Routing Techniques in Wireless Sensor Network: A Survey

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Outline

- **Introduction**
- **Routing challenges and design issues**
- **Routing protocols in WSNs**
  - ☐ Network structure based
  - ☐ Protocol operation based
- **Discussion**
- **Conclusion**

Introduction

- **Routing in WSNs is very challenging**
  - ☐ Impossible to build a global addressing scheme as in other wireless networks.
  - ☐ Tightly constrained in terms of energy, processing, and storage capacities.
  - ☐ Sensor networks are application specific
  - ☐ Position awareness of sensor nodes is important
  - ☐ Data redundancy
  - ☐ Etc.

Routing challenges and design issues

- **Node deployment**
  - Application-dependent
- **Energy consumption without losing accuracy**
  - The malfunction of some sensor due to power failue can cause topological changes
- **Data reporting method**
  - Time-driven vs. Event-driven vs. query-driven
- **Node/link heterogeneity**
- **Fault tolerance**
  - The failure of sensor nodes should not affect the overall task of the sensor network.

Routing challenges and design issues

- **Scalability**
  - ☐ Any routing scheme must be able to work with huge number of sensor nodes.
- **Network dynamics**
- **Connectivity**
  - ☐ High connectivity in sensor networks precludes them from being completely isolated from each other.
- **Coverage**
  - ☐ A sensor node can only cover a limited physical area of the environment.

Routing challenges and design issues

- **Data aggregation**
  - Data aggregation is the combination of data from different sources according to a certain aggregation function
- **Quality of service**
  - Bounded latency for data delivery
  - Energy conservation is a trade-off with QoS

Routing protocols in WSNs

- Classifying by the network structure:
    - Flat-based routing
    - Hierarchical-based routing
    - location-based routing
- Classifying by the protocol operation
    - Multipath based
    - Query-based
    - Negotiation-based
    - QoS-based
    - Coherent-based
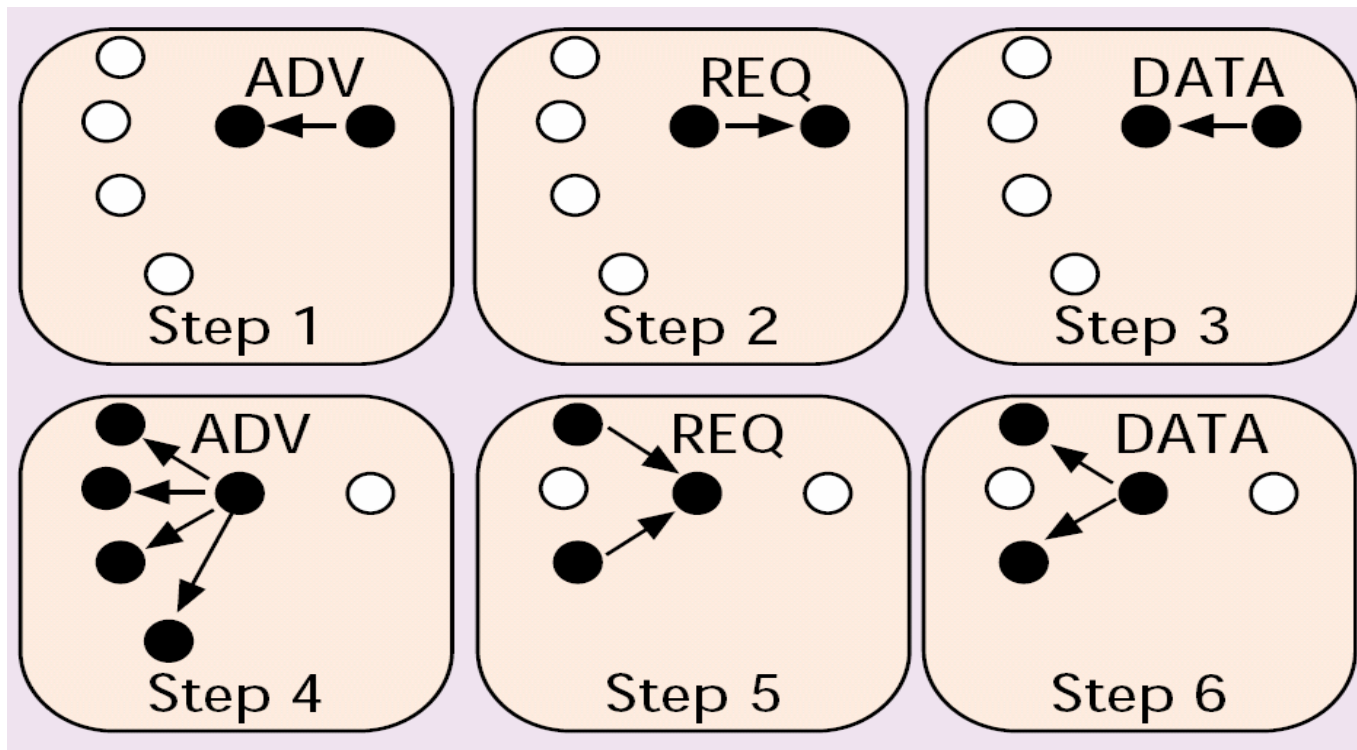
Flat-based routing

- Each node typically plays the same role

- Sensor nodes collaborate to perform the sensing task

- Data-centric routing

  - The BS sends queries to certain regions and waits for data from the sensors located in the selected regions

Flat-based routing

- Sensor Protocols for Information via Negotiation (SPIN)
  - Nodes assign a high-level name to completely describe their collected data
  - Perform metadata negotiation before data transmission
  - Works well in time-driven fashion

Flat-based routing
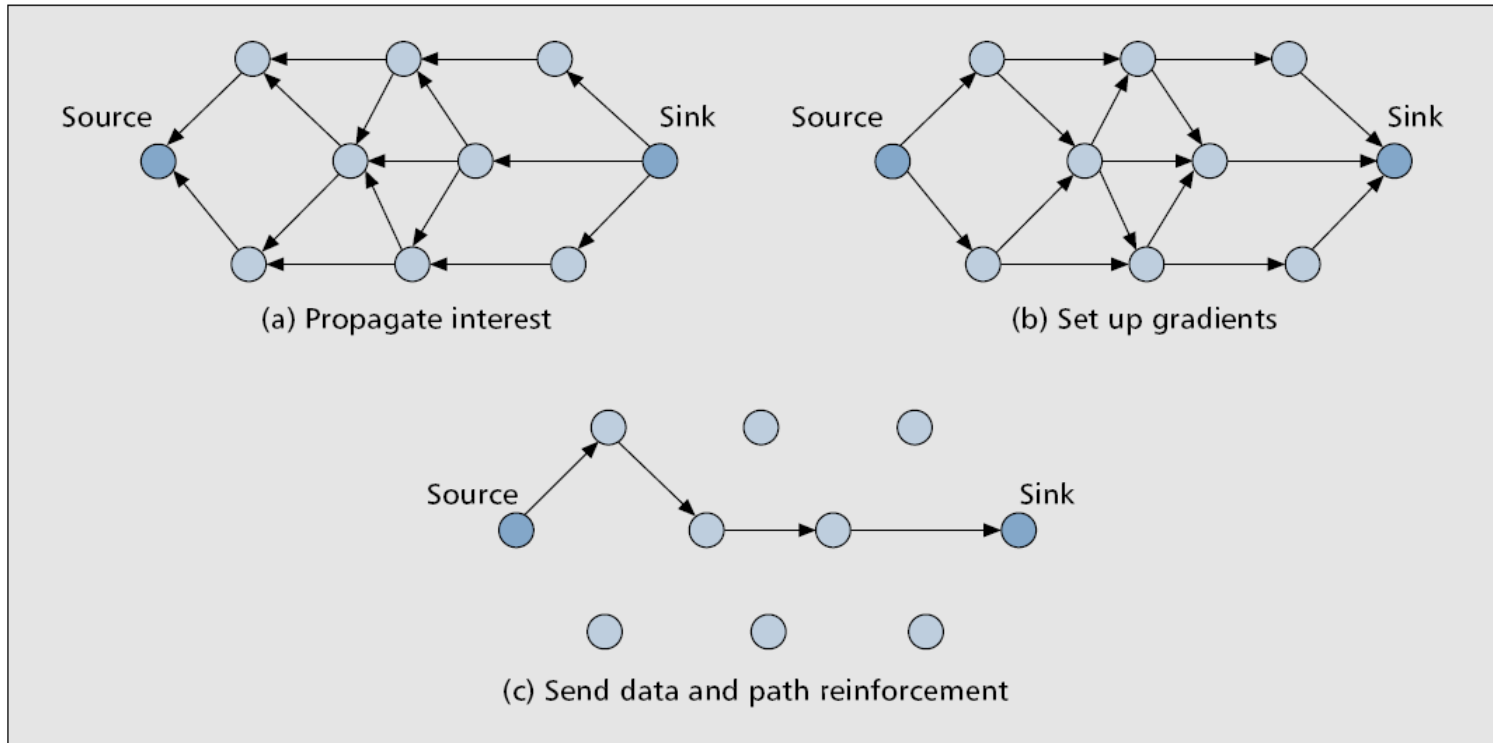
- SPIN's three-stage protocol

Flat-based routing

- SPIN provides more energy savings than flooding.

- Metadata negotiation almost halves the redundant data.

- However, SPIN cannot guarantee delivery of data.

Flat-based routing

■ Directed diffusion

(a) Propagate interest

(b) Set up gradients

(c) Send data and path reinforcement

Flat-based routing

- **Directed diffusion achieve energy saving by:**
  - ☐ Selecting empirically good paths
  - ☐ By cashing and processing data in the network
- **Directed diffusion can spontaneously propagate an important event to some section of the sensor networks**
  - ☐ It is not worth setting up gradients for queries that use the path only once.
- **Flooding the query message by BS to the entire network may decrease the system lifetime of WSNs.**

Flat-based routing

- **Rumor routing**
  - ☐ Employed when the number of events is small and the number of query is large.
  - ☐ When a node detects an event
    - Adds the event to its events table
    - Generates an agent, a long-lived packets, which contains the local event information
    - Let the agents travel the network
  - ☐ When a node generates a query for an event
    - the nodes that know the route may respond to the query
  - ☐ Rumor routing performs well only when the number of events is small.

Flat-based routing

- **Minimum cost forwarding algorithm**
  - ☐ Maintain the least cost estimate from the nodes to the BS.
    - The BS broadcasts a message with the cost set to zero.
    - When each node receives the broadcast message originated at the BS, checks to see if the estimate in the message plus the link cost on which it is received is less than the current estimate.
    - If yes, the node updates the broadcast message; and resends it.
  - ☐ Every node will check if itself is on the least cost path when receiving the forwarding message sent to BS.

Flat-based routing

- **Energy-Aware Routing**
  - ☐ Maintain a set of paths instead of only one optimal path
  - ☐ These path are chosen by means of a certain probability
  - ☐ By having paths chosen at different times, the energy of any single path will not deplete quickly.
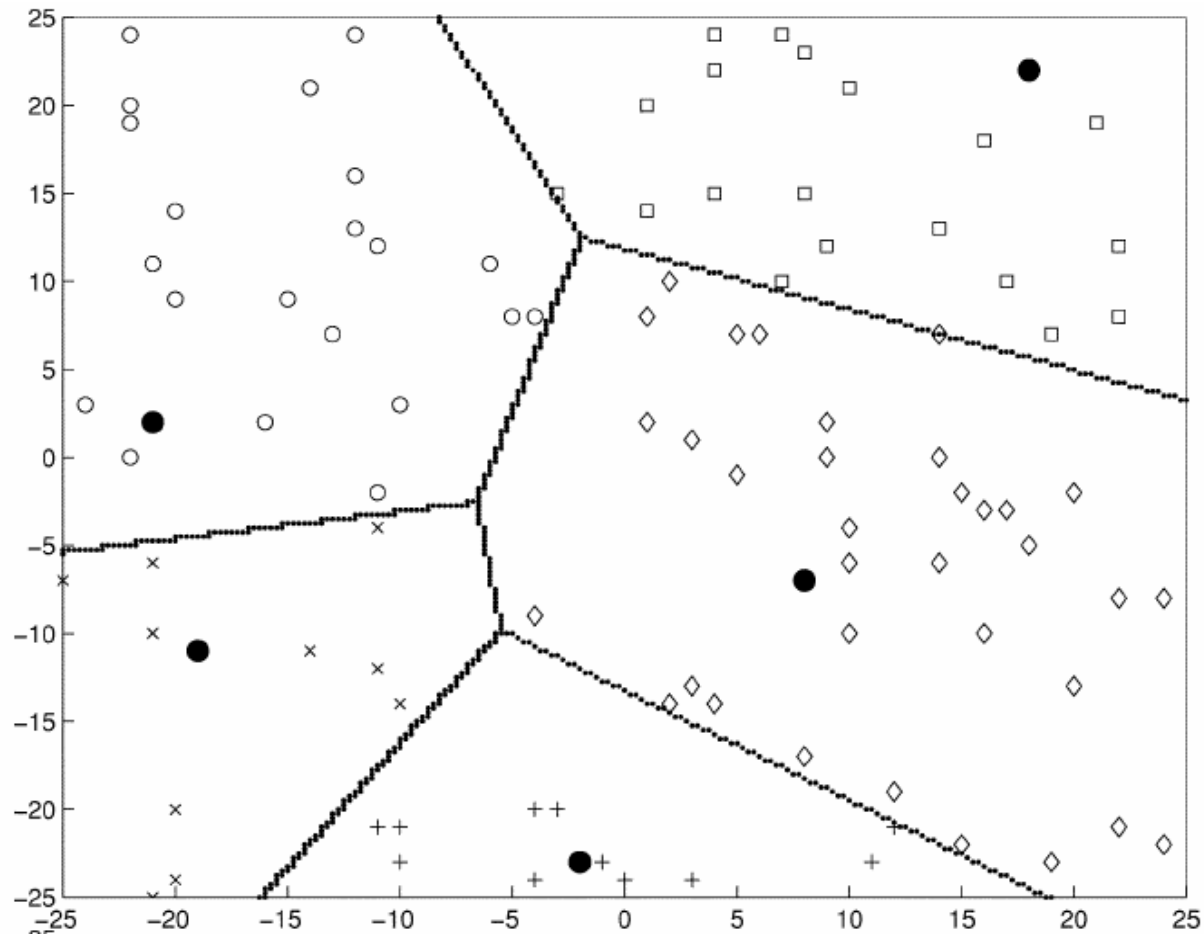
Hierarchical-based routing

- Nodes will play different roles in the network
- Higher energy nodes can be used to process and send the information
- Low energy nodes can be used to perform the sensing job
- Hierarchical-based routing is an efficient way to lower energy consumption within a cluter.

Hierarchical-based routing

- ■ LEACH protocol
  - □ Randomly selects a few sensor nodes as cluster heads and rotates this role to evenly distribute the energy load of sensor nodes.
  - □ LEACH is separated into two phases
    - ■ Setup phase
      - □ Select the CHs and organize the clusters
    - ■ Steady state phase
      - □ Actual data transfer to the BS according to the TDMA scheduling

Hierarchical-based routing

Hierarchical-based routing

- TDMA scheduling is an energy-efficient way for nodes to send data

- The unreasonable assumption of LEACH
  - All nodes can transmit with enough power to reach the BS
  - All nodes always have data to send
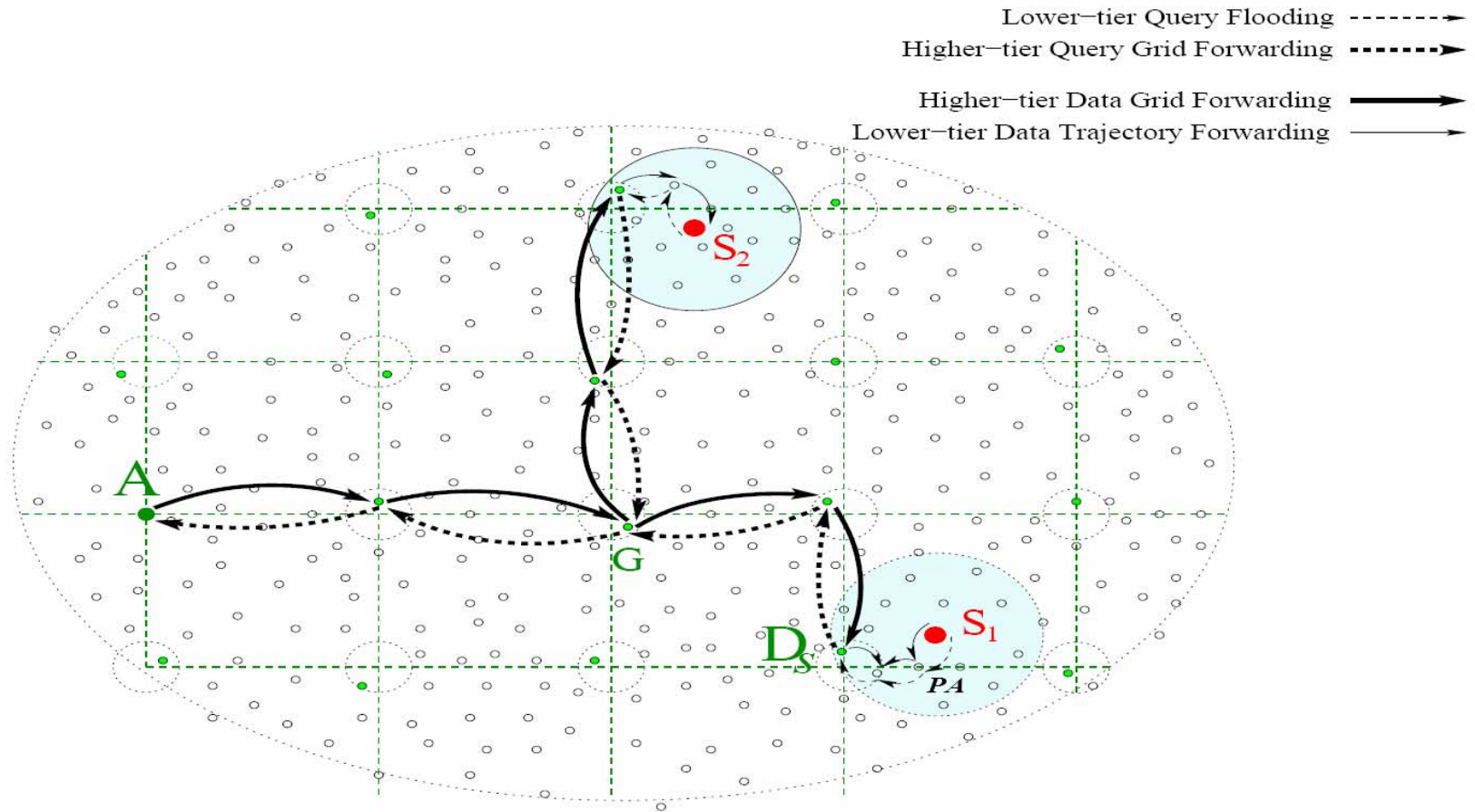
Hierarchical-based routing

- **Threshold-Sensitive Energy Efficient Network Protocols**
  - ☐ Sensor nodes sense the medium continuously, but data transmission is done less frequency.
  - ☐ CH sends its members two threshold
    - Hard threshold
    - Soft threshold
  - ☐ The node will transmit data only when:
    - The current value of the sensed attribute is greater than the hard threshold.
    - The current value of the sensed attribute differs from sensed value by an amount equal to or greater than the soft threshold.

Hierarchical-based routing

- **Two-tier Data Dissemination**
  - ☐ Each data source proactively builds a grid structure that is used to disseminate data
  - ☐ BS flood a query to the dissemination point of its local cell.
  - ☐ The dissemination point will forward the query to the source on the higher-tier.
  - ☐ Source return the data via the reverse path to the BS.

Hierarchical-based routing

Lower-tier Query Flooding ------->
Higher-tier Query Grid Forwarding ••••••••>
Higher-tier Data Grid Forwarding ------->
Lower-tier Data Trajectory Forwarding ------->

location-based routing

- Sensor nodes are addressed by means of their locations

- Sensor nodes' positions are exploited to route data in the network

- The location information can be obtain by GPS or by exchanging relative coordinates of neighbors for estimation.

location-based routing

- **Geographic Adaptive Fidelity (GAF)**
    - ☐ The network area is first divided into fixed zones and form a virtual grid.
    - ☐ The cluster size is dependent on the required transmitting power and communication direction.
    - ☐ Inside each zone, nodes will elect one sensor node to stay awake for a certain period of time, and then the rest go to sleep.
    - ☐ A CH can ask the sensor nodes in its cluster to switch on and start gathering data if it senses an object.

Classifying by the protocol operation

- ## Multipath based
  - ☐ Maintain multiple path from sink to source.
  - ☐ Enhance the system life time and fault tolerance
- ## Query-based
  - ☐ Sink node propagate a query for data.
  - ☐ Nodes with this data sends the data that matches the query back to the node that initiated the query
- ## Negotiation-based
  - ☐ Use high-level data descriptors in order to eliminate redundant data transmissions through negotiation.

Classifying by the protocol operation

- ## QoS-based
  - □ The network has to satisfy certain QoS metrics (delay, energy, bandwidth, etc.) when delivering data to the BS.
- ## Coherent and Noncoherent based
  - □ In coherent routing, the data is forwarded to aggregators after minimum processing.
  - □ In noncoherent data processing routing, nodes will locally process the raw data before it is sent to other nodes for further processing.

Discussion

- **Further research issues**
  - QoS problem posed by video and imaging sensors and real-time application
  - The mobility of nodes
    - BS or source or sensor nodes mobility
    - How to handle the overhead of the position update and topology change
  - The integration of sensor networks with wired networks

Discussion

- **Some directions for designing the routing protocol**
  - ☐ Main objective: prolonging network lifetime
  - ☐ Exploit redundancy
  - ☐ Tiered architectures
  - ☐ Achieve desired global behavior with adaptive localized algorithms
  - ☐ Leverage data processing and exploit computation near data sources to reduce communication
  - ☐ Time and location synchronization
  - ☐ Self-configuration and reconfiguration
  - ☐ Secure routing

Conclusion

- **We discussed** routing challenges and design issues

- Two categories of routing protocols have been discussed
  - ☐ Classifying by the network structure
  - ☐ Classifying by the protocol operation

- Highlight the design directions and possible issues