# CS 525M – Mobile and Ubiquitous Computing Seminar

## A Survey on Sensor Networks

*presented by*

Jeffrey R. Bacon

# Background Info

- Published in 2002
- At the *Georgia Institute of Technology*
- Authors:
  - Ian F. Akyildiz
  - Weilian Su
  - Yogesh Sankarasubramaniam
  - Erdal Cayirci

# What's a sensor network?

- Large number of sensor nodes
  - Multifunction sensors
  - Low-cost
  - Low-power
  - Tiny
  - Mobile

# Uses

- Military
  - Command
  - Control
  - Communications
  - Intelligence
  - Surveillance
  - Reconnaissance
  - Targeting
- Health
  - Monitor patients
  - Assist disabled patients
- Commercial
  - Manage inventory
  - Monitor product quality
  - Monitor disaster/dangerous areas

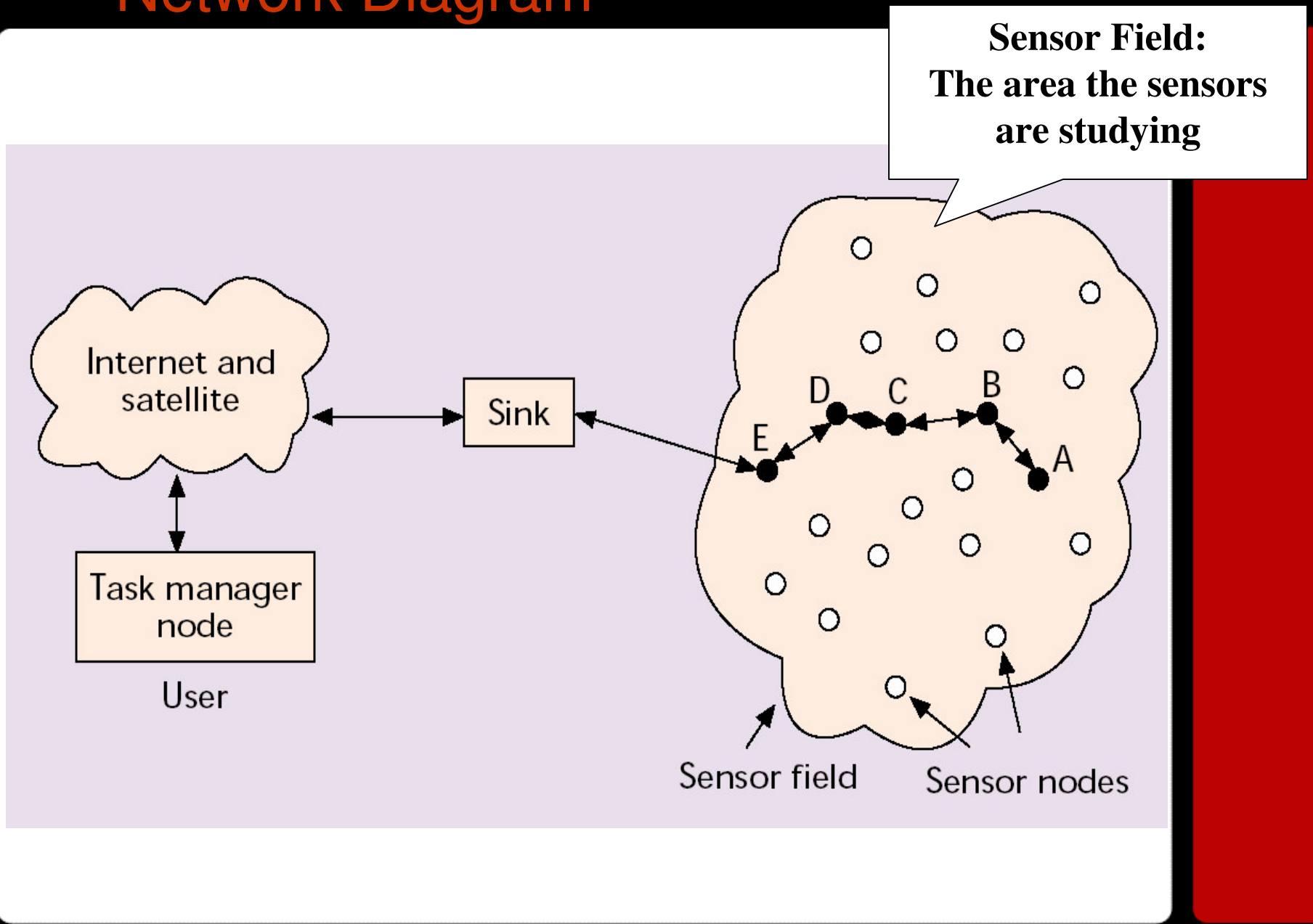
# How is this different?

- Not a traditional ad-hoc network
  - Number of nodes can be orders of magnitude higher
  - Sensors densely deployed
  - Sensor nodes prone to failure
  - Topology changes frequently
  - Broadcast paradigm (not point-to-point)
  - Limited power, computing, memory
  - No global identification

# Network Parts

- Sensor Field:  The area that the sensors can examine
- Sensor Nodes:  The sensors & other physical components
- Sink:  A local workstation that gathers data and manages the network
- The Internet/Satellite:  Sends data gathered by sink to other locations
- Task Manager/User:  End user controlling/receiving data

# Network Diagram



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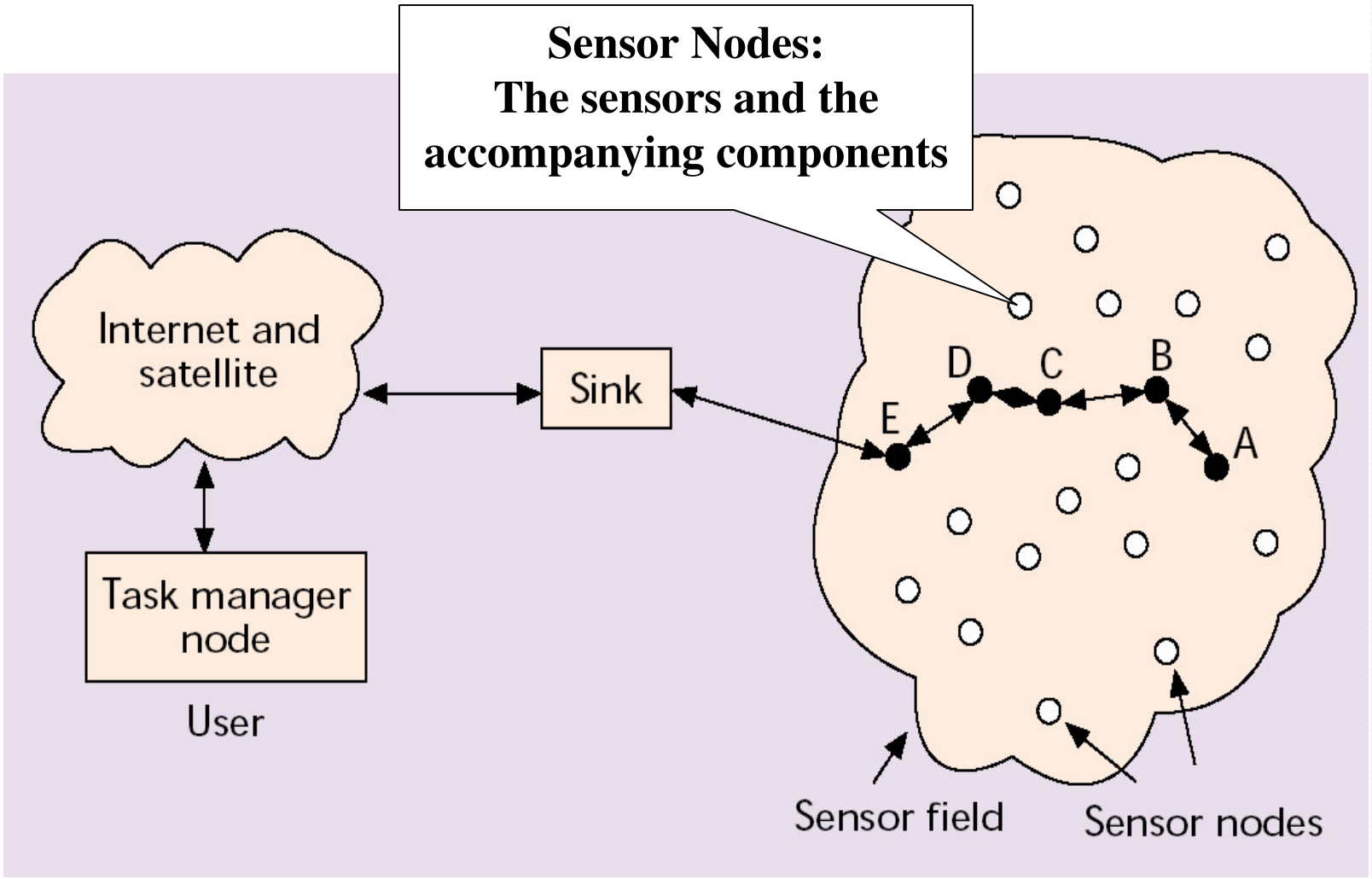

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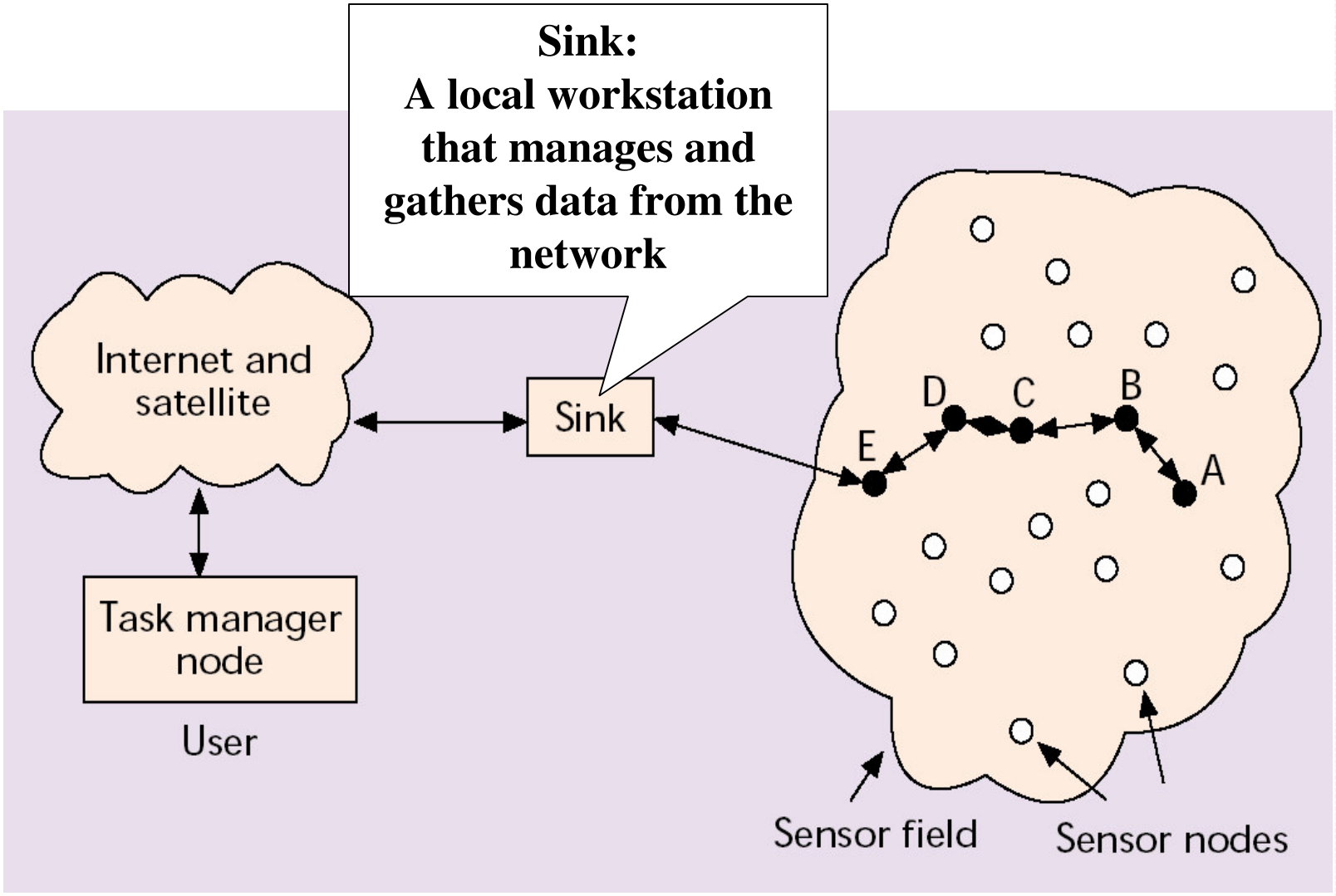

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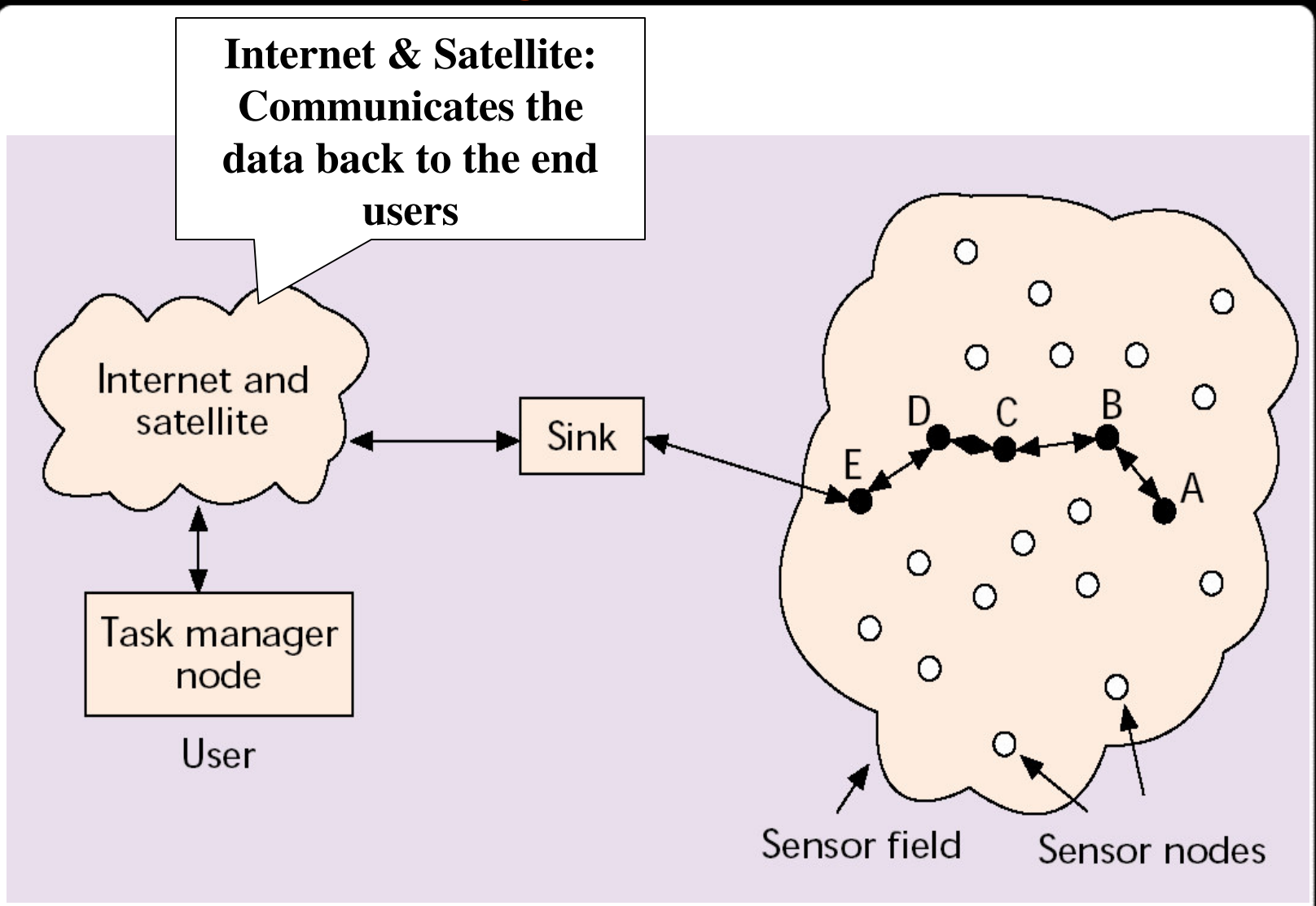

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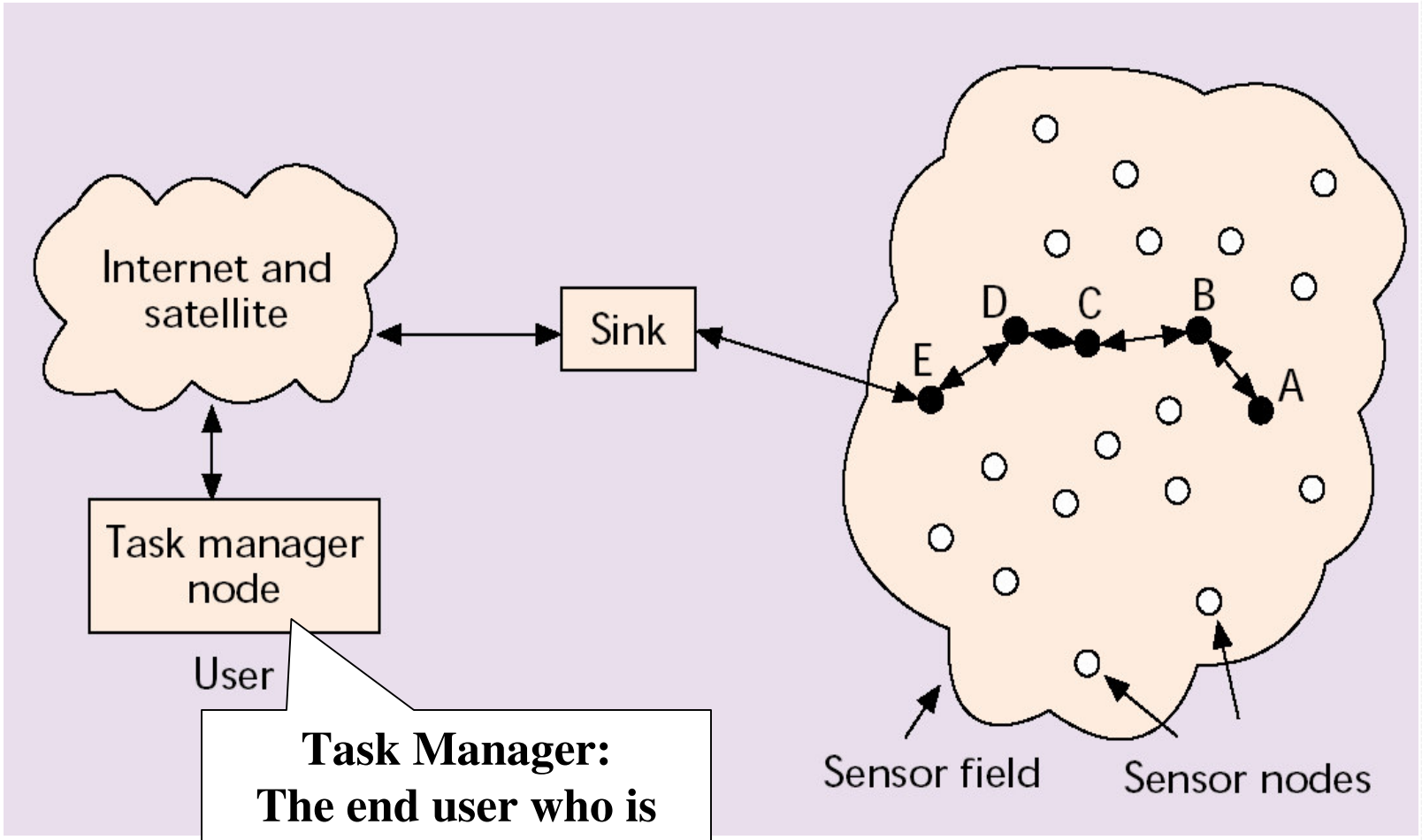
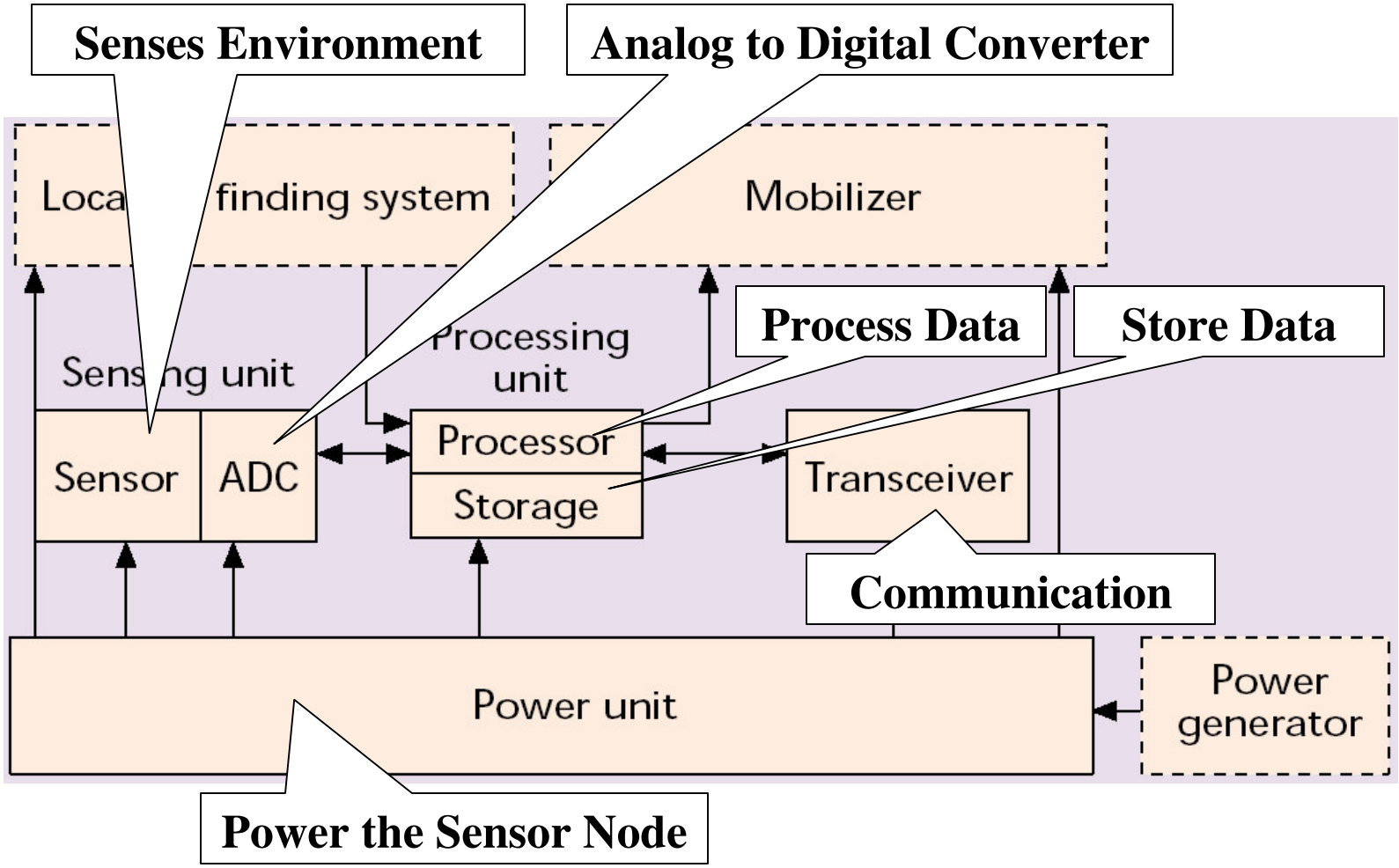


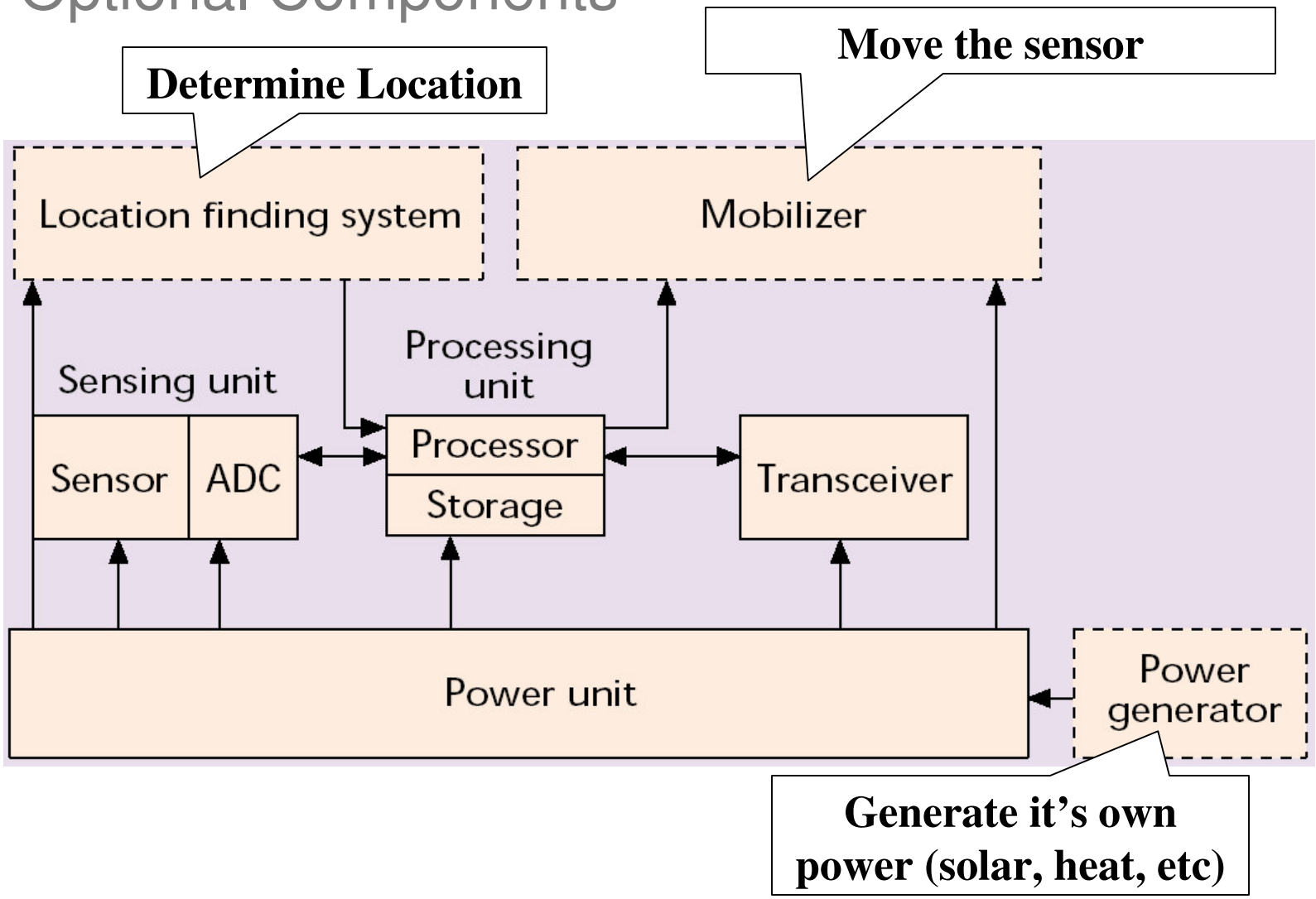
# Typical Sensor Node

## Always present components



# Typical Sensor Node

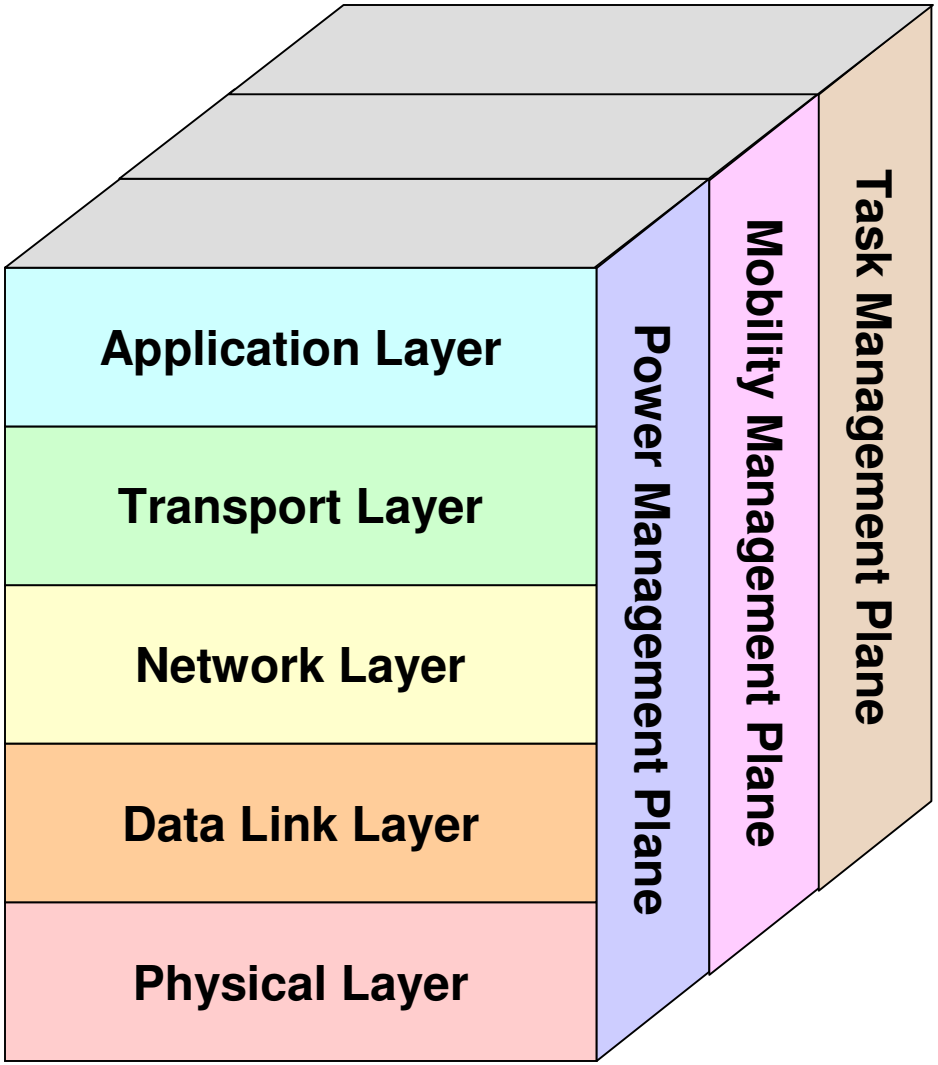
## Optional Components



# Issues to Consider

- Fault Tolerance
  (Fragile devices in rough terrain will break often)
- Scalability
  (Hundreds or thousands of nodes)
- Production Costs
  (Bluetooth is 10x the target cost)
- Topology
  (Up to 20 nodes per cubic meter)
- Deployment
  (Thrown or even launched from missles)
- Environment
  (Inside machinery, biohazards, behind enemy lines)
- Transmission Media
  (Radio has interference, infrared and optical require line of sight)
- Power Consumption
  (Less than 0.5A, 1.2V, power can cut out and change the network)

# Protocol Stack



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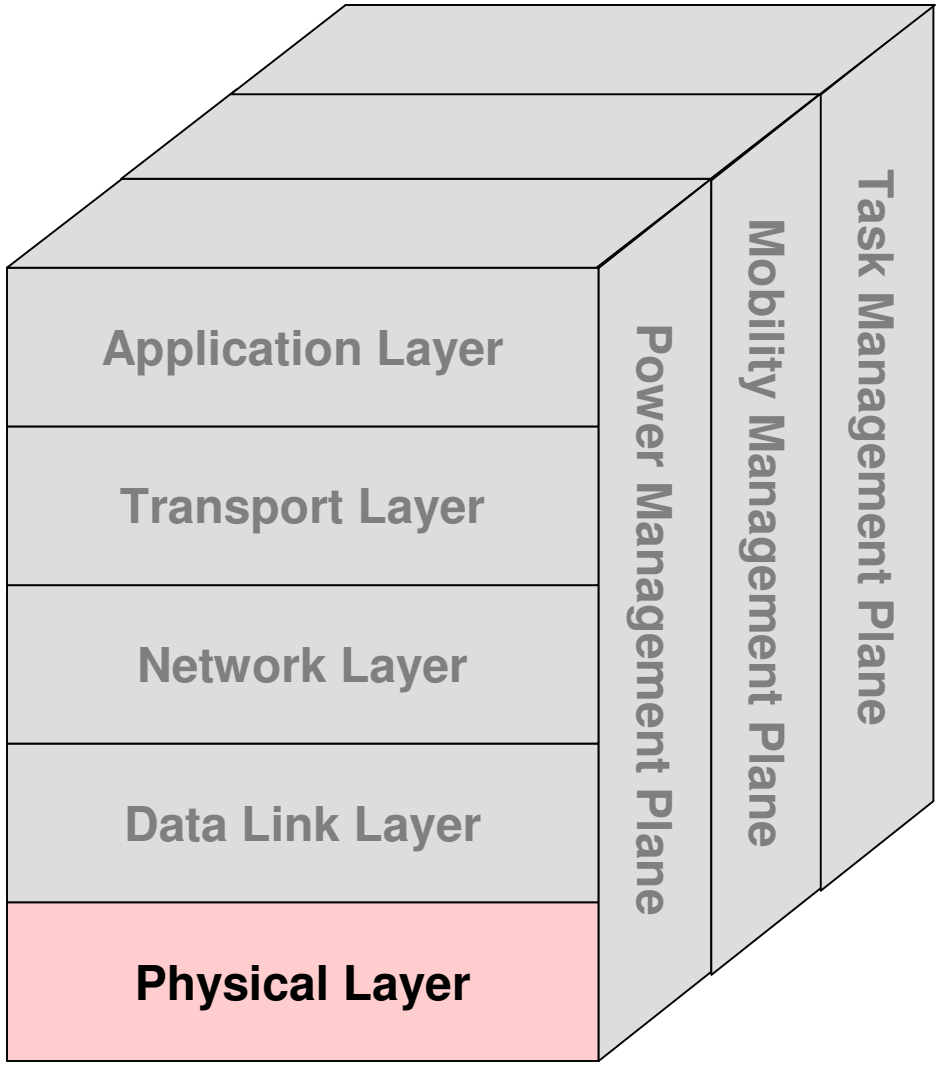


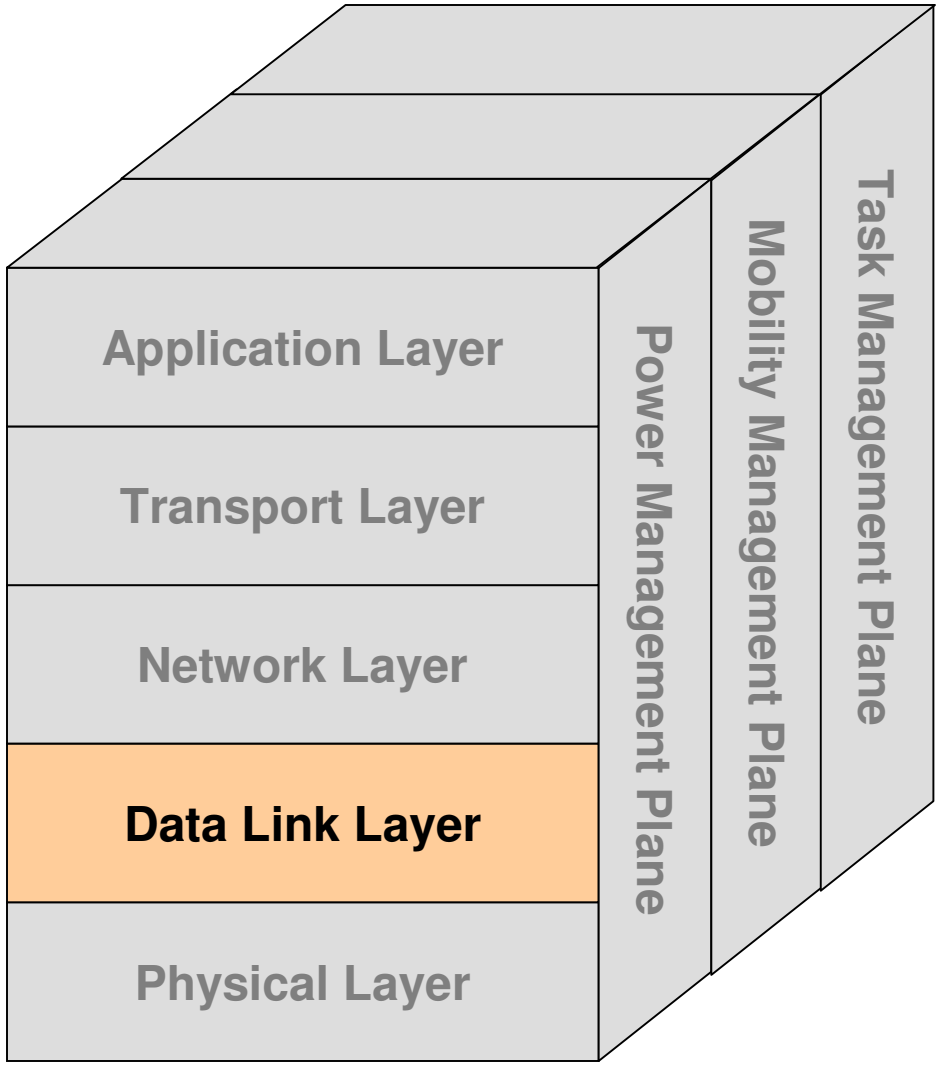
# Physical Layer Issues

- 915 MHz Industrial/Scientific/Medical band
- Power Consumption
  - Most important Issue
  - Communication is very expensive
  - Sometimes can be replenished
    - Solar or other means

# Open Research

- Need better power modulation schemes
- Need to overcome signal propagation effects
- The usual hardware issues:
  - Smaller!
  - Faster!
  - Cheaper!

# Protocol Stack



# Medium Access Control

- Existing MAC protocols inadequate
  - Very large number of nodes
  - Transmission power is very low
  - Topology changes frequent
  - Power consumption requirements
- MAC for Sensor Networks
  - Power saving modes required
  - Timeouts preferred to acknowledgements

# SMACS

- SMACS: “Self-Organizing MAC for Sensor Networks”
  - Link Layer organization
  - Discover neighbors automatically
  - Establishes schedules without global master node
  - How it works:
    - Random fixed time slots
    - Takes advantage of low bandwidth requirements
    - Turns off radio transmitter when not in use

# EAR Algorithm

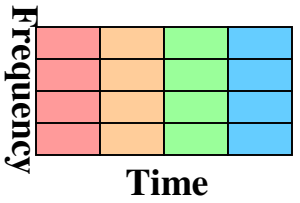
- EAR:  Eavesdrop and Register algorithm
  - Works with SMACS
  - Establishes seamless connection
  - Nodes control own connections
    - Drops when necessary
    - Saves messaging overhead

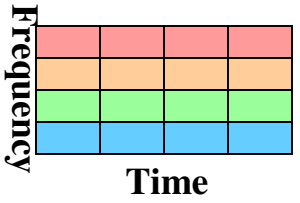
# CSMA-Based Mac

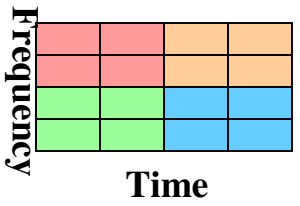
- CSMA: Carrier Sense Multiple Access
  - Listening mechanism and backoff scheme
  - Energy-efficient “listen periods”
  - Random delays help prevent collisions
  - ARC: Adaptive Transmission Rate Controls
    - Balances rates of originating and route-through traffic
    - Makes all nodes favored roughly equally

# Hybrid TDMA/FDMA

- Centrally controlled
  - Requires nearby high power base station
- Combines:
  - TDMA
    - Time Division Multiple Access
    - All bandwidth to one sensor at a time
  - FDMA
    - Frequency Division Multiple Access
    - Minimal bandwidth to every node
- Hybrid method:
  - Finds optimal division
  - Divides channels AND frequencies up



# Power Saving at Link Level

- Simple off/on can cost *more* energy
  - Short, frequent packets mean many starts and stops
  - Startup energy could cost more

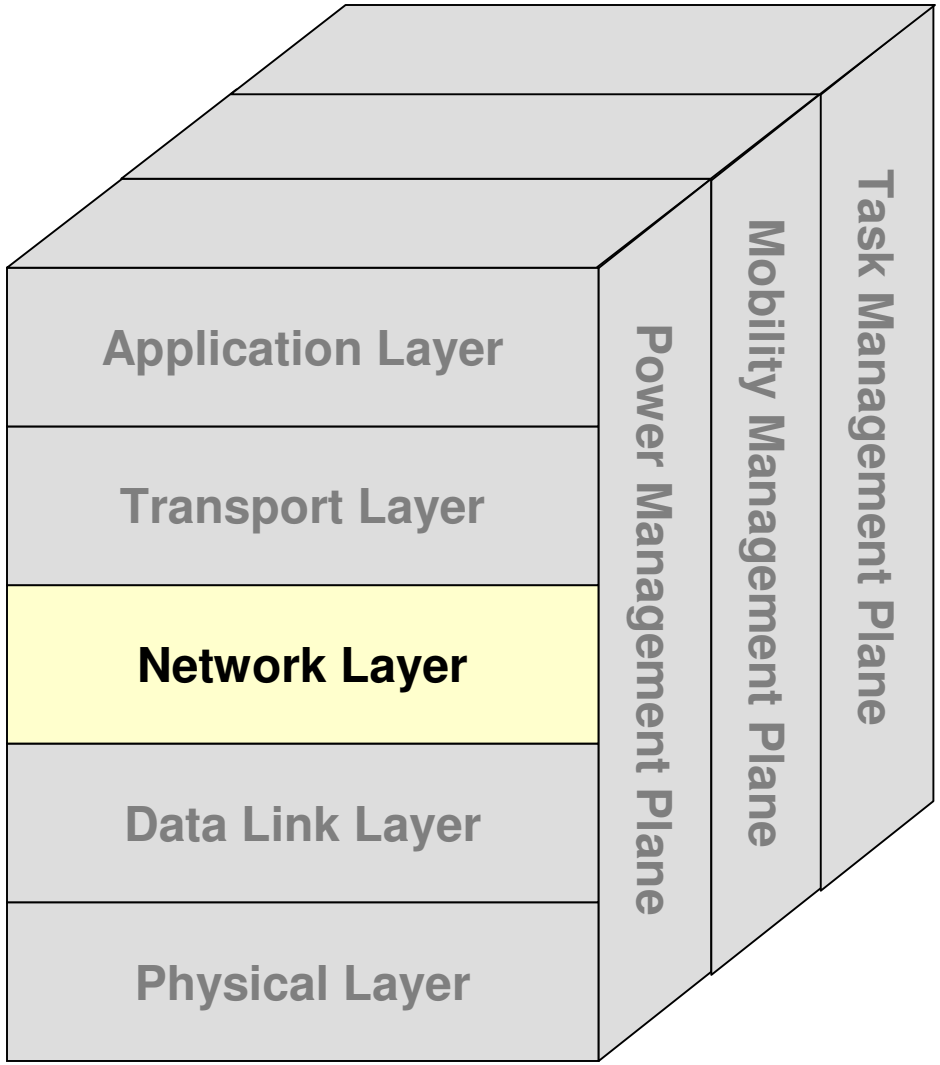
# Error Control

- Automatic Repeat Request (ARQ)
  - Bad!  Too much energy!
- More power to signals
  - Bad!  Too much energy!
- Forward Error Correction (FEC)
  - Good! … but inefficient and costly to microprocessor.
  - Built in FEC chips recommended

# Open Research

- Better MAC protocols needed
- Research on energy lower bound
- Error control coding research
- Power-saving research

# Protocol Stack

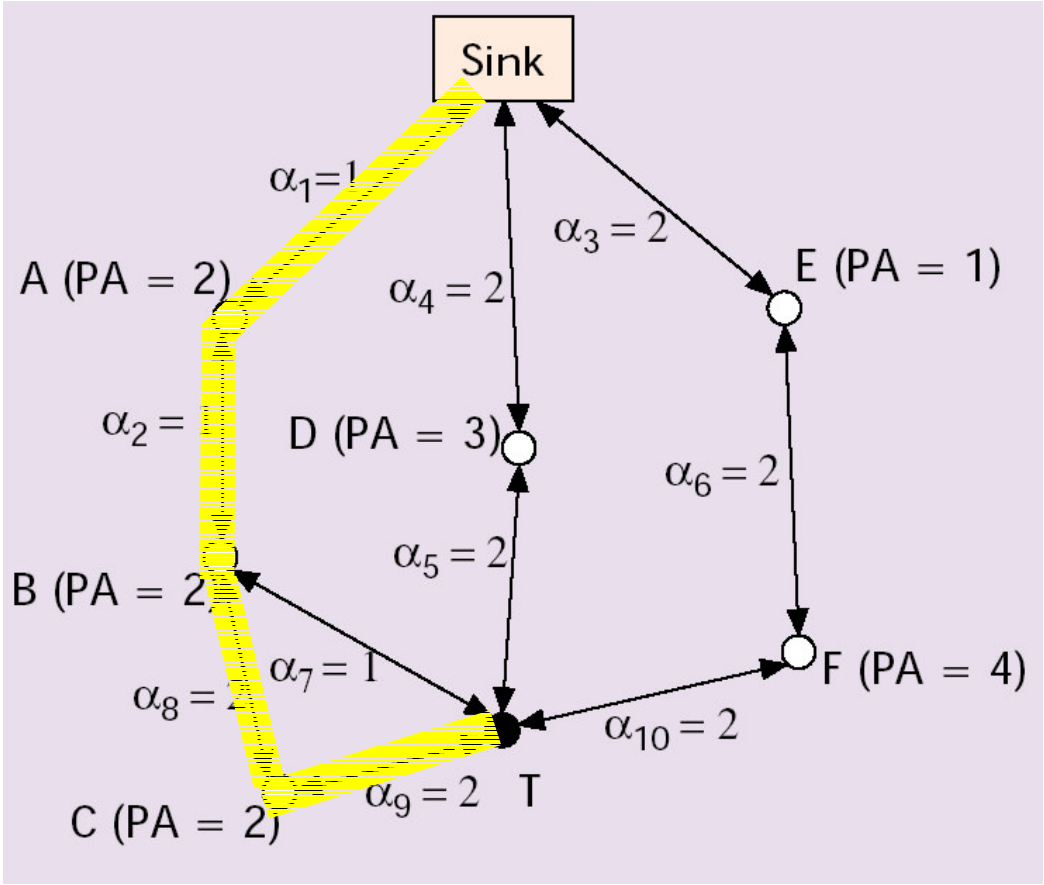


# Routing

- Maximum Power Available (PA)
- Minimum Energy (ME)
- Minimum Hop (MH)
- Maximum Minimum Power Available
- Data-Centric

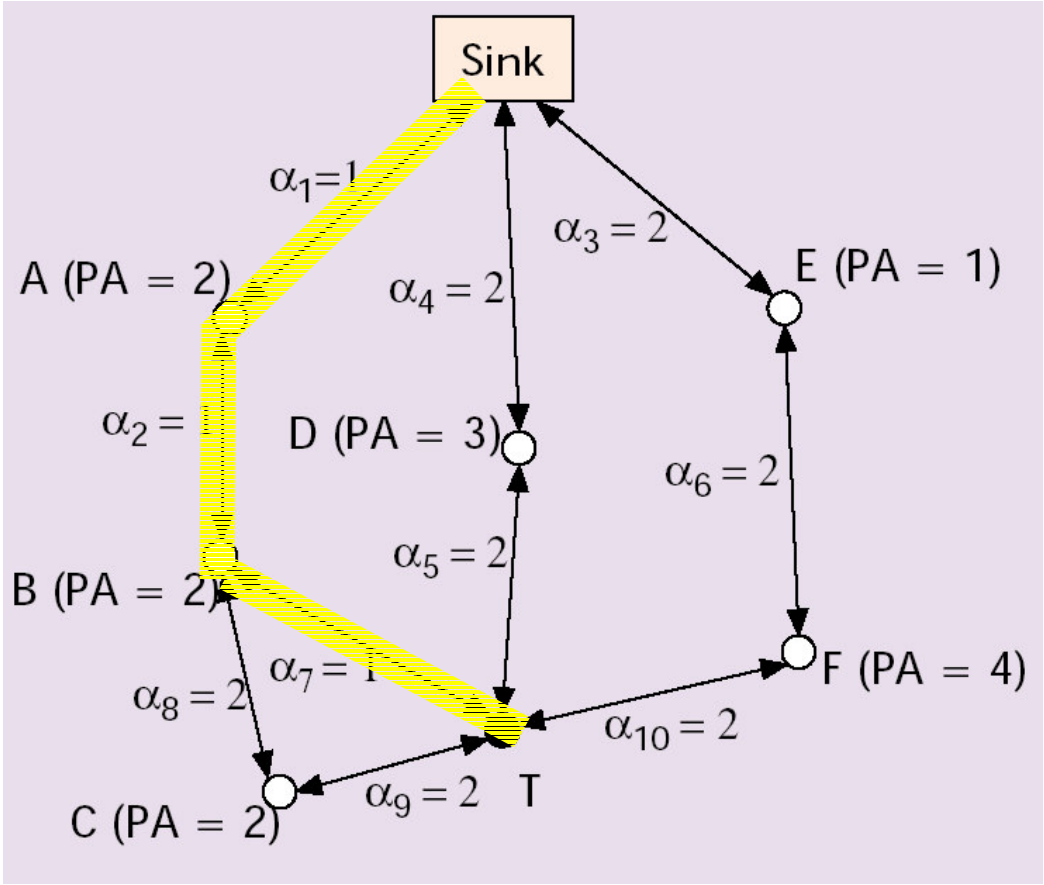
# Routing

- Maximum Power Available Route



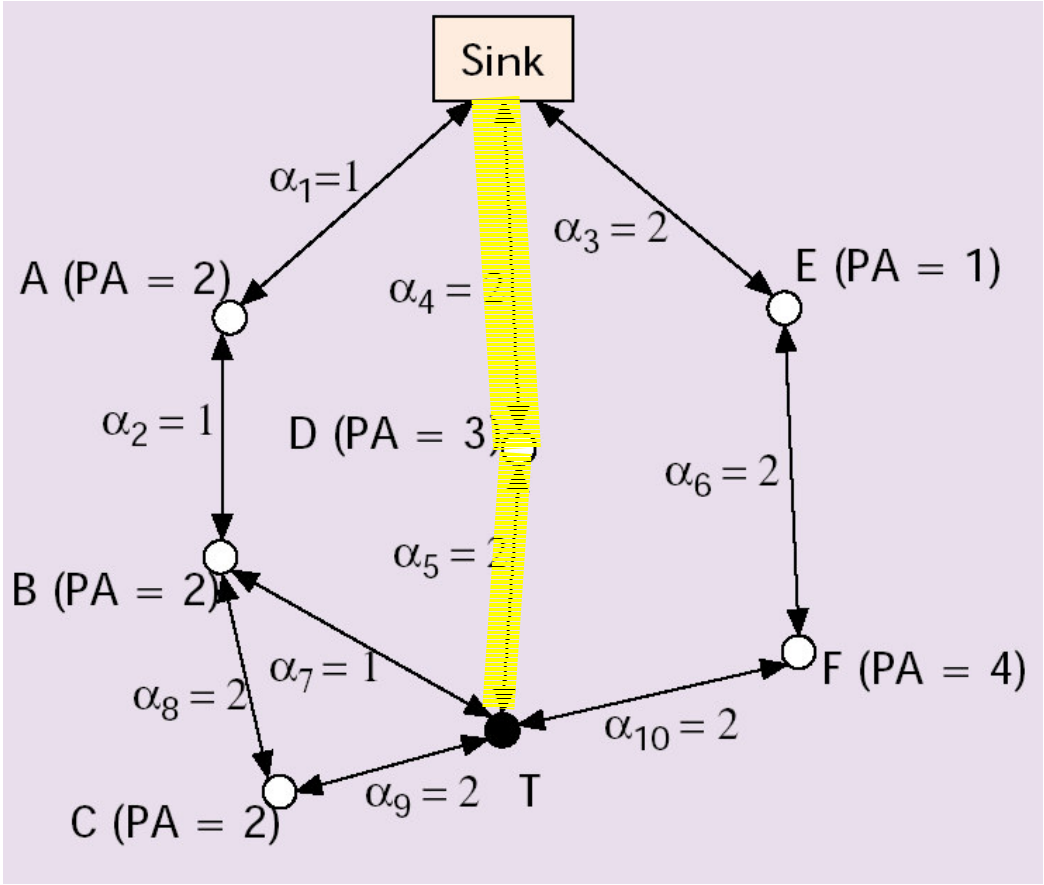
# Routing

- Minimum Energy Route



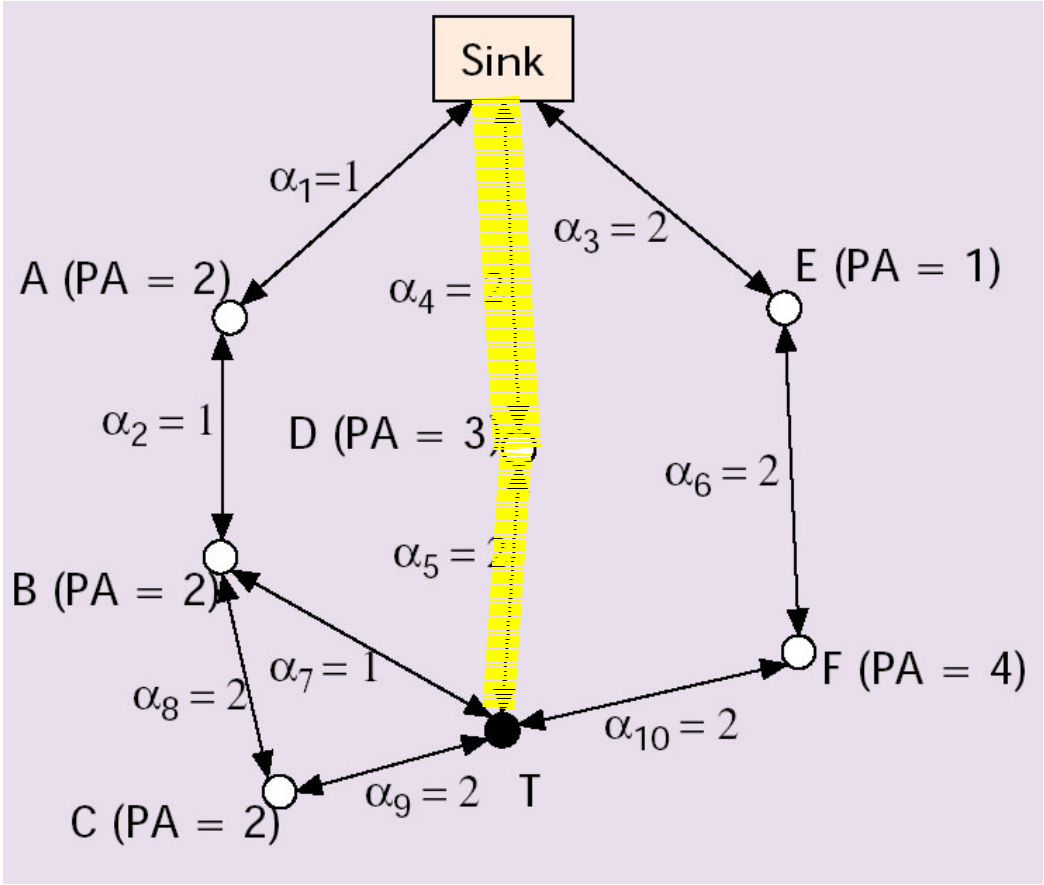
# Routing

- Minimum Hop Route



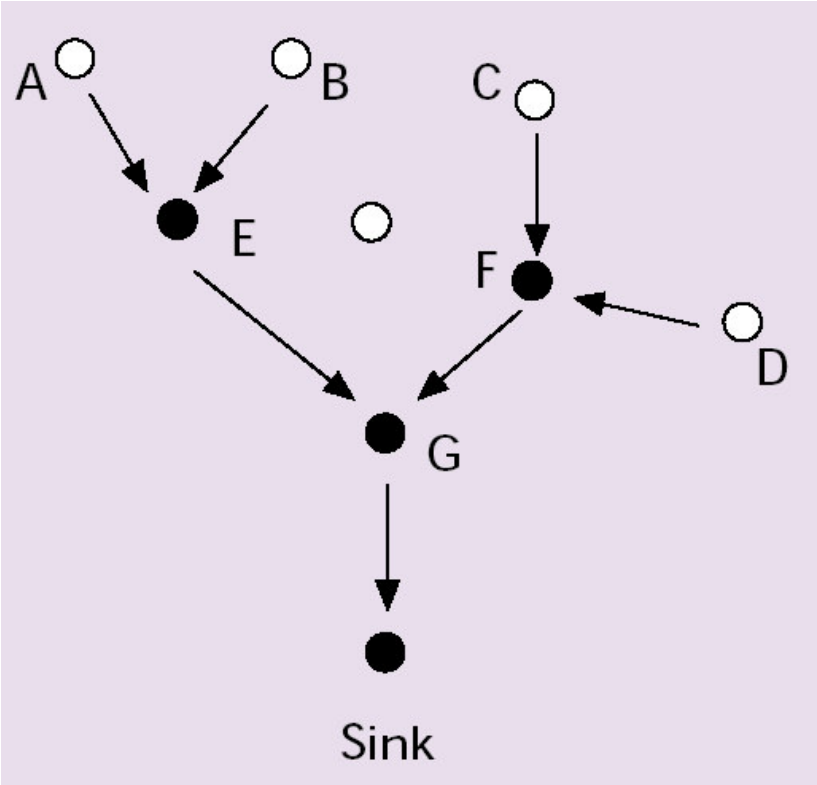
# Routing

- Maximum Minimum Power Available Node Route



# Data Aggregation

- Aggregate data at sensor level
  - Requires more processor power
  - Requires less transmission power



# Attribute-Based Naming

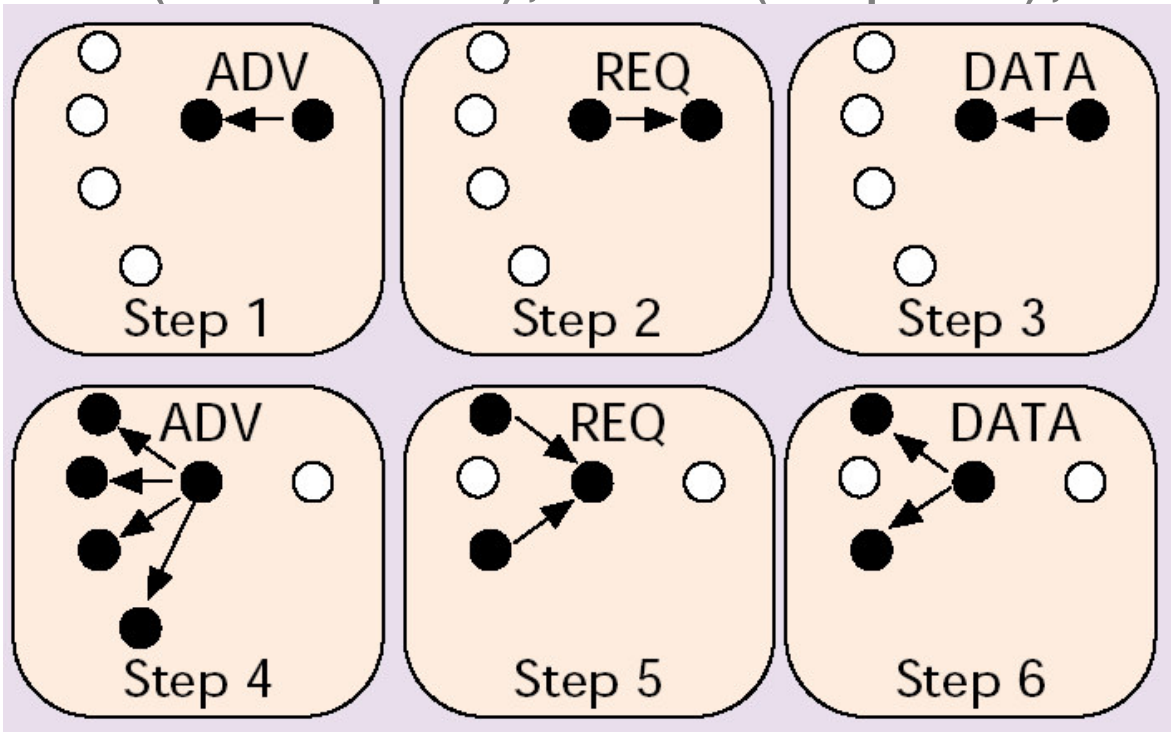
- Only get data from specific nodes
- Don’t send data from other nodes to save power
- Attribute-value pairs requested by name

# Overview of methods

- Small Minimum Energy Communication Network
  - Create network subgraphs that connect all nodes but using the least energy
- Flooding
  - Saves overhead of topology change and route discovery
  - High energy, data implosion
- Gossiping
  - Like flooding, but sends to a random neighbor
  - No data implosion, but slow

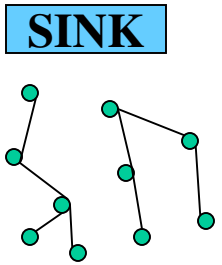
# SPIN

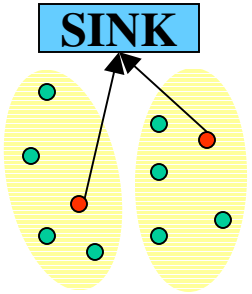
- Sensor Protocols for Information via Negotiation
- Get requested data only
- ADV (descriptor), REQ (request), DATA



# Overview of methods, cont.

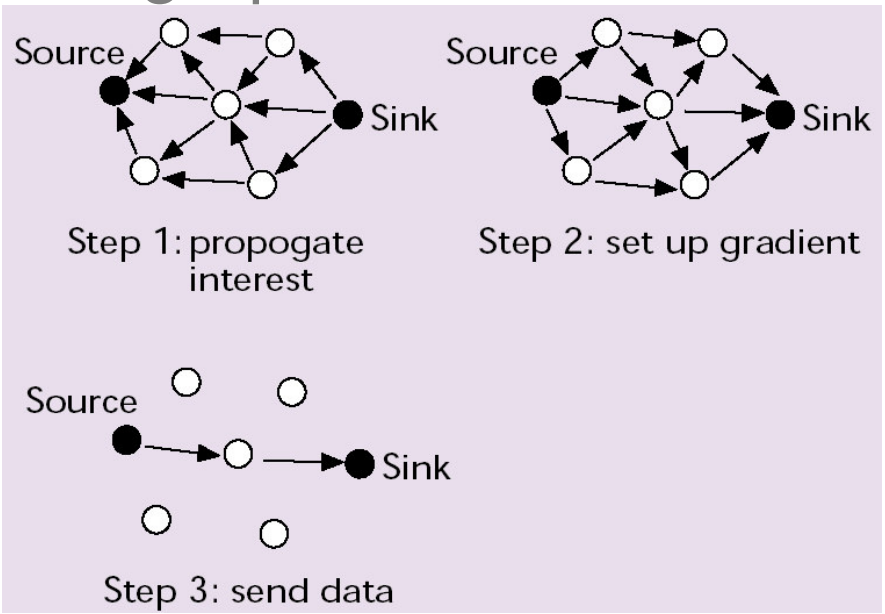
- Sequential Assignment Routing (SAR)
  - Create multiple trees
  - Root of each tree is one-hop neighbor of the sink
  - Avoids nodes with low quality of service
- Low-Energy Adaptive Clustering Heirarchy (LEACH)
  - Randomly select nodes as “clusterheads” that send to the sink
  - Clusterheads inform other nodes
  - Other nodes determine their own cluster
  - Change clusterheads on a regular basis



# Overview of methods, cont.

- Directed Diffusion
  - Base station sends out *interest* to nearest nodes
  - Nodes propogate message outwards
  - Directed graph formed



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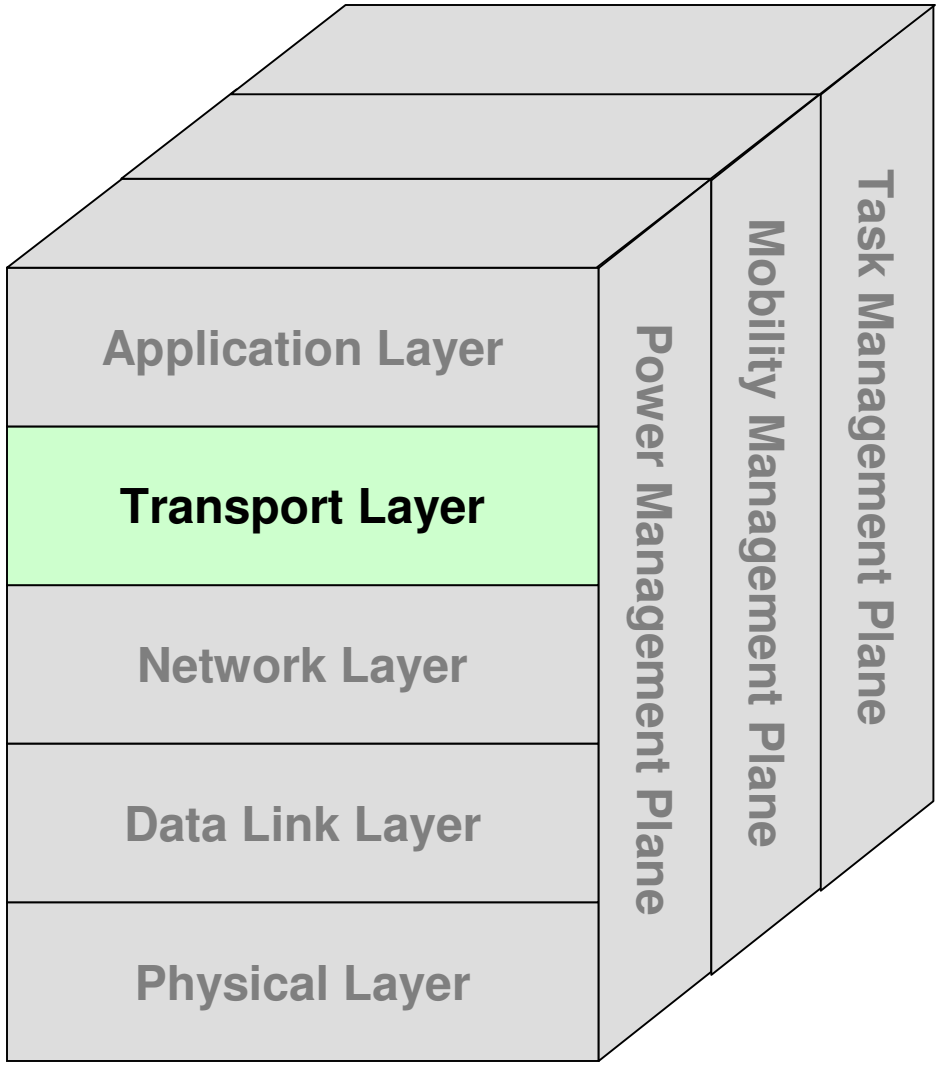
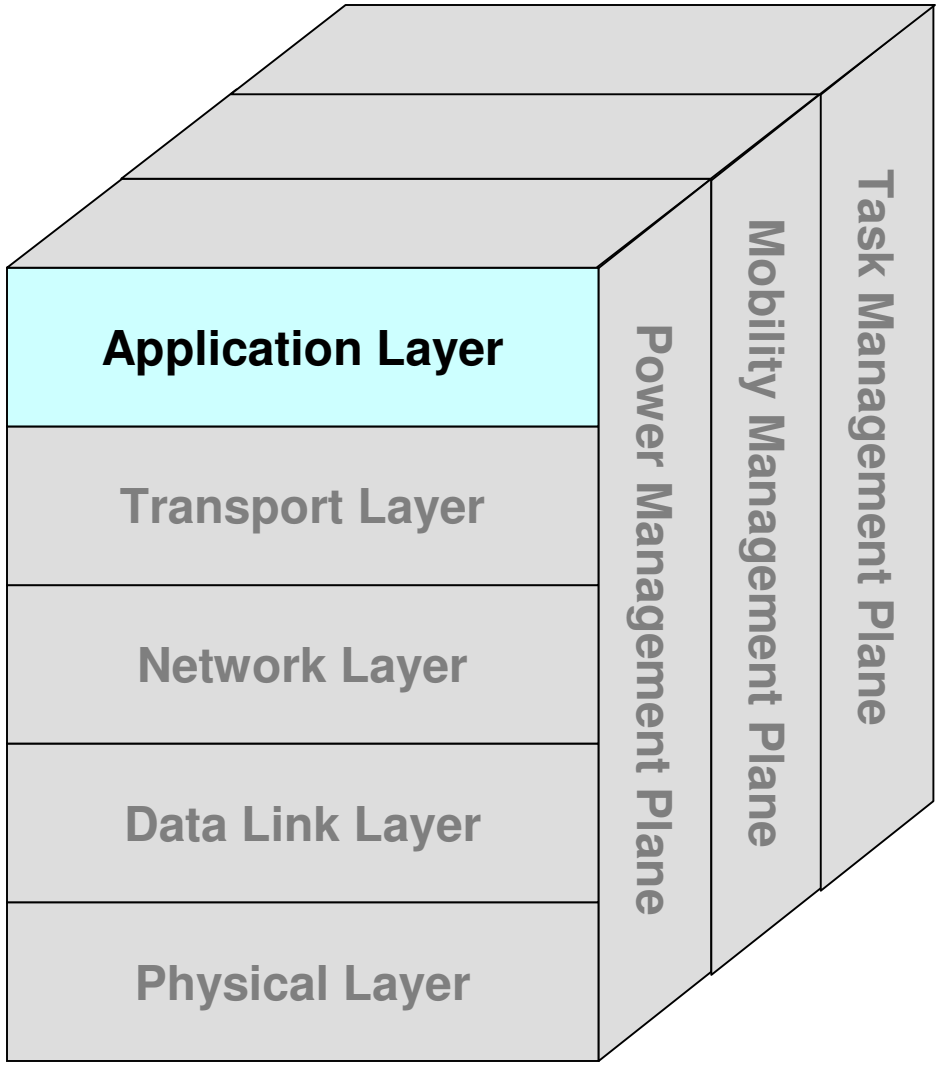


# Transport Layer

- Hasn't really been addressed by anyone yet!
- TCP/UDP don't address some concerns:
  - Power consumption
  - Lack of global addressing
  - Attribute-based naming
- Likely answer:
  - TCP or UDP between sink and end user
  - UDP-like protocol between sink and sensor nodes

# Protocol Stack



# Application Layer Overview

- Sensor Management Protocol
  - Makes lower levels transparent
  - Handles:
    - Data aggregation
    - Attribute based naming
    - Clustering
    - Location finding
    - Time Synchonization
    - Mobilization
    - Turning nodes off and on
    - Getting status
    - Reconfiguring
    - Authentication
    - Key Distribution
    - Security

# Application Layer Overview

- Task Assignment and Data Advertisement Protocol (TADAP)
  - Send out *interest*
  - Nodes only return data that user is interested in

# Query Languages

- Sensor Query and Data Dissemination Protocol
  - Like SQL for sensor networks
  - “Get the locations of the nodes that sense temperature higher than 70 degrees”
- Sensor Query And Tasking Language
  - A larger query project that includes things SQDDP does not
  - Only in the proposal stage

# Conclusion

- We’re not there yet!
- Main issues that need work:
  - Fault tolerance
  - Scalability
  - Cost
  - Hardware
  - Topology Changes
  - Environment
  - Power Consumption

Questions?