A Survey on Sensor Networks

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Outline

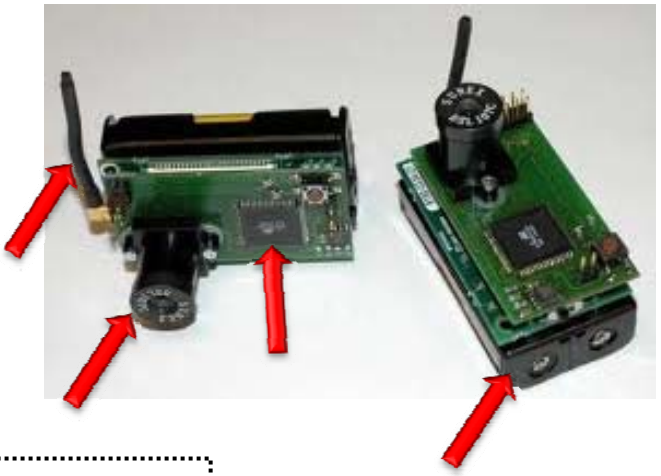
- **Introduction**
- **Sensor Networks Communication Architecture**
- **Protocol Stack**
  - Physical Layer
  - Data Link Layer
  - Network Layer
  - Transport Layer
  - Application Layer
- **Conclusion**

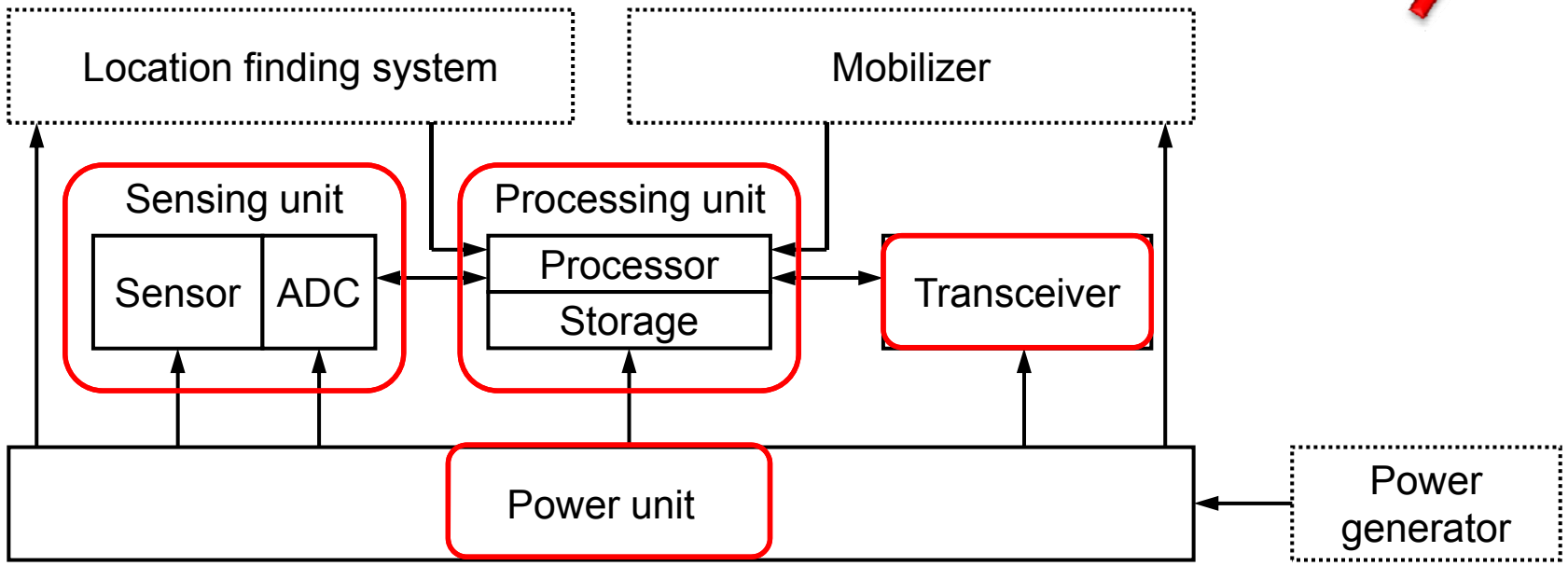
Introduction [1/4]

- **What is Sensor Network?**
  - **Sensor**
    - A transducer that converts a physical, chemical, or biological parameter into an electrical signal
  - **Sensor network**
    - Composed of a large number of sensor nodes
      - Wireless communication, densely deployed
    - The position of sensor nodes need not be engineered or pre-determined
      - Protocols and algorithms must possess **self-organizing capabilities**

Introduction [2/4]

- **Components of a sensor node**





Introduction [3/4]

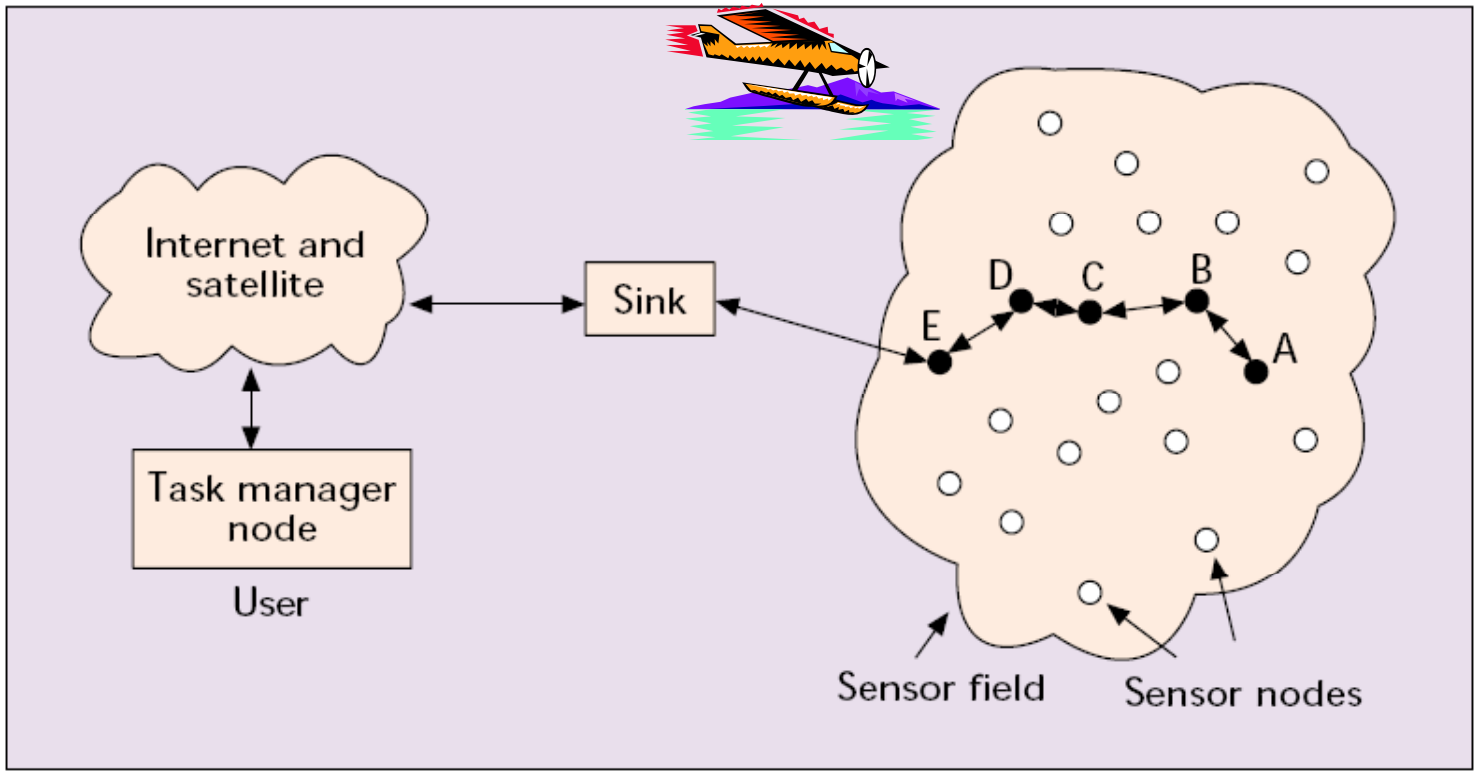
- **Application areas**
  - **Military**
    - Target tracking, surveillance, and reconnaissance
  - **Health**
    - Monitor patients and assist disabled patients
  - **Other commercial applications**
    - Managing inventory, monitoring product quality, and monitoring disaster areas

Introduction [4/4]

- **Sensor network** vs. **Ad hoc network**
  - The number of sensor nodes is much more than ad hoc network
  - Sensor nodes are densely deployed
  - Sensor nodes are prone to failures
  - The topology of sensor network changes very frequently
  - Sensor nodes mainly use a broadcast communication paradigm
  - Sensor nodes are limited in power, computational capacities, and memory
  - Sensor nodes may not have global ID

Sensor Networks
Communication Architecture [1/4]

- The sensor nodes are usually scattered in a sensor field
- Sensor nodes have the capabilities to collect data and route data back to the sink
- The sink may communicate with the task manager node via Internet or Satellite



Sensor Networks
Communication Architecture [2/4]

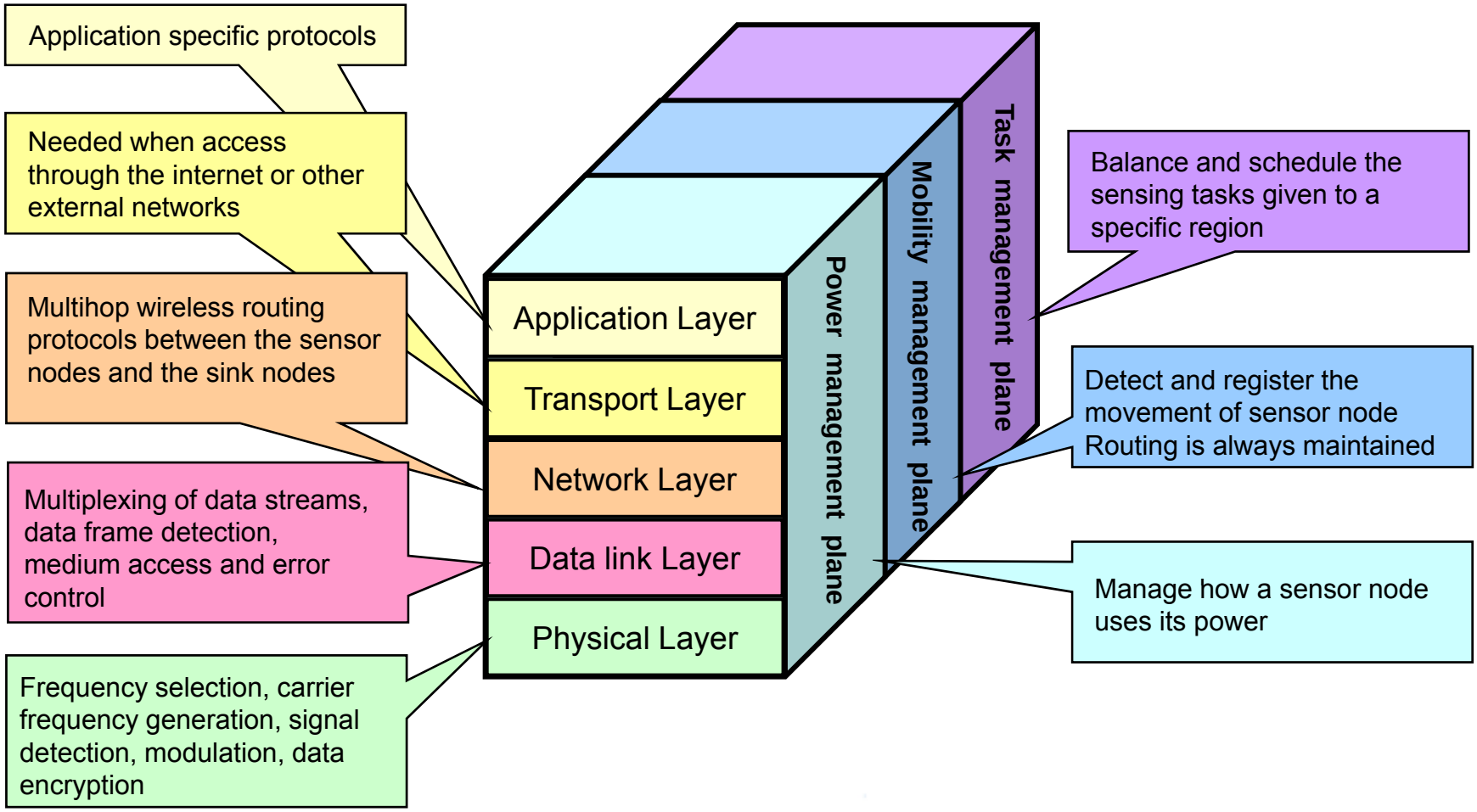
- **Design factors**
  - **Fault tolerance**
    - Sensor nodes may fail
      - Lack of power, physical damage, or environmental interference
  - **Scalability**
    - Large number of nodes, high density
  - **Production costs**
    - Since the sensor networks consist of a large number of nodes, the cost of a single node is very important
    - The cost of each sensor node has to be kept low
  - **Hardware constraints**
    - Small size, limited power

Sensor Networks
Communication Architecture [3/4]

- **Design factors (cont'd)**
  - **Sensor network topology**
    - Node deployment and topology maintenance strategy
  - **Environment**
    - Interior of large machinery
    - Bottom of an ocean
    - Battlefield beyond the enemy lines
    - Home or large building
  - **Transmission media**
    - RF, Infrared, and Optical medium
  - **Power consumption**
    - Sensor node lifetime strongly dependent on battery lifetime
    - Power consumption in sensing, data processing, and communication

Sensor Networks Communication Architecture [4/4]

- **Protocol stack** used by the sink and sensor nodes



Physical Layer [1/2]

- **Responsibility**
  - Frequency selection
  - Carrier frequency generation
  - Signal detection
  - Modulation
  - Data encryption
- **Multi-hop communication**
  - Long distance wireless communication can be expensive
  - Overcome shadowing and path loss effects
- **Energy-efficiency solutions are being pursued**

Physical Layer [2/2]

- **Open research issues**
  - **Modulation schemes**
    - Simple and low-power modulation schemes
  - **Strategies to overcome signal propagation effects**
  - **Hardware design**
    - Tiny, low-power, low-cost transceiver, sensing, and processing units need to be designed
    - Power-efficient hardware management strategy

Data Link Layer [1/4]

- **Responsibility**
  - Multiplexing of data streams
  - Data frame detection
  - Medium access control
  - Error control

- **Medium Access Control (MAC)**
  - **Goals**
    - Creation of the network infrastructure
    - Fairly and efficiently share communication resources between sensor nodes

Data Link Layer [2/4]

- **Reasons existing MAC protocols cannot be used**

	Sensor Network System	Existing Systems
Topology	- No central controlling agent - Frequently changes	Infrastructure-based (Cellular)
Number of nodes	> 1,000	< 8 (Bluetooth)
Primary Goal	Energy efficiency	QoS and Bandwidth efficiency (Cellular, MANET)
Radio Range	Much less than Bluetooth	10M (Bluetooth)
Conclusion	None of existing MAC protocols can be directly used in sensor networks	

Data Link Layer [3/4]

- **The features and effectiveness of MAC protocols**

MAC protocol	Channel access mode	Sensor network specifics	Power conservation
SMACS and EAR	Fixed allocation of duplex time slots at fixed frequency	Exploitation of large available bandwidth compared to sensor data rate	Random wake up during setup and turning radio off while idle
Hybrid TDMA/FDMA	Centralized frequency and time division	Optimum number of channels calculated for minimum system energy	Hardware-based approach for system energy minimization
CSMA-based	Contention-based random access	Application phase shift and pre-transmit delay	Constant listening time for energy efficiency

- SMACS (Self-Organizing Medium Access Control for Sensor Networks)
- EAR (Eavesdrop-And-Register)
- TDMA (Time Division Multiple Access)
- FDMA (Frequency Division Multiple Access)
- CSMA (Carrier Sense Multiple Access)

Data Link Layer [4/4]

- **Power saving modes of operation**
  - Turn the transceiver off when it is not required
    (Can be ineffective due to startup costs)
  - Threshold approach

- **Error control**
  - Simple error control with low complexity encoding/decoding is desirable
  - FEC (Forward Error Correction)
  - ARQ (Automatic Repeat request)

- **Open research issues**
  - MAC for mobile sensor networks
  - Error control coding schemes
  - Power-saving modes of operation

Network Layer [1/8]

- **Responsibility**
  - Provides special multi-hop wireless protocols between sensor nodes and the sink node
- **Design principles**
  - Power efficiency is important consideration
  - Sensor networks are mostly data-centric
  - Data aggregation is useful only when it does not hinder the collaborative effort of the sensor nodes
  - Attribute-based addressing & location awareness

Network Layer [2/8]

- **Energy-efficient route**
  - Based on available power (PA) or the energy required (α) for transmission in the links
    - **Maximum PA route**
    - **Minimum energy route**
    - **Minimum hop route**
    - **Maximum minimum PA node route**

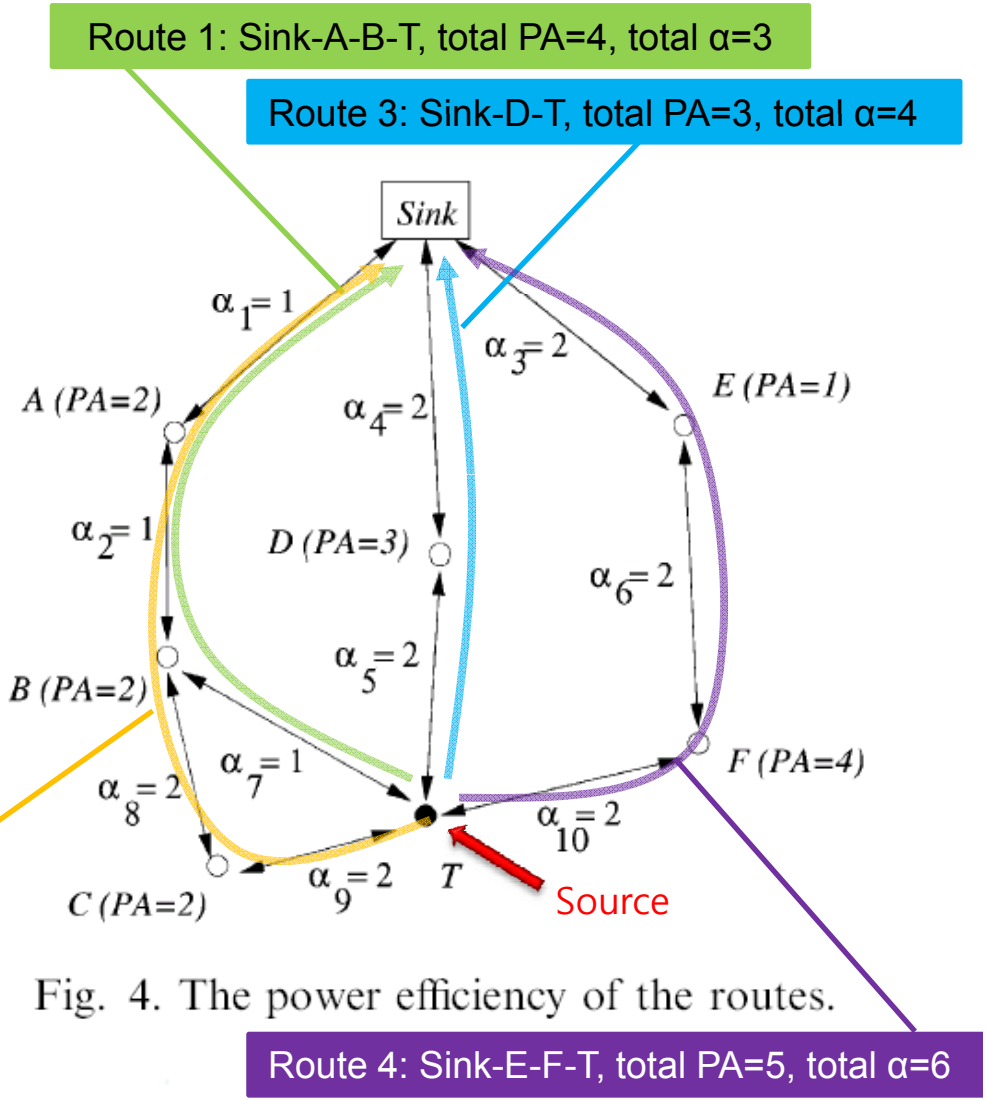
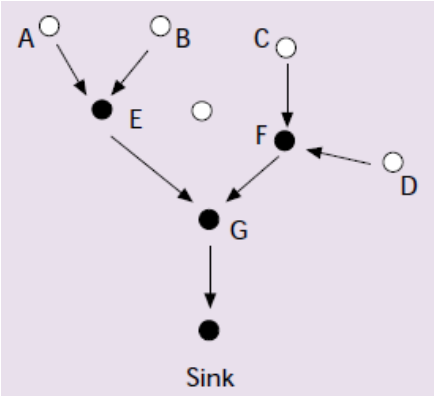


Fig. 4. The power efficiency of the routes.

Network Layer [3/8]

- **Data-centric routing**
  - Lack of global identification – Hard to select nodes to be queried
  - ***Interest dissemination*** is performed to assign the sensing tasks to the sensor nodes
    - The sink broadcasts queries to sensor nodes and waits for data

- **Data aggregation**
  - Solves overlap problem in data-centric routing
  - Method for combining the data coming from multiple sensor nodes into meaningful information



Network Layer [4/8]

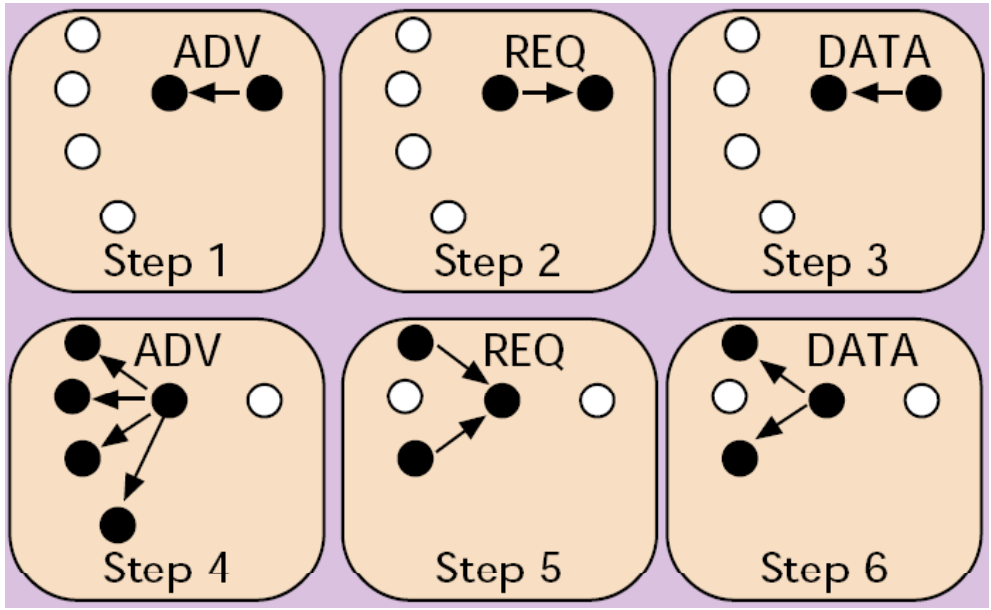
- **Small Minimum Energy Communication Network (SMECN)**
  - Computes energy-efficient sub-network
  - Maintains minimum energy property such that there is a minimum energy path in sub-graph for every pair of node

- **Flooding**
  - Each node broadcasts the data until maximum hops or destination reached
  - Not suitable because of implosion, overlap and resource blindness

- **Gossiping**
  - A node randomly picks up a neighbor and forwards the packet
  - Avoids implosions but takes longer time to propagate the message

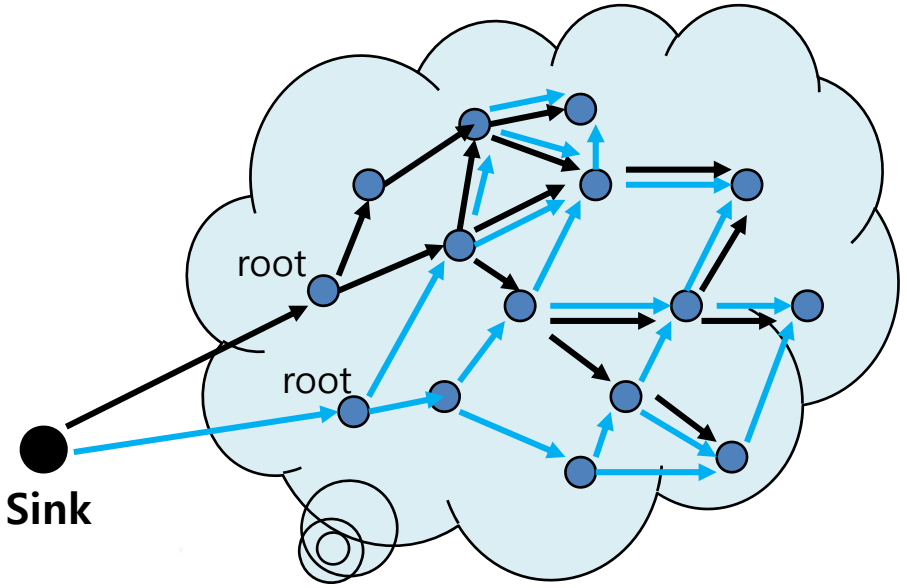
Network Layer [5/8]

- **Sensor Protocols for Information via Negotiation (SPIN)**
  - Address deficiency of flooding by negotiation and resource adaptation
  - Broadcast limited by negotiation
  - Based on data-centric routing
  - Three messages: ADV, REQ, and DATA



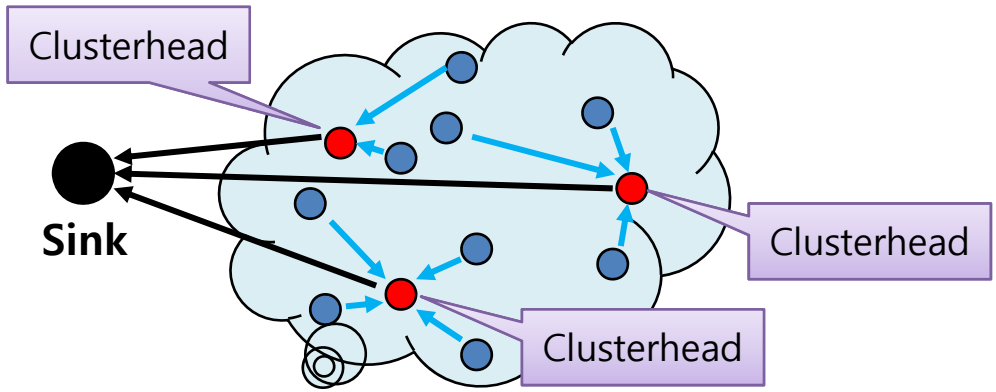
Network Layer [6/8]

- **Sequential Assignment Routing (SAR)**
  - Creates multiple trees such that root is one hop away from sink
  - Each tree grows outwards avoiding nodes with low QoS and energy reserves
  - Nodes belong to multiple trees and selects one tree to relay information back to sink
  - Two parameters associated with each path
    - Energy resource
    - Additive QoS metric



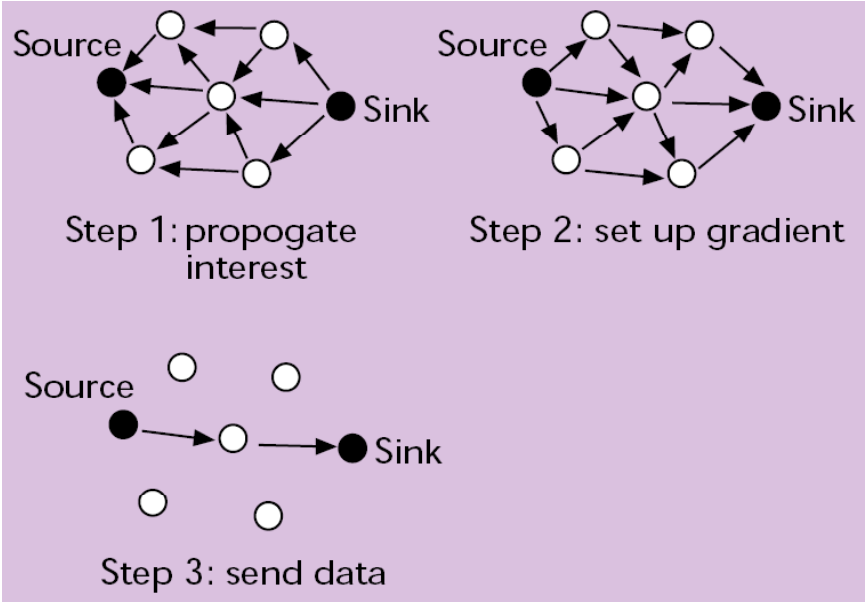
Network Layer [7/8]

- **Low-Energy Adaptive Clustering Hierarchy (LEACH)**
  - Minimizes energy dissipation
  - Two phases:
    - Setup
      - Randomly selects clusterheads which communicates with sink
      - Clusterheads broadcast their address and sensor nodes pickup clusterheads based on signal strength of clusterheads
    - Steady
      - Begin sensing and transmitting data to the clusterhead
      - Clusterheads aggregate data from the nodes
      - After sometime in this phase the network goes back in setup phase



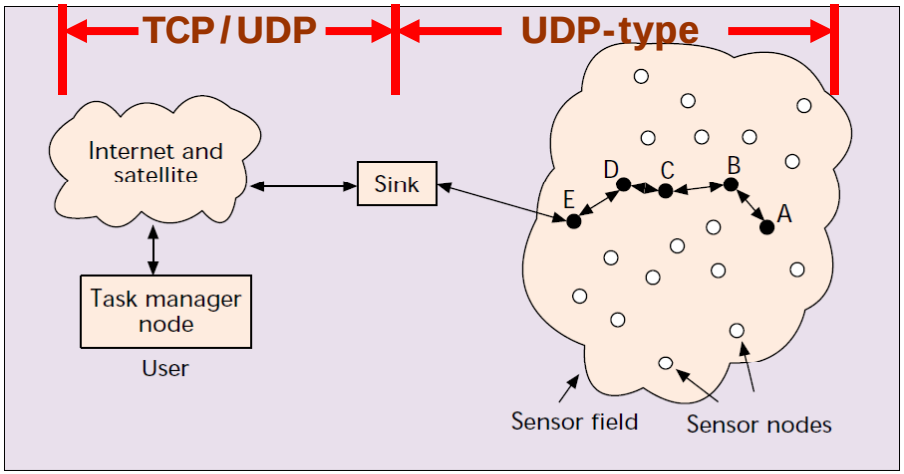
Network Layer [8/8]

- **Directed Diffusion**
  - Step1: Sink sends out interest (task description) to all sensor
  - Step2: As interest propagates, the gradient from source to sink is setup
  - Step3: When the source has data for the interest, the source sends the data along the interest's gradient path
  - Sink must refresh and reinforce the interest when it starts to receive data from the source



Transport Layer

- Needed when the system is accessed through internet or external network
- **TCP splitting needed**
  - To make sensor networks interact with other networks
  - Communication between an user node and the sink node
    - TCP or UDP via the internet or satellite
  - Communication between the sink node and a sensor node
    - UDP-type protocol, because each senor node has limited memory



Application Layer

- Potential application layer protocols for sensor networks remains a largely unexplored region
- **Application layer protocols**
  - **SMP** (Sensor Management Protocol)
    - Perform administrative tasks
  - **TADAP** (Task Assignment and Data Advertisement Protocol)
    - Interest dissemination
  - **SQDDP** (Sensor Query and Data Dissemination Protocol)
    - Issue queries, respond to queries, and collect replies

Conclusion

- In the future, this wide range of application areas will make sensor networks an integral part of our lives
- Realization needs to satisfy the constraints such as scalability, topology changes, power consumption, environment etc.
- New wireless ad hoc networking techniques are required to overcome this constraints