A Survey on Sensor Networks

Ian F. Akyildiz, Weilian Su,
Yogesh Sankarasubramaniam, and Erdal Cayirci

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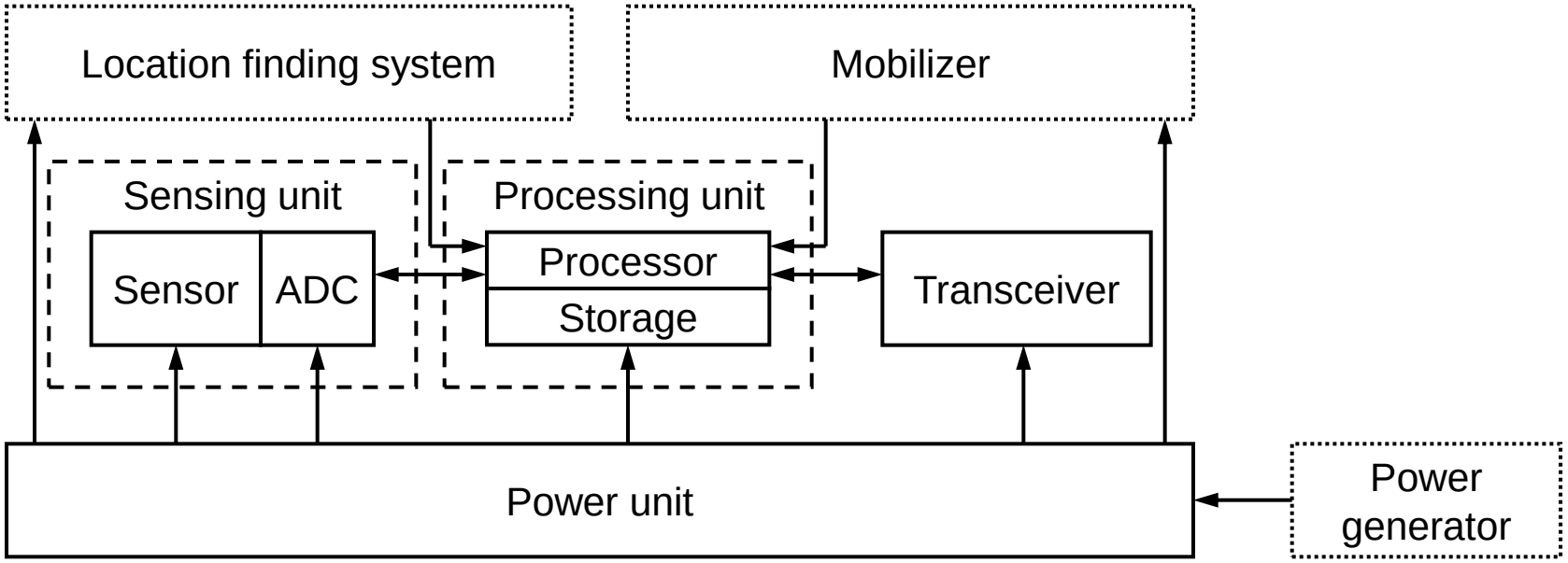
Introduction

- **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-dete rmined
      - Protocols and algorithms must possess self-organizing capabilities

Introduction

- **Components of a sensor node**



Introduction

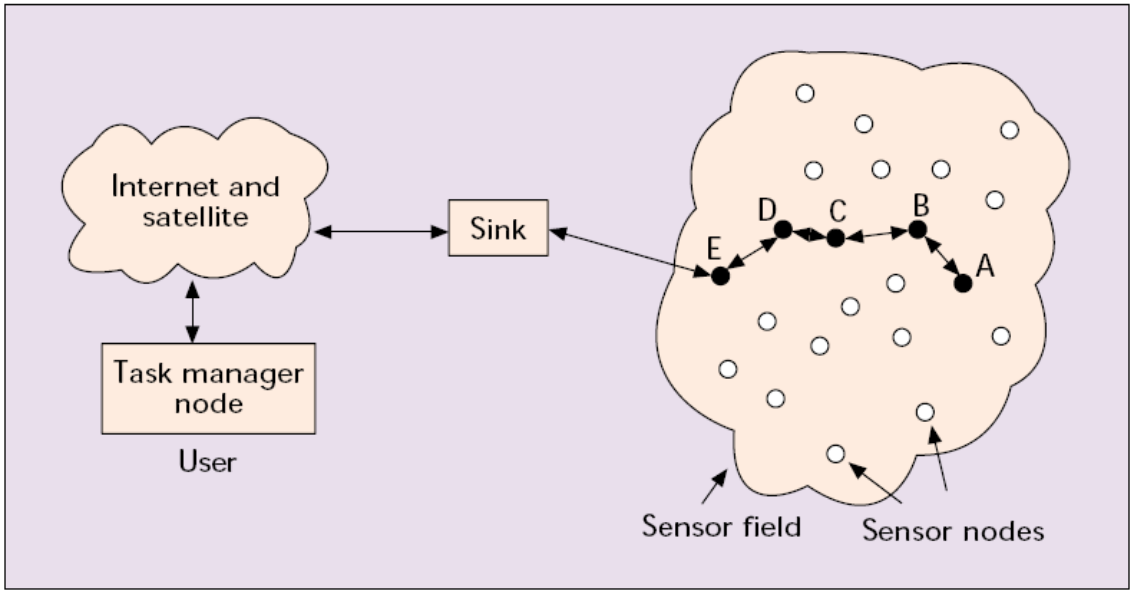
- **Application areas**
  - **Military**
    - Target tracking, surveillance, and reconnaissance
  - **Health**
    - monitor patients and assist disabled patients
  - **Other commercial applications**
    - managing inventory, monitoring product quality, and monitoring disaster areas

Introduction

- **Differences from traditional ad hoc networks**
  - **The number of sensor nodes is much more than ad hoc network.**
  - **Densely deployed**
  - **Prone to failures**
  - **The topology of sensor network changes very frequently**
  - **Mainly use a broadcast communication paradigm**
  - **Sensor nodes are limited in power, computational capacities, and memory**
  - **May not have global ID**

Introduction

- **Key design issues**
  - Low-cost
  - Low-power
- **Sensor network overview**



Sensor Networks Communication Architecture

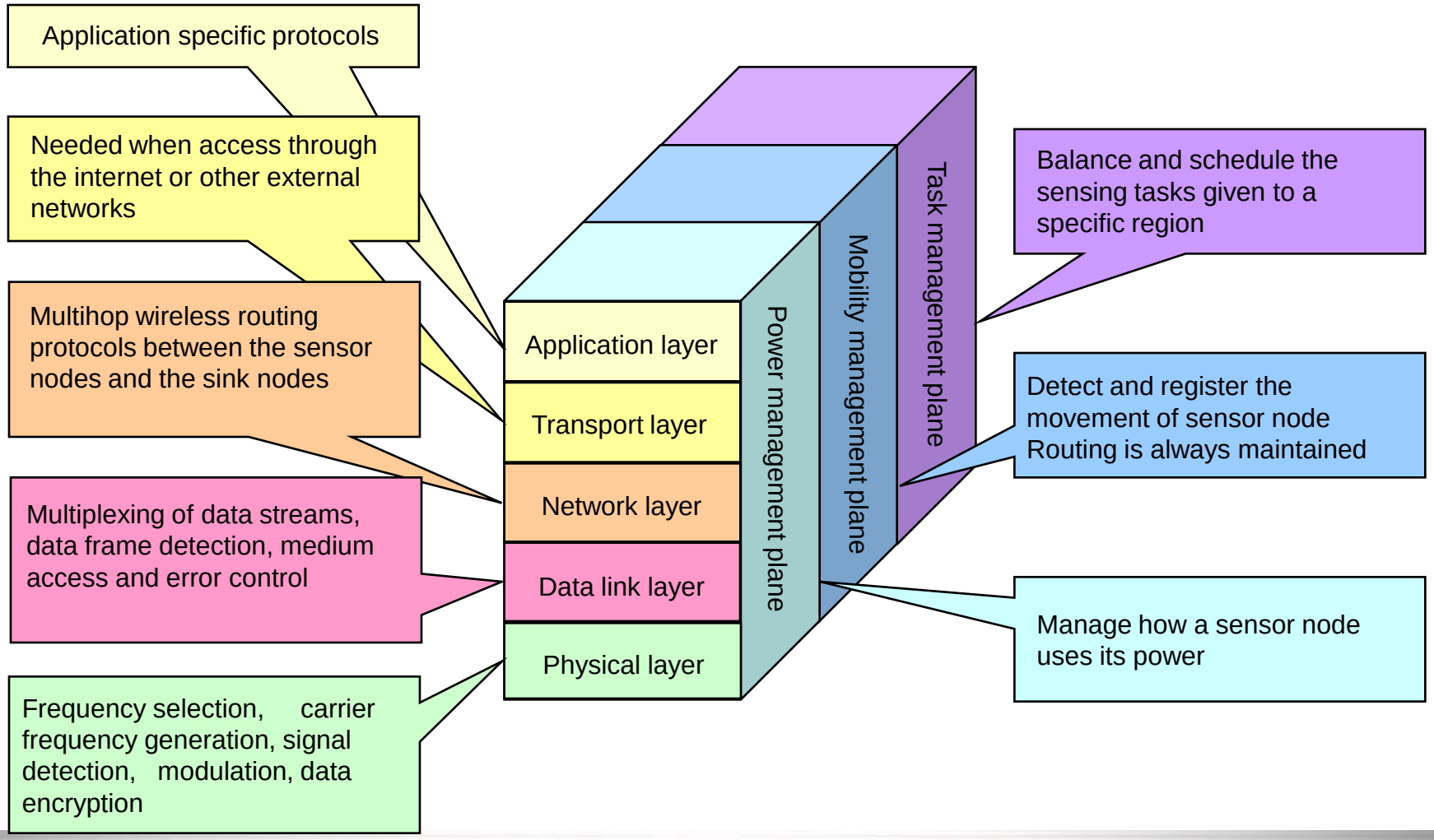
- **Design factors**
  - **Fault tolerance**
    - Sensor nodes may fail
      - Lack of energy, physical damage, or environmental interference
  - **Scalability**
    - Large number of nodes, high density
  - **Production costs**
    - Since the sensor networks consist of a large number of nodes, the cost of a single node is very important.
    - The cost of sensors has to be less expensive than traditional sensors
  - **Hardware constraints**
    - Small device, limited power

Sensor Networks Communication Architecture

- **Design factors**
  - **Sensor network topology**
    - Node deployment strategy
  - **Environment**
    - Interior of large machinery
    - Bottom of an ocean
    - Battlefield beyond the enemy lines
    - Home or large building
  - **Transmission media**
    - RF, Infrared
  - **Power consumption**
    - Sensing, processing, communication

Sensor Networks Communication Architecture

- **Protocol stack**



Physical Layer

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

Physical Layer

- **Transmission media**
  - **RF**
  - **Infrared**
- **Open research issues**
  - **Modulation schemes**
  - **Strategies to overcome signal propagation effects**
  - **Hardware design**

Data Link Layer

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

- **Medium Access Control**
  - **Goals**
    - Creation of the network infrastructure
    - Fairly and efficiently share communication resources between sensor nodes
  - **Existing MAC protocols cannot be used**
    - No central controlling agent like BS
    - Topology changes are more frequent

Data Link Layer

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

	Sensor	**Others**
Topology	No central controlling agent	Infrastructure-based (Cellular)
Number of nodes	> 1,000	< 8 (Bluetooth)
Primary Goal	Energy efficiency	QoS and Bandwidth efficiency (Cellur, MANET)
Conclusion	None of existing MAC protocols can be directly used in sensor networks	

Data Link Layer

- **Self-Organizing Medium Access Control for Sensor Networks (SMACS)**
  - **Kind of distributed infrastructure-building protocol**
  - **Enables nodes to discover their neighbors**
  - **Establish transmission/reception schedules for communication**
  - **Not need for any local or global master nodes**
- **Eavesdrop-And-Register algorithm**
  - **Enables seamless connection of mobile nodes**
- **Hybrid TDMA/FDMA Based**
  - **Centrally controlled MAC scheme**
  - **Time synchronization costs**

Data Link Layer

- **CSMA-Based Medium Access**
  - **Listening mechanism**
    - Power conservation
  - **Backoff scheme.**
    - Robustness against repeated collisions.
  - **ARC (Adaptive transmission Rate Control)**
    - Balancing the rates of originating and route-through traffic

MAC protocol	Channel access mode	Sensor network specifics	Power conservation
SMACS and EAR [13]	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 [8]	Centralized frequency and time division	Optimum number of channels calculated for minimum system energy	Hardware-based approach for system energy minimization
CSMA-based [9]	Contention-based random access	Application phase shift and pretransmit delay	Constant listening time for energy efficiency

Data Link Layer

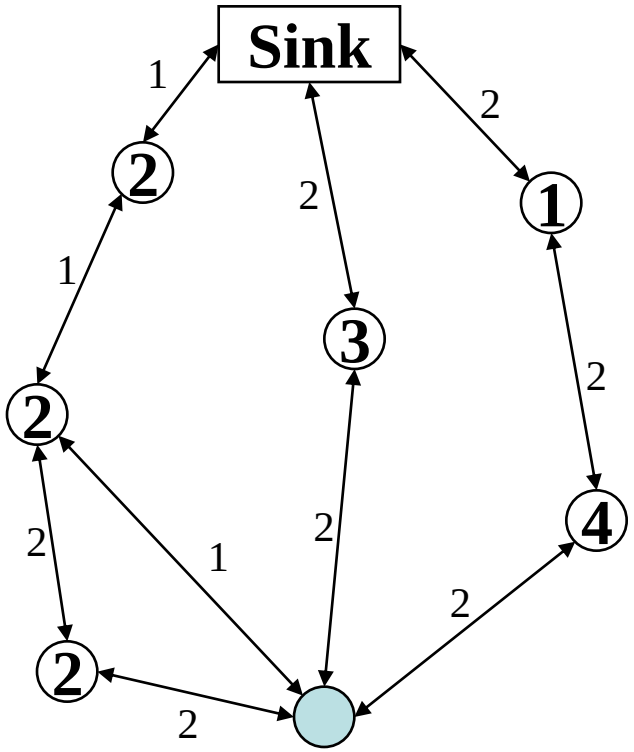
- **Power saving modes of operation**
  - **Turn the transceiver off when it is not required (not recommended)**
- **Error control**
  - **Simple error control is recommended**
  - **FEC (Forward Error Correction)**
  - **ARQ (Automatic Repeat request)**
- **Open research issues**
  - **MAC for mobile sensor networks**
  - **Error control coding schemes**
  - **Power-saving modes of operation**

Network Layer

- **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
- **Open research issues**
  - Improvement or development network-layer protocols

Network Layer

- **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



Network Layer

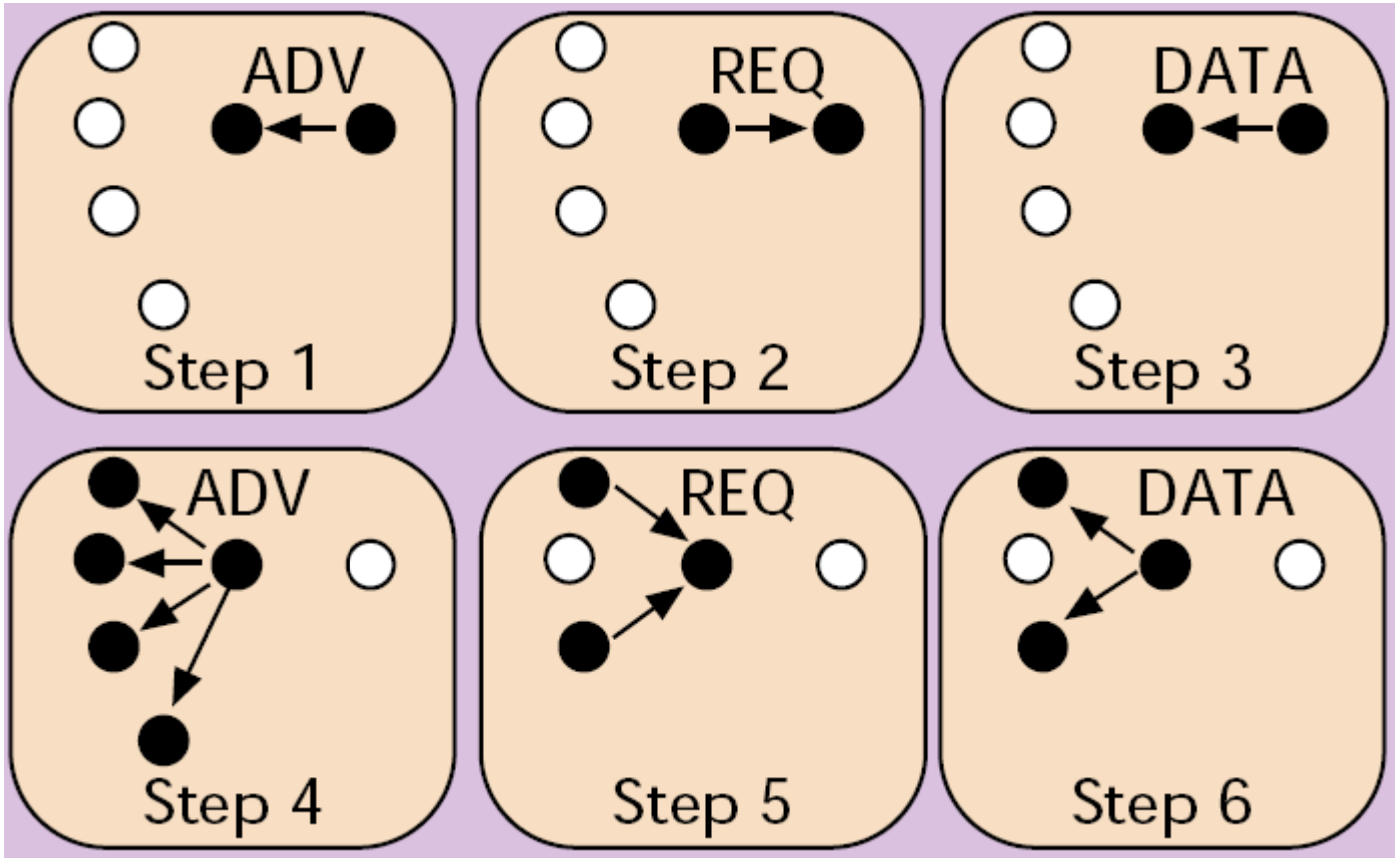
- **Data centric routing protocol**
  - **Lack of global identification – Hard to select nodes to be queried**
  - **The sink sends queries to certain regions and waits for data from the sensors located in selected regions**
- **Flooding**
  - **Broadcast a data packet to all of neighbors**
  - **Pros : simple**
  - **Cons : Implosion, overlap, resource blindness**

Network Layer

- **Gossiping**
  - Send a data packet to a randomly selected neighbor
  - Pros: Avoids the implosion problem
  - Cons: long propagation delay
- **Sensor Protocols for Information via Negotiation (SPIN)**
  - Broadcast limited by negotiation
  - Three messages: ADV, REQ, and DATA
- **Directed Diffusion**
  - Sets up gradients for data to flow from source to sink during interest dissemination

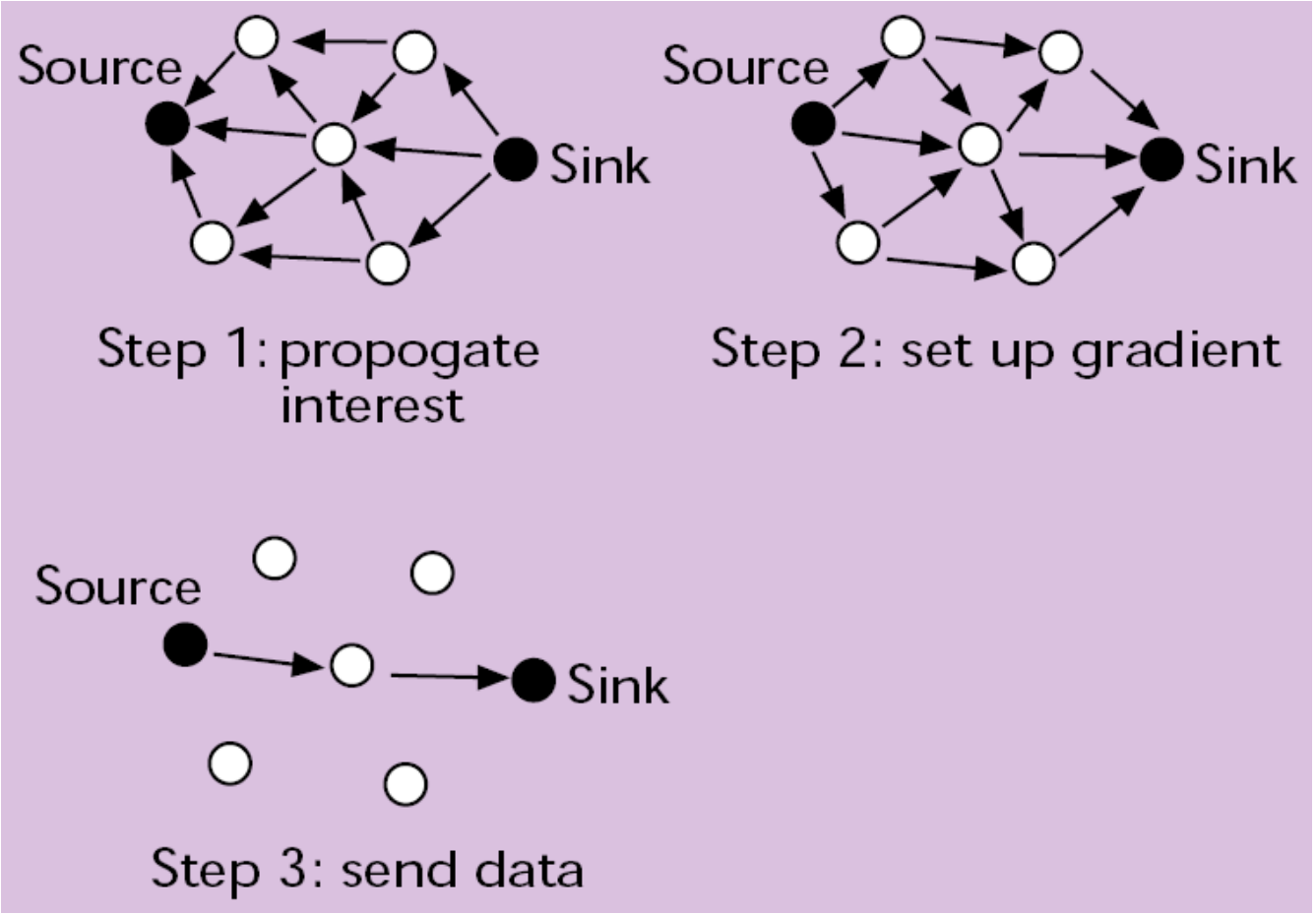
Network Layer

- SPIN



Network Layer

- **Directed Diffusion**



Network Layer

- **Low-Energy Adaptive Clustering Hierarchy (LEACH)**
  - **Randomly select sensor nodes as cluster-heads**
  - **Setup phase**
    - Sensor node chooses a rand(0~1)
    - If rand(0~1) is less than the threshold, the sensor node is a cluster-head
    - The cluster-head advertise to all sensor nodes in the network.
    - Received the advertisement, they determine the cluster to which they want to belong. (based on signal strength)
  - **Steady phase**
    - Sensing and transmitting data to the cluster-heads
    - Cluster-heads aggregate data from the nodes
  - **After a certain period of time spent on the steady phase, the network goes into the setup phase**

Network Layer

- **Low-Energy Adaptive Clustering Hierarchy (LEACH)**
  - **Pros**
    - Optimize energy used by shutting down node's radios and load balancing
    - Only two hops needed for reaching sink
  - **Cons**
    - Cluster head failure
    - Head selection is difficult to optimize
    - Expensive assumption for all nodes to be capable of long range communication

Transport Layer

- **Responsibility**
  - **System is planned to be accessed through the other external networks**
- **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
- **Open research issues**
  - **Development of transport layer protocols**

Application Layer

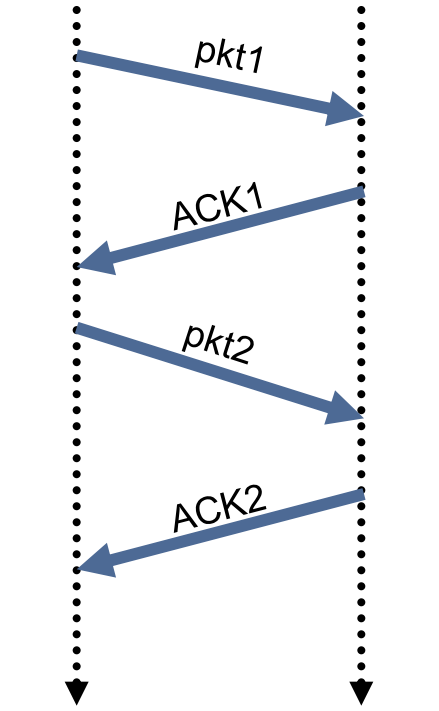
- **Potential application layer protocols for sensor networks remains a largely unexplored region**
- **Application layer protocols**
  - **SMP (Sensor Management Protocol)**
    - Perform administrative tasks
  - **TADAP (Task Assignment and Data Advertisement Protocol)**
    - Interest dissemination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

Conclusion

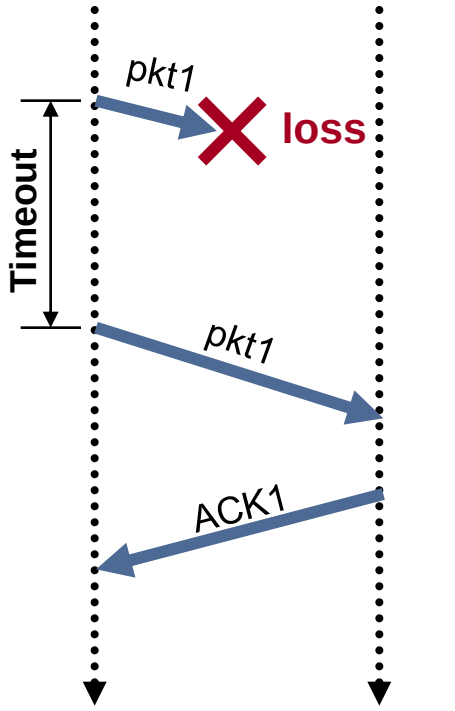
- **In the future, this wide range of application areas will make sensor networks an integral part of our lives**
- **However, realization of sensor networks needs to satisfy the constraints introduced by factors such as *fault tolerance*, *scalability*, *hardware*, *topology change*, *environment* and *power consumption*.**
- **Many researchers are currently engaged in developing the technologies needed for different layers of the sensor networks protocol stack**

ARQ

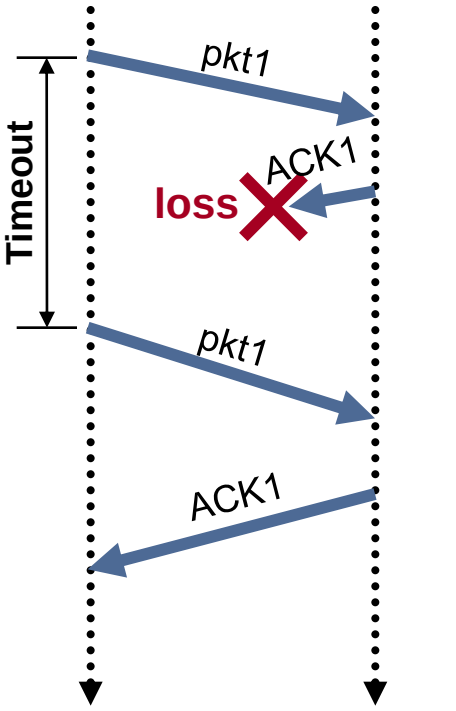
- **How to detect faults occurring?**
  - **TCP error detection**
    - Require additional message (ACK)



No loss



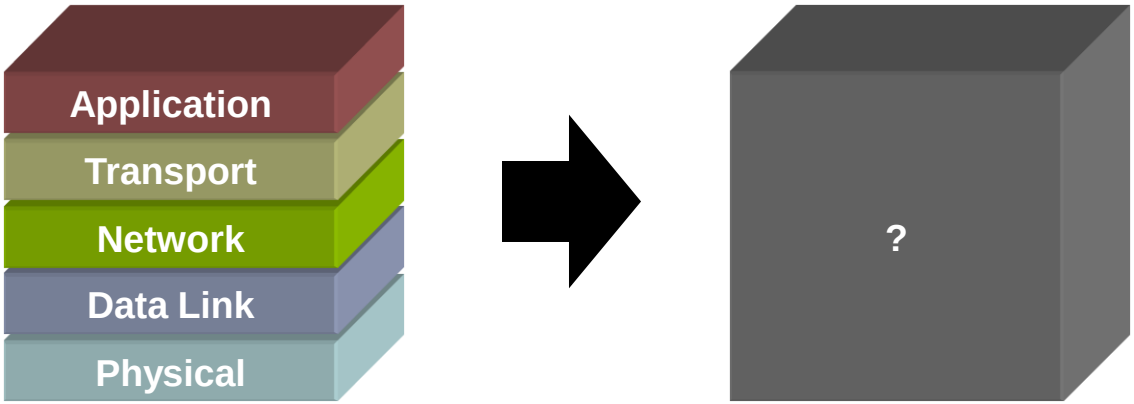
Lost packet



Lost ACK

Cross-layer Design

- **Cross-layer design**



  - **Pros**
    - Overcome potential performance problems
      - Sharing network-status information
  - **Cons**
    - Difficult to maintain
      - Modifications must be propagated across all protocols