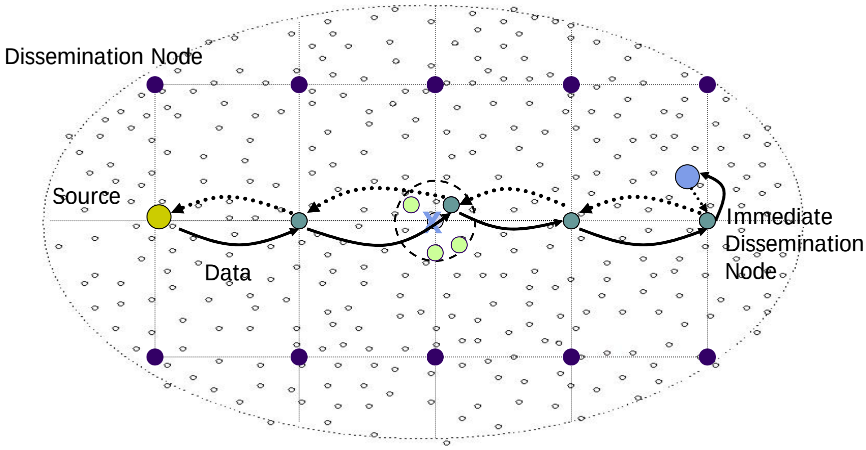
Grid Maintenance



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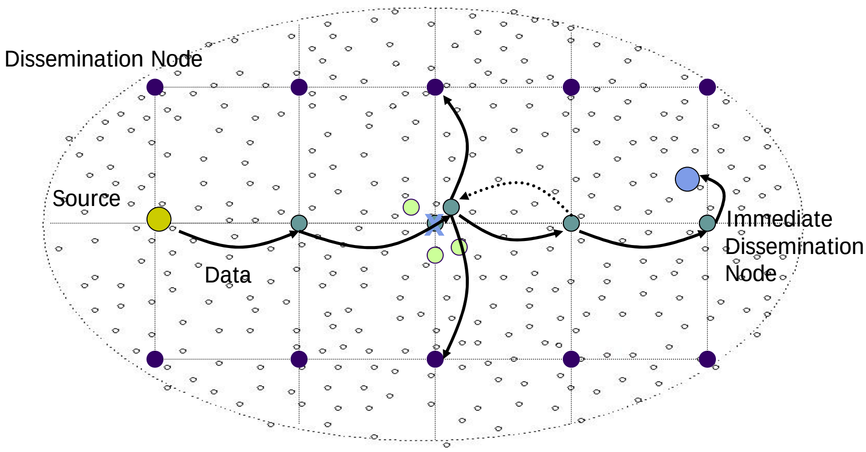
Grid Maintenance (cont'd)



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Conclusion & Problem

- Sending data to moving sinks
- Only few nodes(dissemination node) are involved in data forwarding
- Distributed algorithm
- Multiple source can make a lot of grid
- Data aggregation should be concerned

DCTC

Title : Optimizing Tree Reconfiguration to Track Mobile Targets in Sensor Networks

Authors: Wensheng Zhang, and Guohong Cao
Penn State

Published: INFORCOM '2004

Motivation

- This paper proposing energy efficient techniques to detect and track a mobile target.
- A *convoy tree* is a moving tree which tracks the target.
  - It is dynamically configured to add and prune some nodes as the target moves.
  - As the convoy tree reconfigures itself, the root may also need to be changed.

DCTC Framework

DCTC: Dynamic Convoy Tree-Based Collaboration

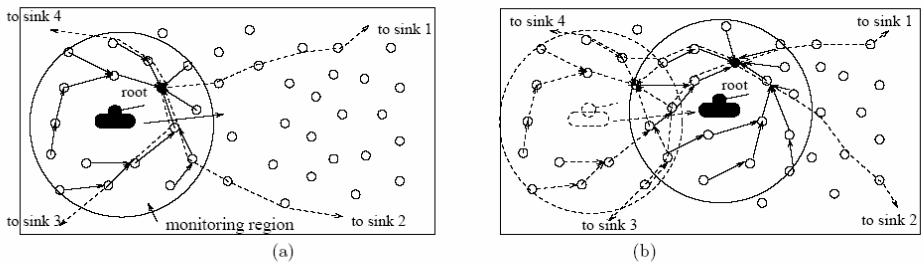

Figure 1: Using convoy tree to track the target

Two parts of question:

1. How to migrate the root of the tree when the target moves?
2. How to reconfigure the rest part of the tree?

Reconfiguration Algorithm I

- The Complete Reconfiguration Algorithm
  - The new root broadcast a reconfiguration announcement to its neighbors.
  - All nodes in the tree change their locations to minimize their levels in the new tree and broadcast the changes.
- Advantage: minimize the energy consumption in the data collection processes
- Disadvantage: increase the reconfiguration overhead

Reconfiguration Algorithm II

- The Interception-based Reconfiguration Algorithm
  - Only the nodes which close to the line that is vertical to the line connecting the old root and new root change their locations
- Advantage: reduce both the reconfiguration overhead and the energy consumption

An Optimal Method for Root Migration

- The root keeps monitoring its distance to the target.
- When the distance become larger than a certain threshold (*d*), it will be replaced by the node which is closest to the center of the current monitoring region.
- *d* affects the energy consumed in data collection and tree reconfiguration.

Conclusions

- Simulation results showed that the developed optimal method for root migration matched the analytical results.
- The tree reconfiguration scheme using the optimal root migration method and the interception-based reconfiguration algorithm has the lowest energy consumption.