Routing Protocols for Wireless Sensor Networks

Routing protocol survey

- ***Traditional technique***
  - Flooding
  - Gossiping

- Routing technique
  - Flat-routing
  - Hierarchical-routing
  - Location-based routing

[1]Ian F. Akyildiz, Weilian Su, Yogesh Sankarasubramaniam, and Erdal Cayirci Georgia Institute of Technology" A Survey on Sensor Networks" IEEE Communications Magazine • August 2002

Flooding(1/2)

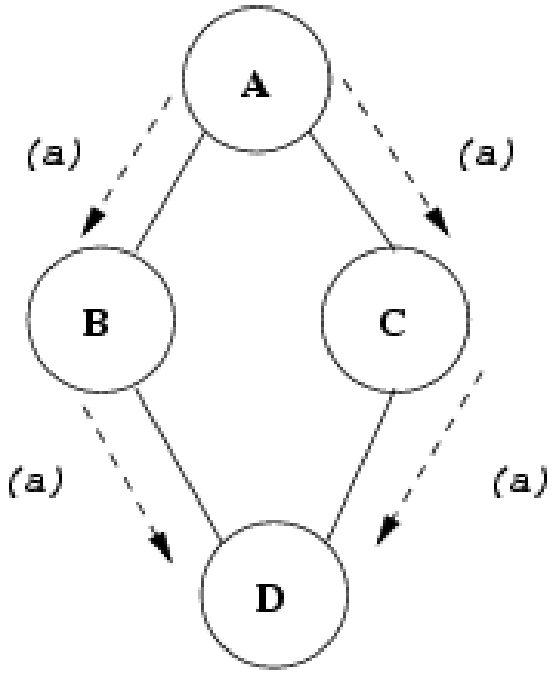
- A classical mechanisms to relay data in sensor networks without the need for any routing algorithms and topology maintenance.

- drawbacks:
  - Implosion
  - Overlap
  - Resource blindness

A Simple Solution: Flooding

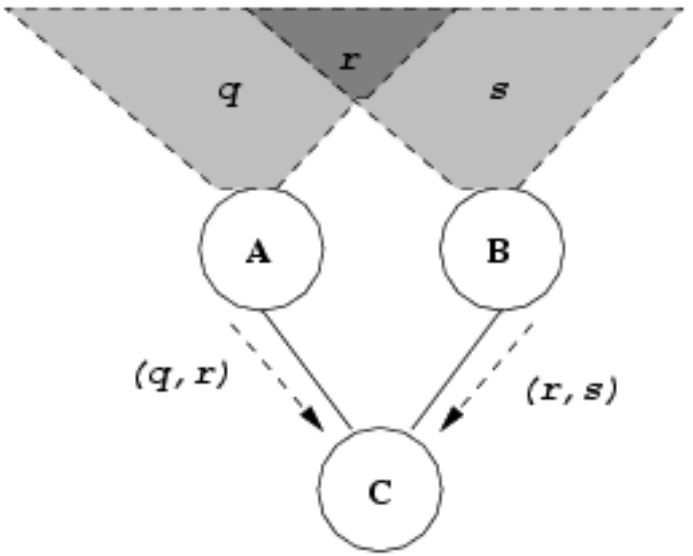
Suffers from 3 deficiencies:

- Implosion: Resources wasted by sending duplicate copies of the same data.



Flooding (Problems)

- Overlap: Common pieces of data are gathered and sent.



- Resource Blindness:

  Flooding does not modify its activities based on amount of energy available.

Gossiping

- A slightly enhanced version of flooding where the receiving node sends the packet to a randomly selected neighbor which picks another neighbor to forward the packet to and so on.
- Advantage: avoid the implosion
- Drawback: Transmission delay

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- ***Current routing technique[1]***
  - ***Flat-routing***
  - Hierarchical-routing
  - Location-based routing

[1]JAMAL N. AL-KARAKI, AHMED E. KAMAL,” ROUTING TECHNIQUES IN WIRELESS SENSOR NETWORKS: A SURVEY**”,**
IEEE Wireless Communications • December 2004

Flat-routing

- ***SPIN (Sensor Protocols for Information via Negotiation)***
- DD (Directed diffusion)
- Rumor routing

SPIN's Approach

2 key innovations introduced:

- Negotiation

To solve implosion and resource overlap,

SPIN nodes *negotiate* before sending data.

Use of descriptors called *meta-data* to

name/describe data.

- Resource Adaptation

Each node has a *resource manager* that keeps track of resources at the node. Probed by applications.

4 variants of SPIN

1. A wireless Point to Point Network with no queuing delays or dropping of packets.

- SPIN-PP and SPIN-EC

2. Realistic network with unreliable broadcast channel.

- SPIN-BC and SPIN-RL

SPIN Overview

2 basic ideas:

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

SPIN features

- Application level control

  Pursues the principles of Application Level Framing (ALF). Common data naming followed between transmission protocol and application.

  Propose to make *routing decisions* in application controlled and application specific ways using knowledge of topology, resources, data layout.

SPIN features (contd.)

- Meta-Data

  Used to describe data collected.

  Must be shorter than the data, and if two pieces of data are the same then they should have the same meta-data.

  Application-specific: Example a camera sensor could take (x,y,O) as metadata where x,y are coordinates and O is orientation.

- SPIN Resource Management

  SPIN applications poll their resources to find out how much energy is available.

  Make informed decisions by obtaining this information from a specified interface.

SPIN Message types

- ADV – new data advertisement. Contains the meta-data.
- REQ – request for data. Sent when a node wants a data.
- DATA – data message. Contains the actual data.

SPIN Protocols

1. SPIN – PP

   Optimized for a point-to-point link where A and B can talk to each other without interfering with other nodes. To send to n-neighbors, cost is n times that of sending to one neighbor.

   3 stages : ADV-REQ-DATA

2. SPIN-EC

   When a node observes that its energy is below a threshold it reduces its participation. Only starts a stage of the protocol that it can finish.

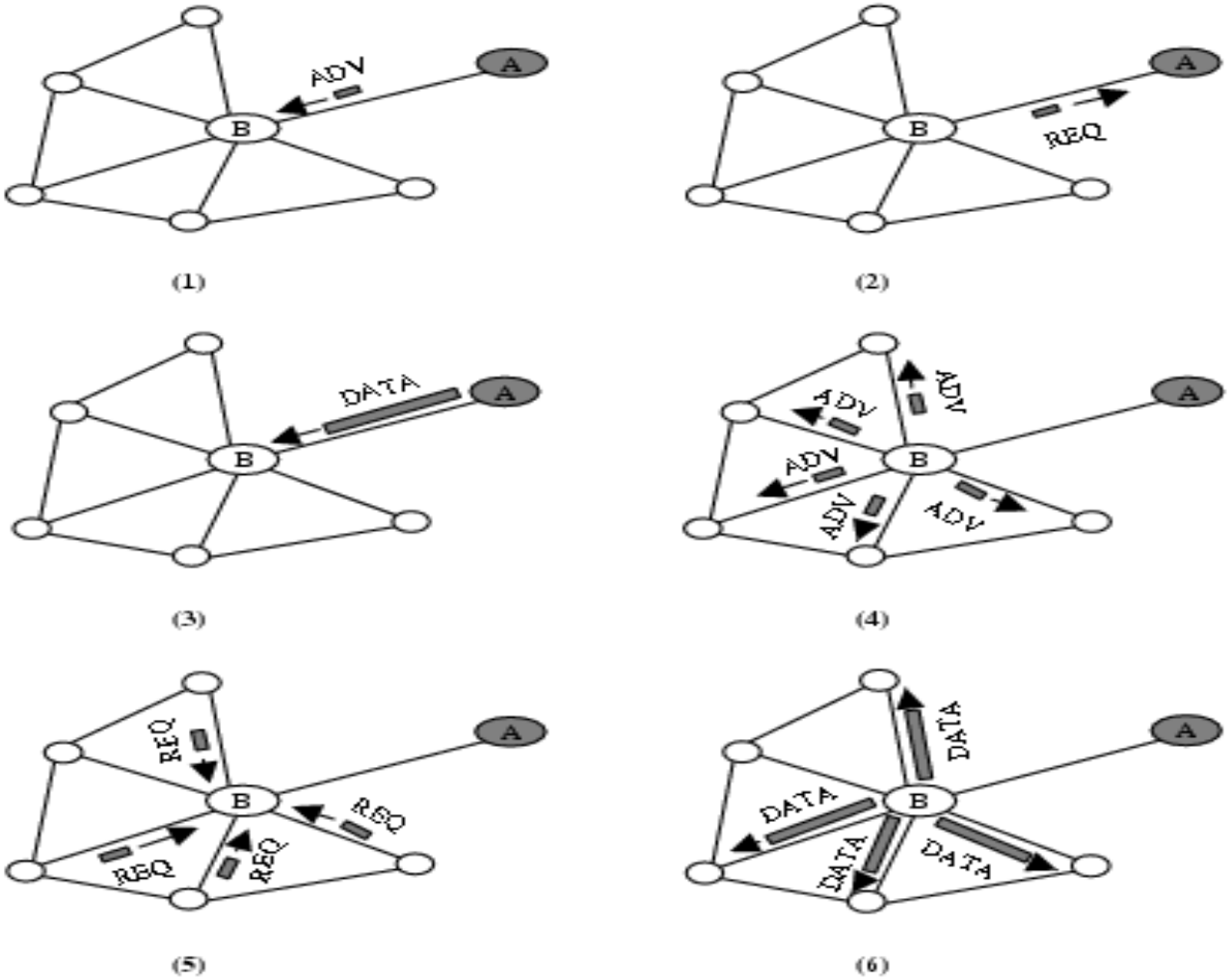

Figure 3: The SPIN-PP Protocol. Node A starts by advertising its data to node B (1). Node B responds by sending a request to node A (2). After receiving the requested data (3), node B then sends out advertisements to its neighbors (4), who in turn send requests back to B (5,6).

SPIN

- Topological changes are localized
- provides more energy savings than flooding, and metadata negotiation almost halves the redundant data.
- Drawback: SPIN's data advertisement mechanism cannot guarantee delivery of data.

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Hierarchical-routing

- ***LEACH (Low Energy Adaptive Clustering Hierarchy)***
- PEGASIS (Power-Efficient Gathering in Sensor Information Systems)
- TEEN(APTEEN) (Threshold-Sensitive Energy Efficient Protocols)

LEACH[1]

- LEACH is a cluster-based protocol
- Setup phase
- Steady state phase

[1]. Heinzelman, A. Chandrakasan and H. Balakrishnan, “Energy-Efficient Communic
Protocol for Wireless Microsensor Networks,” *Proc. 33rd Hawaii Int’l. Conf. Sys. Sci*

Assumptions about sensor nodes

- All nodes can transmit with enough power to reach the BS.
- All nodes have the computational power to support different MAC protocols.

LEACH

- Nodes organized into local clusters.
- One node acting as the cluster head.
- All non-cluster head nodes transmit their data to the cluster head
- Cluster head receive data from all the members perform data aggregation and transmit data to remote BS.
- Cluster head node needs more energy compared to cluster members.
- To avoid draining the battery of any node cluster heads are randomly chosen on rotation basis.

Leach operation

- Set-up phase: Clusters are organized
- Steady-state phase: Data are transferred from nodes to the cluster head and on to the BS.

Time line showing leach operation

Cluster-Head Selection Algorithm

LEACH

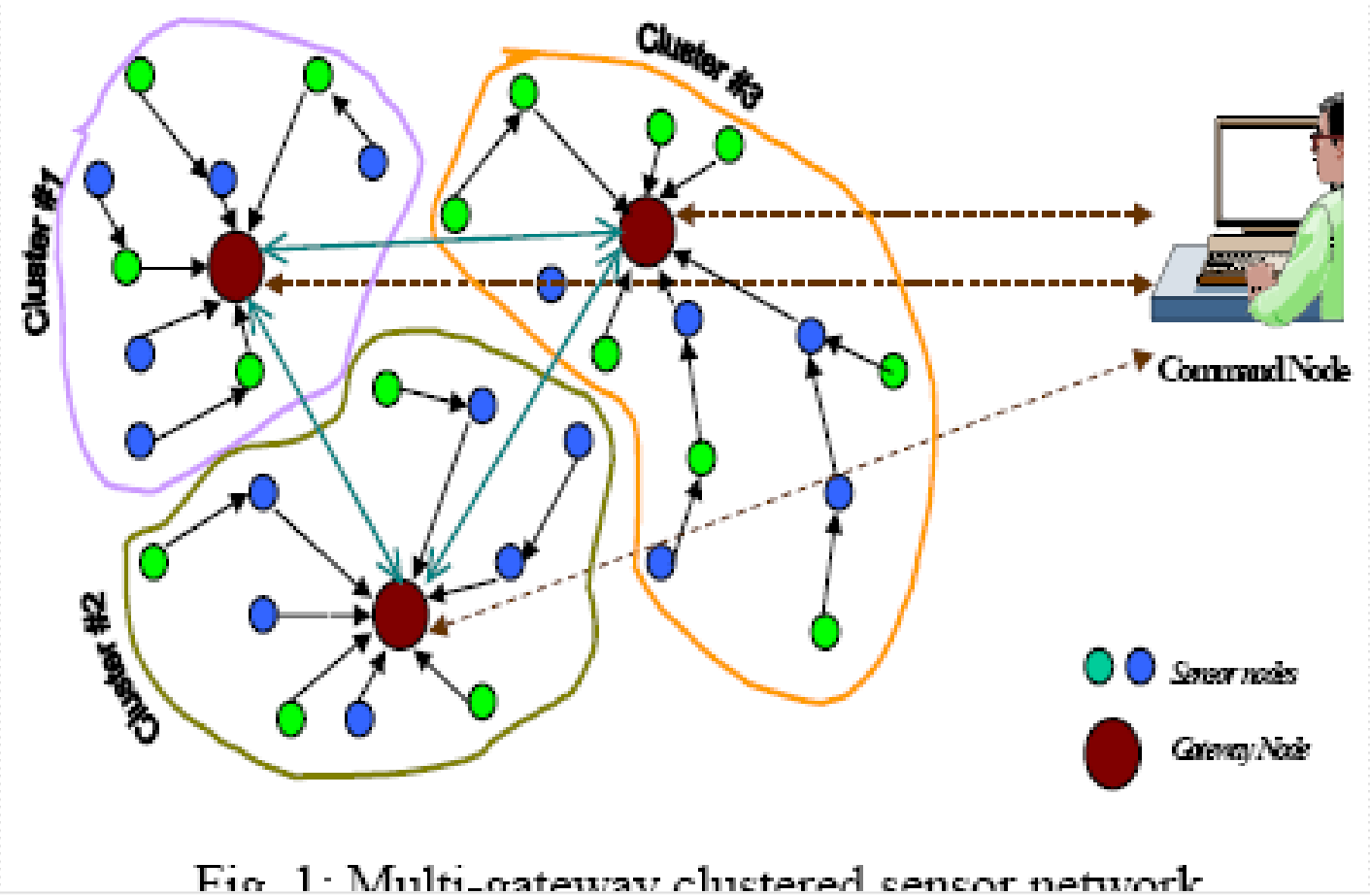


Fig. 1: Multi-gateway clustered sensor network

LEACH: Operation

- Periodic process
- Three phases per round:
  - Advertisement
    - Election and membership
  - Setup
    - Schedule creation
  - Steady-State
    - Data transmission

LEACH: Advertisement

- Cluster head self-election
  - Status advertised to nearby nodes
- Non-cluster heads must listen to the medium
  - Choose membership based on signal strength
    - RSSI
    - E_b/N_0

LEACH: Setup

- Nodes broadcast membership status
  - CSMA-CA
- Cluster heads must listen to the medium
- TDMA schedule created
  - Dynamic number of time slots

LEACH: Data Transmission

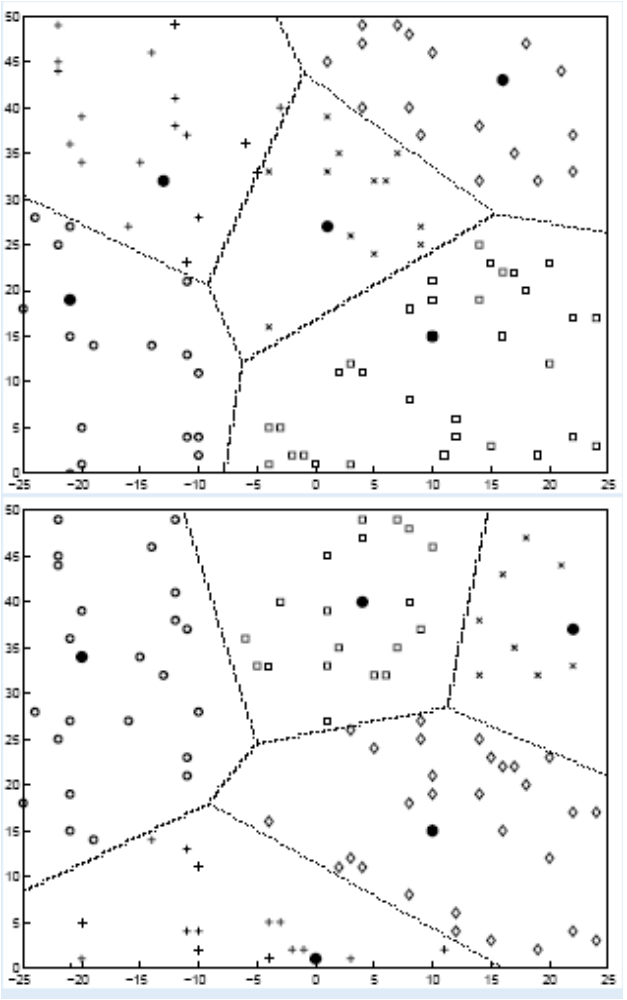
- Nodes sleep until its time slots
- Cluster heads must listen to each slot
- Cluster heads aggregate/compress and transmit to Sink
- Phase continues until the end of the round

Low-Energy Adaptive Clustering Hierarchy (LEACH)

- Adaptive Clustering
  - Distributed
- Randomized Rotation
  - Biased to balance energy loss
- Heads perform compression
  - Also aggregation
- In-cluster TDMA

LEACH: Adaptive Clustering

- Periodic independent self-election
  - Probabilistic
- CSMA CA used to advertise
- Nodes select advertisement with strongest signal strength
- Dynamic TDMA time slots



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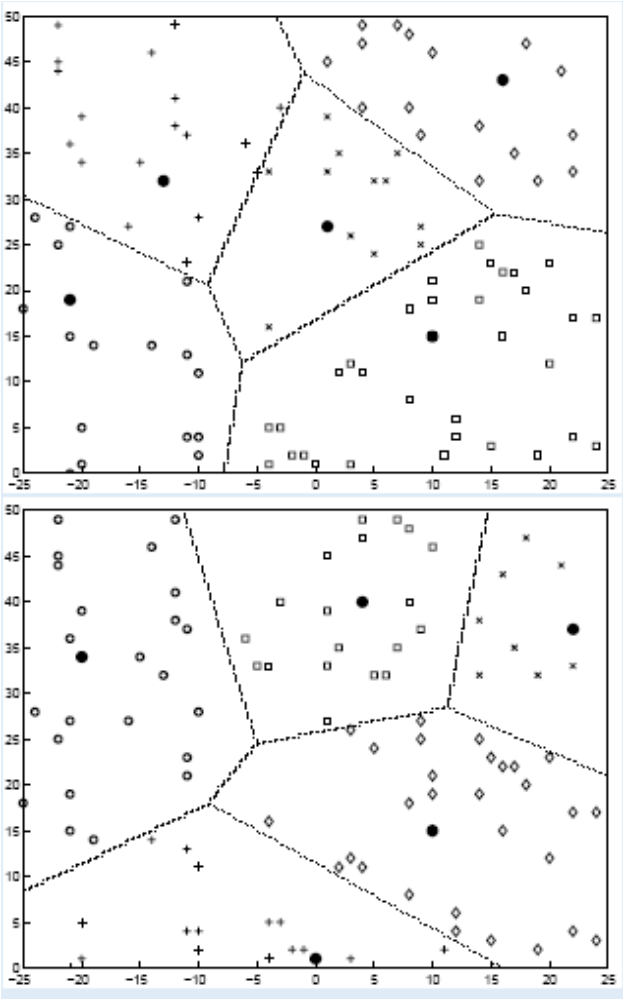


LEACH: Randomized Rotation

- Cluster heads elected every round
  - Recent cluster heads disqualified
  - Optimal number not guaranteed
- Residual energy considered
- P= Desired cluster head percentage
- r = Current Round
- G = Set of nodes which have not been cluster heads in 1/P rounds

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

LEACH: Hierarchical Clustering

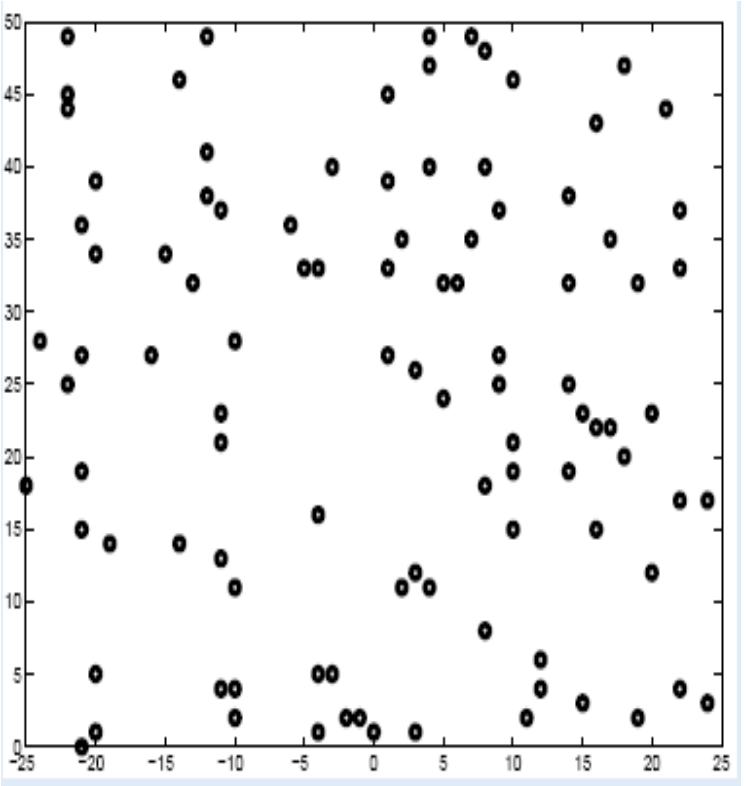
- Not currently implemented
- Efficient when network diameters are large

LEACH

- Drawbacks
  - It is not applicable to networks deployed in large regions
  - The idea of dynamic clustering brings extra overhead
  - The protocol assumes that all nodes begin with the same amount of energy capacity in each election round, assuming that being a CH consumes approximately the same amount of energy fore ach node

Performance: Parameters

- MATLAB Simulator
- 100-node random network
- E_{elec} = 50nj/bit
- ε_{amp} = 100pJ/bit/m2
- k = 2000 bits



Comparison between SPIN LEACH and directed diffusion[1]

	SPIN	LEACH	Directed diffusion
Optimal route	No	No	Yes
Network lifetime	Good	Very good	Good
Resource awareness	Yes	Yes	Yes
Use of meta-data	Yes	No	Yes

[1]W. Heinzelman, A. Chandrakasan and H. Balakrishnan, “Energy-Efficient Communication Protocol for Wireless Microsensor Networks,” *Proc. 33rd Hawaii Int’l. Conf. Sys. Sci.*, Jan. 2000.