A Survey on Sensor Networks

IEEE Communications Magazine August 2002

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Contents

Introduction

- Recent advances in wireless communication have enabled the development of low-cost sensor networks

- Sensor Nodes
  - Low Cost, Low Power, Multifunctional, Small Size, Densely Deployed
  - Position needs not be predefined
  - Self-Organizing Capabilities

Introduction

- Hard to directly apply traditional wireless ad hoc networking techniques to sensor network

Property	Sensor Network	Wireless ad hoc Network
#Nodes	Very Large	Less than Sensor Networks
#density	Very High	Not High
Failure	Prone to Failure	Less Prone to Failure
Topology	Frequently Changed	Less Frequently Changed
Communication	Broadcast Communication	Point to Point Communication
Resource	Limited power, memory	More Resource
Global Identification	No	Yes

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

Sensor Networks Architecture

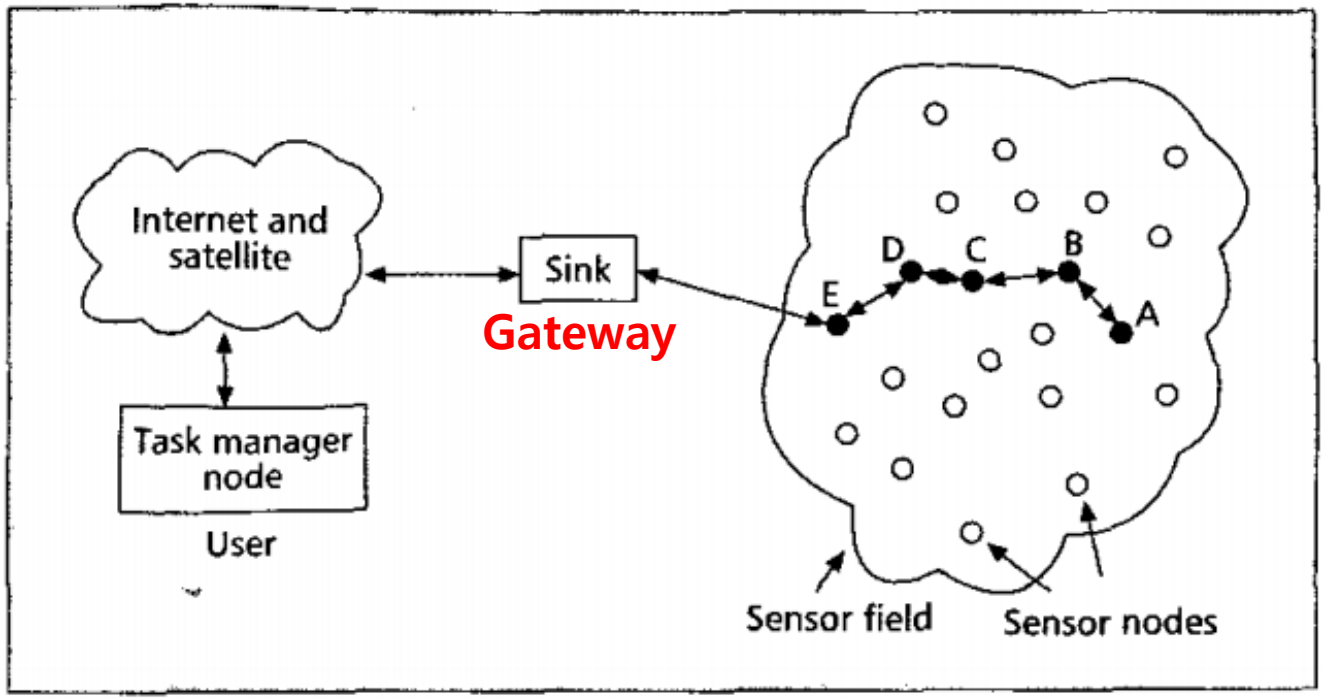

Figure 1. *Sensor nodes scattered in a sensor field.*

- Many Design Factors
  - Fault Tolerance
  - Scalability
  - Production Cost
  - Hardware Constraints
  - Sensor Network Topology
  - Environment
  - Transmission Media
  - Power Consumption

Design Factors

- Fault Tolerance
  - The failure of sensor nodes should not affect the overall Network
- Scalability
  - It must be able to work with very large number of nodes.
- Production Cost

Design Factors (cont'd)

- Primary Hardware
  - Sensing Unit
    - Sensors
    - ADC
  - Processing Unit
  - Transceiver Unit
  - **Power Unit**
- Application dependent
  - Location Finding System
  - Mobilizer

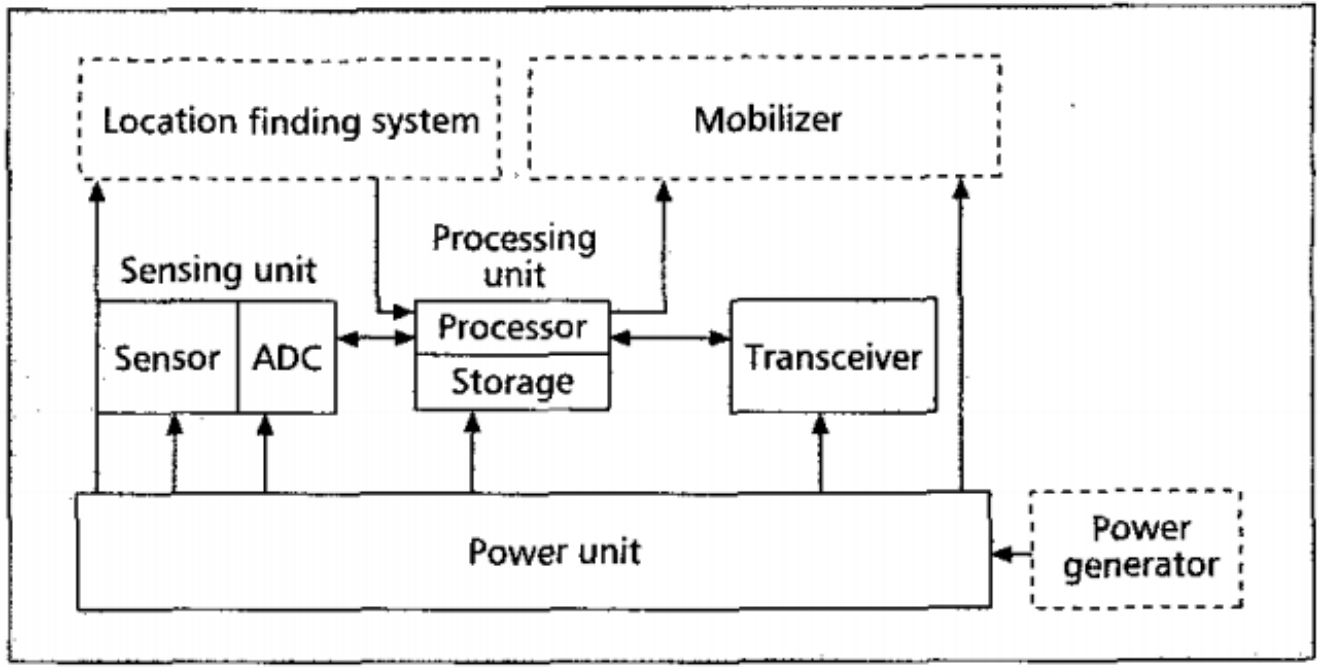

Figure 2. *The components of a sensor node.*

Design Factors (cont'd)

- Sensor Network Topology
  - Predeployment and deployment phase
  - Post deployment phase
  - Redeployment of additional nodes phase

- Power Consumption
  - Very Limited
  - Sensor lifetime depends on battery lifetime.
  - Can cause significant topological changes
  - Power Management

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Protocol Stack

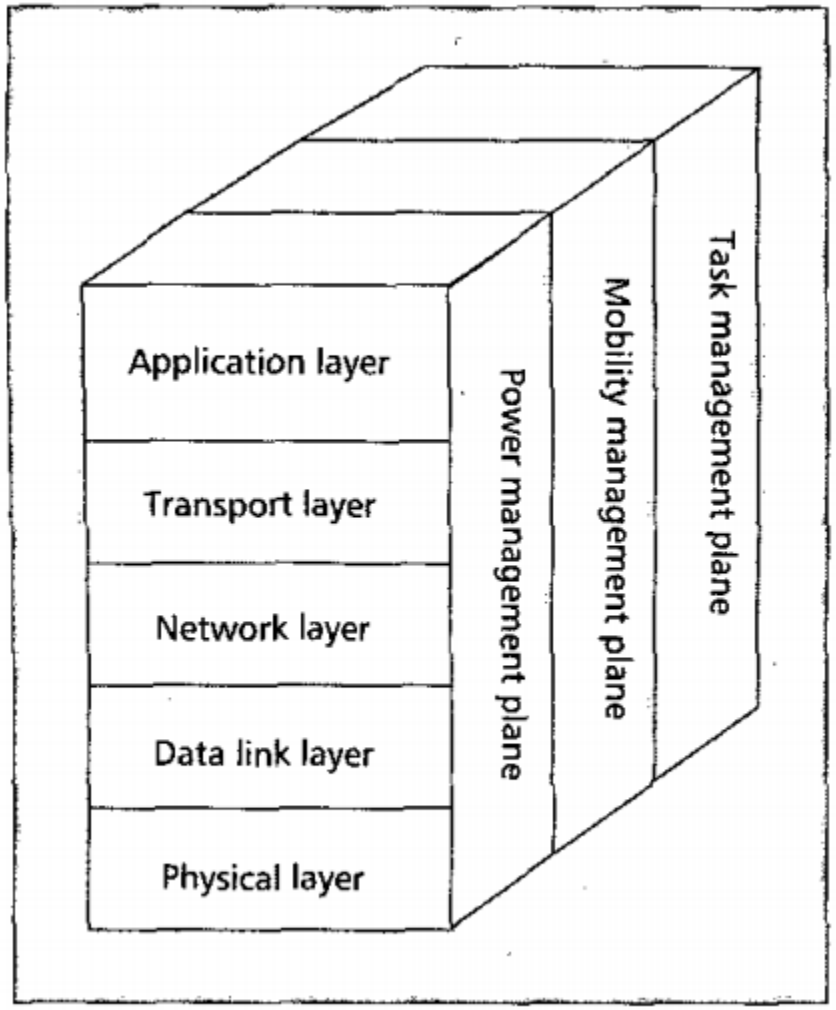

Figure 3. *The sensor networks protocol stack.*

- Network Layer
  - Application Layer
  - Transport Layer
  - Network Layer
  - Data link Layer
  - Physical Layer
- Additional
  - Power Management
  - Mobility Management
  - Task Management

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Physical Layer

- Responsible for
  - Frequency selection
  - Signal detection
  - Modulation
    - Binary modulation
    - M-ary modulation
  - Encryption

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Data Link Layer

- It ensures reliable point to point and point to multipoint connections in a communication networks.

- Medium Access Control (MAC)
  - Two goals in a wireless multi-hop self-organizing sensor network
    - The creation of network infrastructure.
    - Share resources fairly and efficiently.

- Error Control
  - FEC (Forward Error Correction
  - ARQ (Automatic Repeat reQuest)

Medium Access Control (MAC)

- Reasons Existing MAC Protocols Cannot be Used
  - Cellular system
    - Mobile node is only single hop away from base station (infrastructure-based)
    - Power conservation is not much important
      - Unlimited power supply for base station, Replenishing batteries of phone.
    - Central controlling agent like base station.
  - Bluetooth & mobile ad hoc network
    - Topology is star and stable (master & slave)
    - Power isn’t important (can be replaced by user)
    - Small number of nodes

Medium Access Control (MAC)

- SMACS and EAR
  - SMAC
    - SMAC is distributed infrastructure-building protocol
    - It enables nodes to discover their neighbors and establish transmission/reception schedules for communication **without the need for any local global master nodes**
    - Neighbor discovery and channel assignment phase are combined
    - No network wide synchronization (but fined-grained synchronization)
    - Power conservation by random wake-up schedule & turning radio off during idle time slots
  - EAR
    - Providing continuous service to mobile nodes
    - Mobile nodes have full control of connection
    - Assumption is that network is mainly static and mobile node has a number of stationary nodes.

Medium Access Control (MAC) (cont'd)

- CSMA-Based Medium Access
  - Listening & backoff
    - Constant listening periods -> energy efficiency
    - Random delay provides robustness about repeated collisions

- ARC
  - Linear increase and multiplicative decrease approach.
  - Route-trough traffic is preferred over originating traffic.

Medium Access Control (MAC) (cont'd)

- Hybrid TDMA/FDMA-Based
  - Frequency-division & Time-division
  - If the transmitter consumes more power -> TDMA
  - If receiver consumes more power -> FDMA

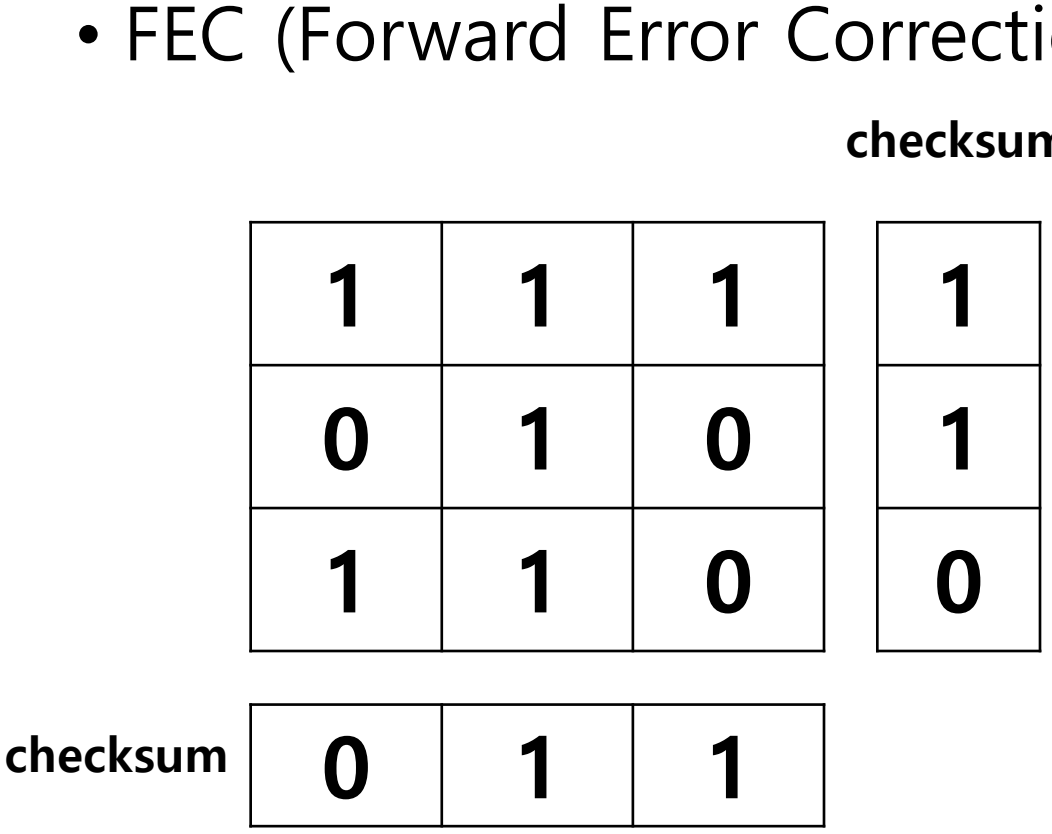
Summary of MAC

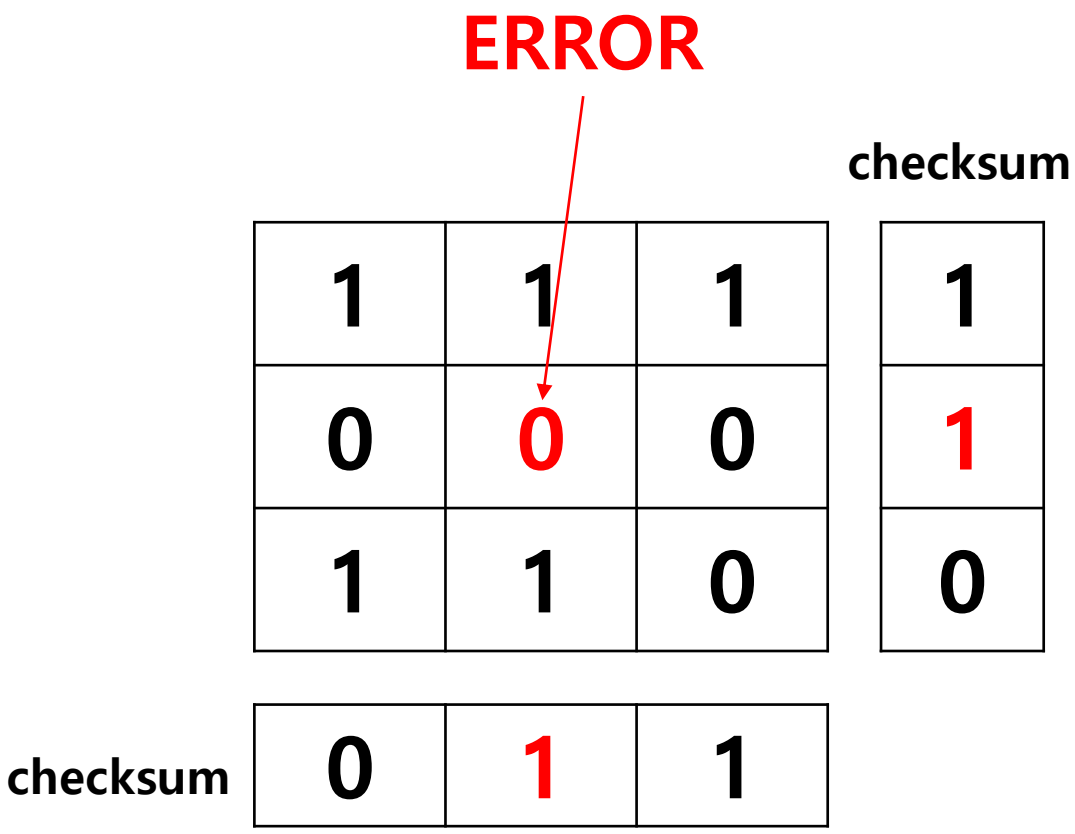
MAC protocol	Channel access mode	Sensor network specifics	Power conservation
SMACS and EAR [13]	Fixed allocation of duplex time slots at fixed frequency	Exploitation of large available bandwidth compared to sensor data rate	Random wake up during setup and turning radio off while idle
Hybrid TDMA/FDMA [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

Table 1. *A qualitative overview of MAC protocols for sensor networks*

Error correction in Link Layer

- FEC (Forward Error Correction)





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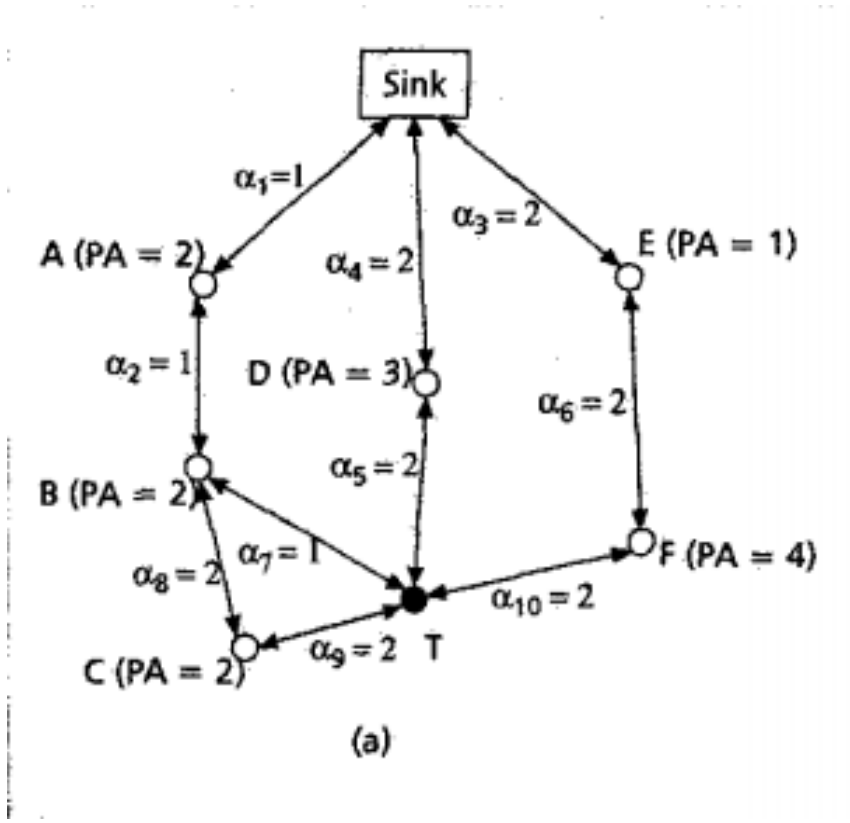
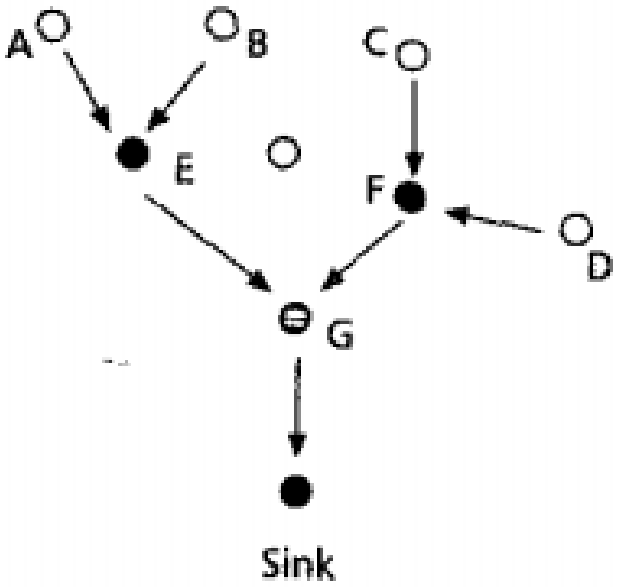
Network Layer



- Assumption
  - PA := Available power
  - α := required power to send msg
  - Source: T, Destination: Sink
  - Route
    - Route 1: T-B-A-SINK PA:4, **α:3**
    - Route 2: T-C-B-A-SINK **PA:6**, α:6
    - Route 3: **T-D-SINK** PA:3, α:4
    - Route 4: T-F-E-SINK PA:5, α:6

- Maximum PA route: route 2
- Minimum energy route: route 1
- Minimum hop route: route 3

Network Layer



(b)

- Data Aggregation Technique
  - Prevent Implosion & overlap

Network Layer

- Flooding
  - Within maximum number of hops, each sensor nodes broadcast messages until it finds destination
  - Doesn’t not require costly topology management and complex discovery
- Gossiping
  - Similar with Flooding, but it doesn’t broadcast but select a receiver randomly

SAR (Sequential Assignment Routing)

- Multiple trees where the root of each tree is one-hop neighbor from the sink
- Most nodes belong to multiple trees
- SAR algorithm selects path based on below metrics

- Two parameters
  - Energy resource: #packets the sensor node can send
  - Additive QoS metric: High value means low QoS

LEACH (Low-Energy Adaptive Clustering Hierarchy)

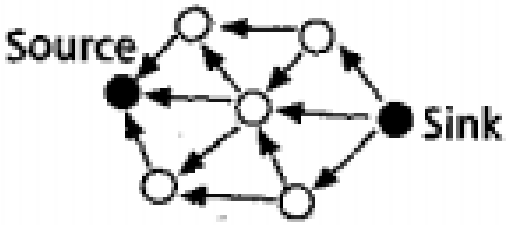
- It randomly select sensor nodes as clusterheads,

- Two phase
  - Setup Phase
    - Cluster heads are selected among sensor nodes randomly
    - Each sensor node is associated with its own clusterhead
    - Communication between sensor nodes and clusterheads is TDMA approach
  - Steady Phase
    - Sensor nodes begin sensing and sending data to its clusterhead
    - Clusterheads aggregate data and send it to the base station

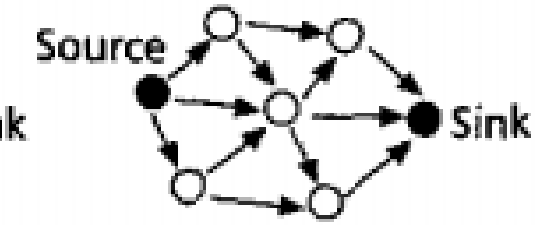
Directed Diffusion

- Step1: Sink sends interest
  Step2: Gradients are set up
  Step3: Source sends the data
  Step4: Sink refreshes and reinforces the interest

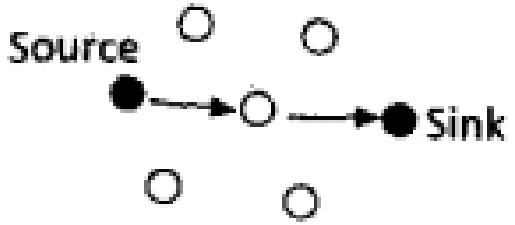
- Based on data centric routing



Step 1: propogate interest



Step 2: set up gradient



Step 3: send data

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Transport Layer

- Hybrid Approach
  - Communication between user and sink node is TCP
  - Communication between sink and the sensor nodes is UDP
  - That’s because sensor node has limited memory

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Application Layer

- SMP (Sensor Management Protocol)
- TADAP (Task Assignment and Data Advertisement Protocol)
- SQADDP(Sensor Query And Data Dissemination Protocol)

SMP

- System Administrators interact with sensor network using SMP

- Administrative Task
  - Introducing rules about data aggregation, attribute-based naming and clustering to the sensor nodes
  - Exchanging data related to the location finding algorithms
  - Time synchronization
  - Moving sensor nodes
  - Turning sensor nodes on and off
  - Querying network configuration, nodes' status
  - Authentication, security

TADDAP

- Efficient interfaces for interest dissemination
  - Interest dissemination by users
  - Advertisement by sensor nodes

SQDDP

- It provides user applications with interfaces to issue queries, respond to queries and collect incoming replies

No Global identification

- Attribute-based naming
  - The locations of the nodes that sense temperature higher than 70
- Location-based naming
  - Temperatures read by the nodes in region A

Contents

Conclusion

- Realization of sensor networks needs to satisfy constraints
- Since the constraints are specific for sensor networks, new wireless ad hoc networking techniques are required