A Survey on Sensor Networks

Donghyun Kang, Dongkwon Lee

Contents

Introduction

- Recent advancement in wireless communications and electr onics has enabled…
- Sensor Node
  - Consist of **sensing, data processing, and communicating compone nts**
    - Cooperating – The nodes are fitted with an onboard processor
    - **Use processing abilities**
  - Low-cost, Low-power, Multifunctional, Small size

Introduction

- Sensor Network
  - **Be composed of a large number of sensor nodes** that are densely deployed
  - Position of sensor nodes need not be predetermined
  - Cooperate effort of sensor nodes
  - Wide range of applications are ensured
    - Health
    - Military
    - Home

Introduction

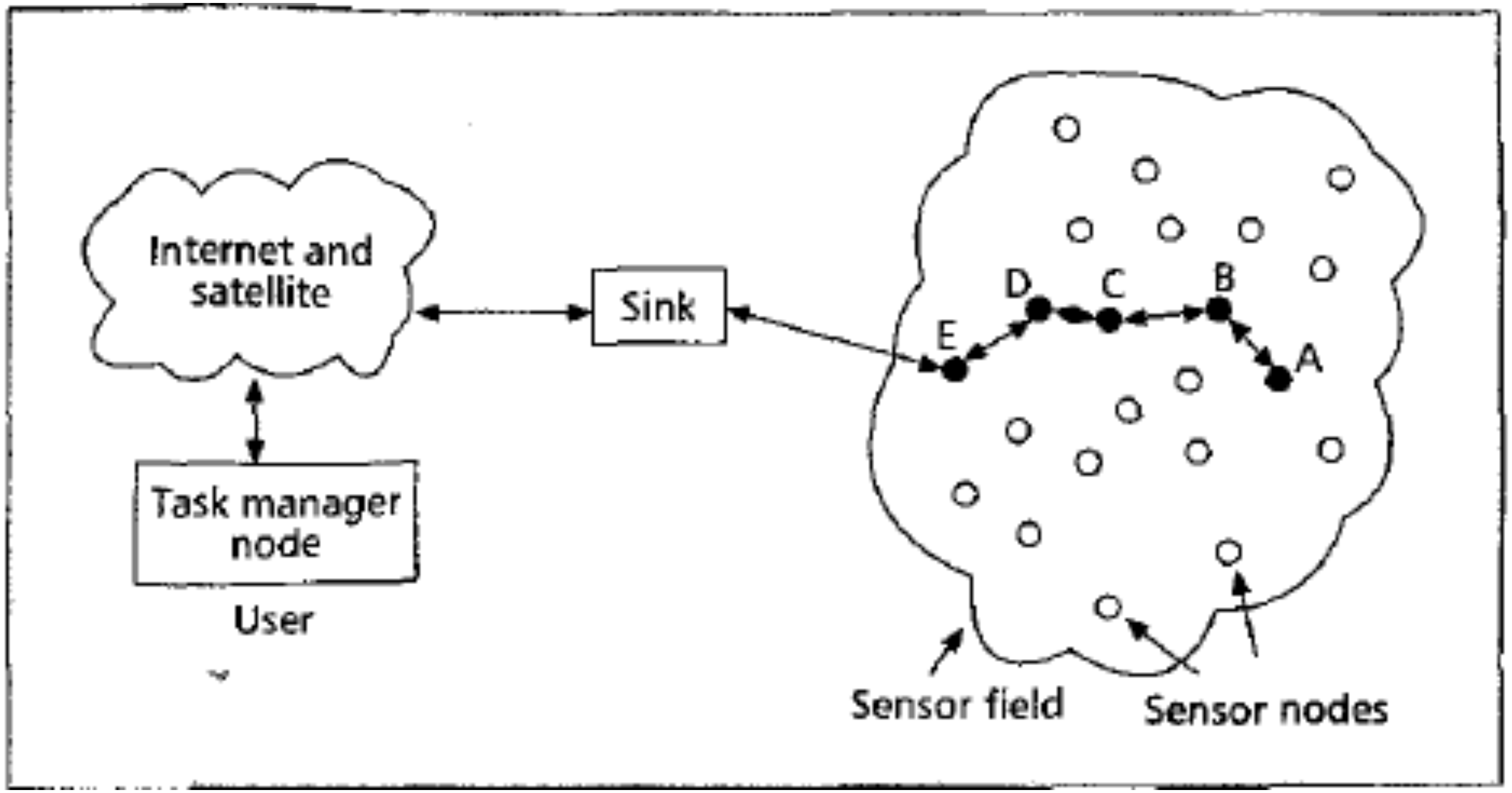
- Protocols for traditional wireless ad hoc network are not well suited to the sensor networks

Feature	Sensor network	Traditional wireless ad hoc network
# of sensor nodes	Very large	Not that large
Density	Densely deployed	Low density
Failure	Prone to failures	Low failure
Topology	Frequently changed	Rarely changed
Communication	Broadcast communication	Point to point communication
Resource	Limited in power, computation capacities and memory	Not that limited
Global identification	May not have	Yes

Contents

Sensor Networks Communication Architecture

- Overview
  - **Sensor nodes**
    - Sensor field
  - Sink



Sensor Networks Communication Architecture

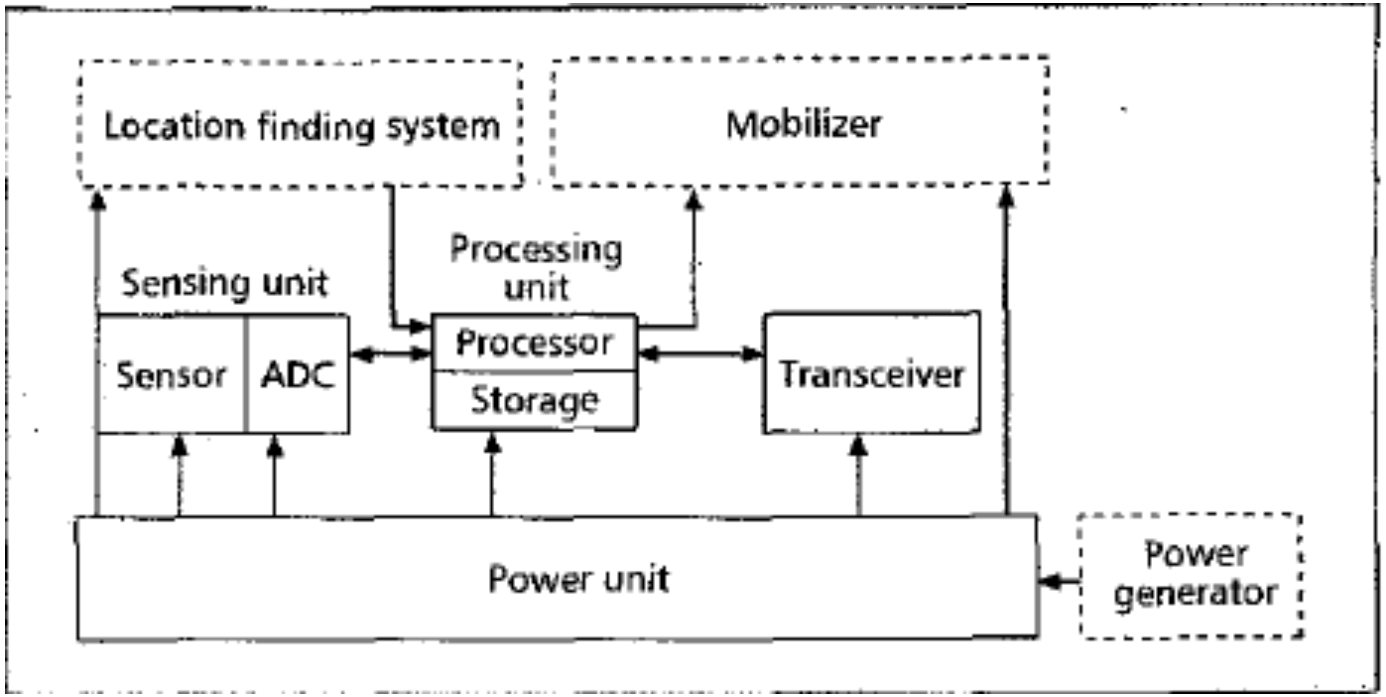
- Many Design Factors
  - Fault Tolerance
  - Scalability
  - Production Costs
  - Hardware Constraints
  - Sensor Network Topology
  - Environment
  - Transmission Media
  - Power Consumption

Design Factors

- Fault Tolerance
  - Ability to sustain sensor network functionalities without any interr uption due to sensor node failures
- Scalability
  - Hundreds ~ millions of sensor nodes
- Production Costs

Design Factors

- Hardware Constraints
  - Sensing unit
    - Sensors
      - Analog signal
    - ADC
      - Analog to Digital Converter
  - Processing unit
  - Transceiver unit
  - Power unit
  - Application-dependent components
    - Location finding system, mobilizer, power generator, …
- Size (weight) & power constraint



Design Factors

- Sensor Network Topology
  - Pre-deployment & deployment
  - Post-deployment
  - Redeployment
- Environment

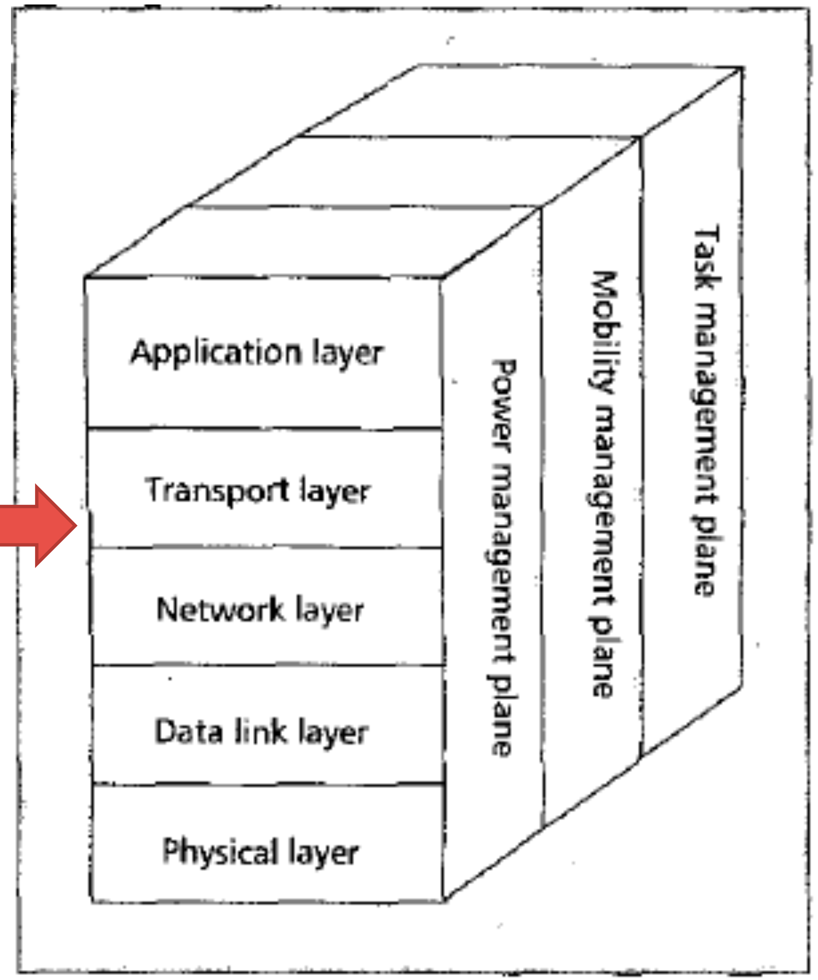
Design Factors

- Transmission Media
  - Radio
  - Infrared
  - Optical media (light)
- Power Consumption
  - Lifetime
  - Conservation & management
  - Power-aware protocols & algorithms

Contents

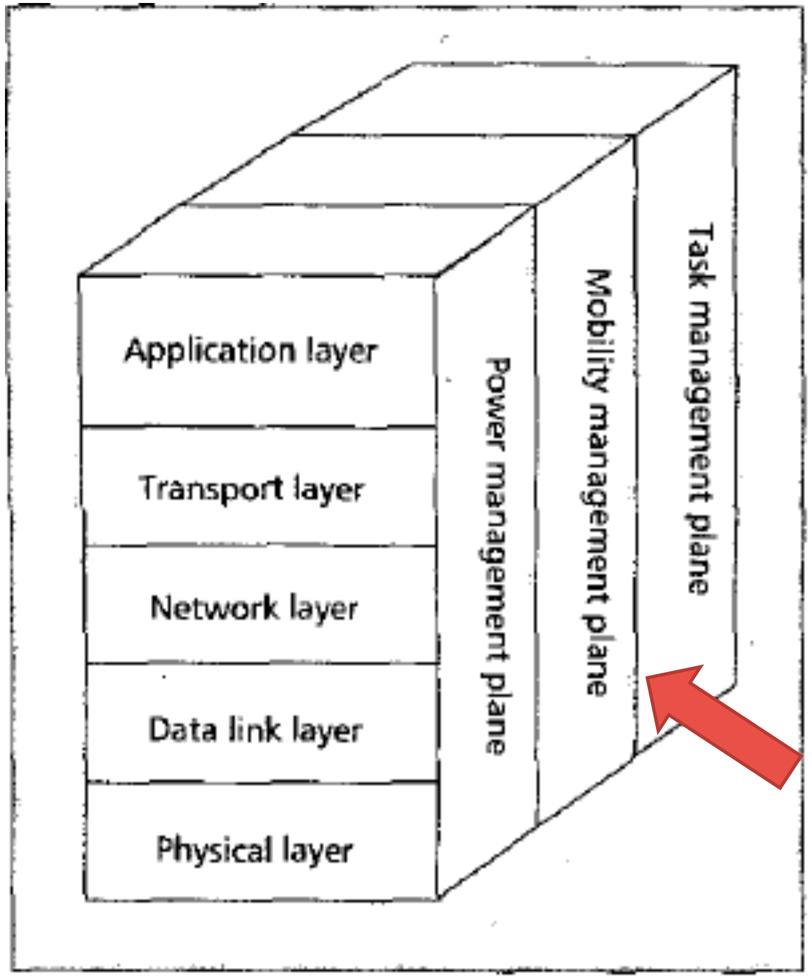
Protocol Stack

- Layers
  - Physical Layer
    - Transmission & receiving techniques
  - Data Link Layer
    - Medium access control protocol w/ considering con straints
  - Network Layer
    - Take care of routing the data supplied by the transp ort layer
  - Transport Layer
    - Help to maintain the flow of data
  - Application Layer
    - Application software



Protocol Stack

- Planes
  - Power management plane
    - Manage how a sensor node uses its power
  - Mobility management plane
    - Detect and register the movement of sens or nodes
  - Task management plane
    - Balance and schedule the sensing tasks



Contents

Physical Layer

- Be responsible for
  - Frequency selection
  - Carrier frequency generation
  - Signal detection
  - Modulation
  - Data encryption
- 915 MHz ISM band has been widely suggested for sensor net works

Physical Layer

- Signal propagation effects & Power Efficiency
  - Minimum output power (proportional to $distance^{2\sim4}$)
  - Multi-hop communication
- Modulation schemes
  - Binary modulation
  - M-ary modulation
- UWB(Ultra Wideband) / IR(Impulse Radio)

Contents

Data Link layer

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

- It is responsible for …
  - Multiplexing of data streams
  - Data frame detection
  - **Medium access control (MAC)**
    - **Two goals in a sensor network**
      - **The creation of network infrastructure**
      - **Share resources fairly and efficiently**
  - **Error control**

MAC (Medium Access Control)

- Existing MAC Protocols Cannot Be Used
  - Existing MAC protocols
    - Versus Cellular system
      - Base station – mobile node <-> no central controlling agent
      - Goal: provision of high quality of service (QoS) & band width efficiency
      - Power conservation is secondary important (Replenishing battery, unlimited power supplement) <-> it is pri me importance in a sensor network
    - Versus Bluetooth and the mobile ad hoc network (MANET)
      - Bluetooth
        - Star network (master node – up to 7 slave nodes)
        - Transmission power: ~20dBm & transmission range: order of tens of meters
      - MANET
        - Goal: the provision of high QoS under mobile conditions
        - Power is not important (Replaceable battery)
        - <-> Less mobility rate, frequent topology change

      <-> sensor network has more larger number of nodes.

      <-> ~ 0dBm transmission power and less radio range

MAC (Medium Access Control)

- MAC for Sensor Networks
  - Demand-based schemes may be unsuitable for sensor networks
    - Large messaging overhead & link setup delay
    - **Fixed allocation and Random access version are suggested**
  - SMACS & EAR
  - CSMA-based Medium Access
  - Hybrid TDMA-FDMA based

  - Power Saving Operation

MAC (Medium Access Control)

- SMACS and EAR
  - SMACS: Self-Organizing Medium Access Control for Sensor Networks
    - Distributed infrastructure-building protocol
      - **Enable nodes to discover their neighbors and establish transmission/reception schedules for global communication with out any global or local master nodes**
    - Neighbor discovery and channel assignment phases are combined
      - Hear all their neighbors -> form a connected network
    - Communication link – pair of time slots operating at a randomly chosen but fixed frequency <Power conse rvation>
      - Available bandwidth >> maximum data rate for sensor nodes
    - No network wide synchronization
  - EAR: Eaves-drop-And-Register Algorithm
    - Offer continuous service to the mobile nodes under both mobile and stationary conditions
    - Decide when to drop connections while minimizing messaging overhead
    - Transparent with SMACS; EAR + SMACS available
    - Network is assumed to be mainly static and mobile node has a number of stationary nodes
  - Drawback
    - Possibility that members already belonging to different subnets might never get connected

MAC (Medium Access Control)

- CSMA-Based Medium Access
  - CSMA: A carrier sense multiple access
  - Traditional CSMA-based schemes
    - Fundamental assumption of stochastically distributed traffic
    - Tend to support independent point-to-point flows
    - **<-> Must be able to support variable but highly correlated and dominantly periodic traffic**
  - Listening mechanism & backoff scheme
    - Constant listen period – energy efficient
    - Introduction of random delay → Robustness against repeated collisions
    - Fixed window & backup schemes → maintain proportional fairness
  - ARC (Adaptive transmission rate control)
    - Achieve medium access fairness
    - Control the data origination rate of a node in order to allow the route-through traffic to propag ate
    - Linear increase and multiplicative decrease approach

MAC (Medium Access Control)

- Hybrid TDMA/FDMA Based
  - T(F)DMA: Time/Frequency division multiple access
  - Assumption
    - System is made up of energy-constrained sensor nodes that communicate to a single nearby high-powered base station
      - The machine monitoring application of sensor networks with strict data latency requir ements is considered
  - If the transmitter consumes more power → TDMA
  - If the receiver consumes more power → FDMA

MAC (Medium Access Control)

- Qualitative overview

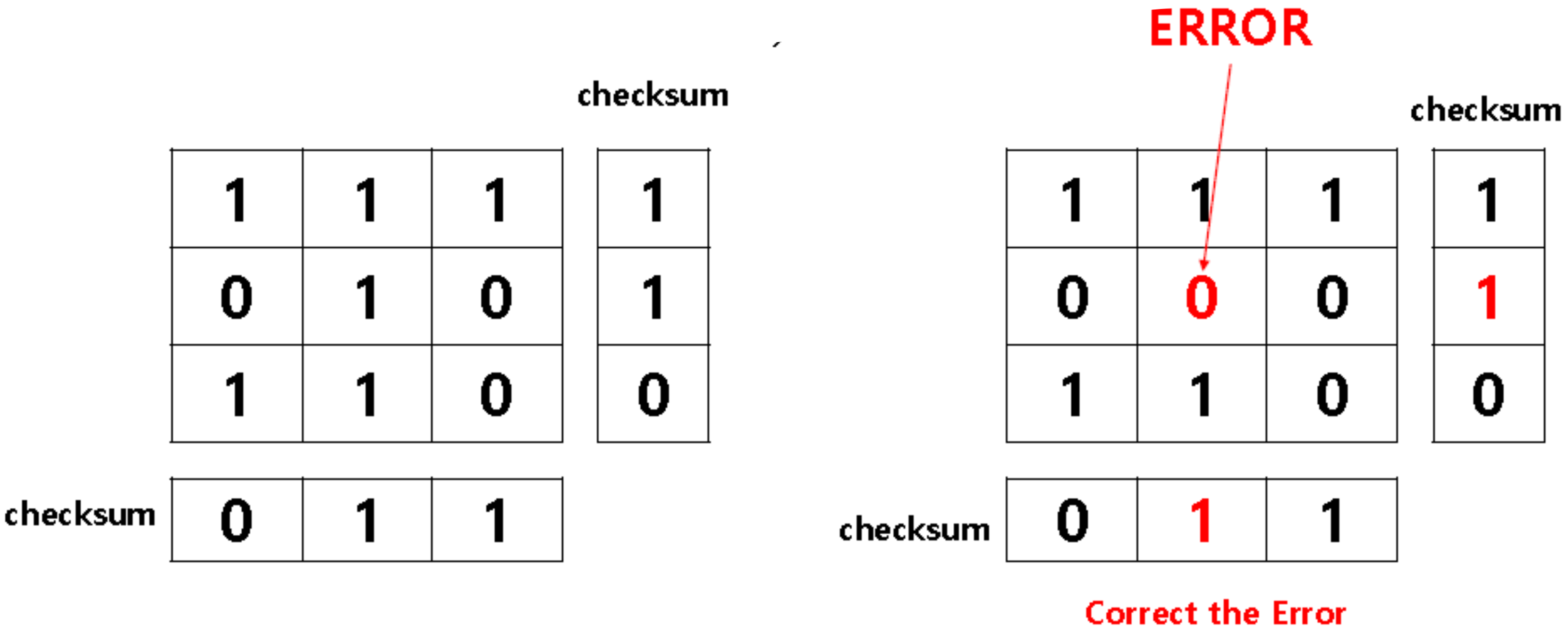
MAC protocol	Channel access mode	Sensor network specifics	Power conservation
SMACS and EAR [13]	Fixed allocation of duplex time slots at fixed frequency	Exploitation of large available bandwidth compared to sensor data rate	Random wake up during setup and turning radio off while idle
Hybrid TDMA/FDMA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

MAC (Medium Access Control)

- Power Saving Modes of Operation
  - Regardless of medium access scheme
  - Example: Turn the transceiver off when it is not required
  - Dependent to its hardware
  - Characterized by Less power consumption ←→ latency overhead

Error Control

- Automatic repeat request (ARQ)
- Forward Error Correction (FEC)



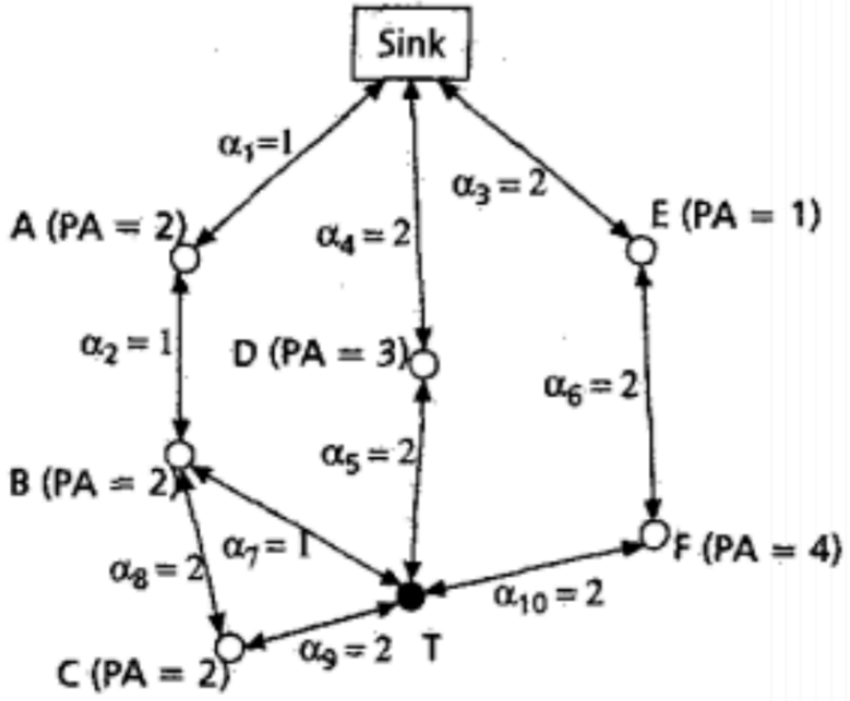
Contents

Network Layer

- Power efficiency routing(choose path)
- Data centric routing(choose source/sink node)
- Data aggregation
- Sensor network schemes

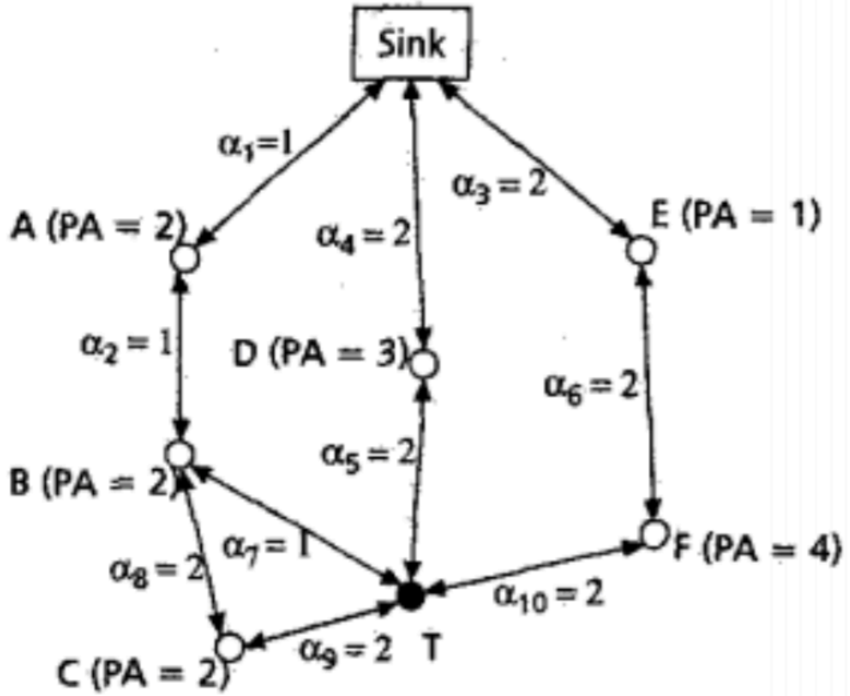
Network Layer

- Power efficiency routing
- Routing paths(PA : Available power, α : required power)
  - 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)



Network Layer

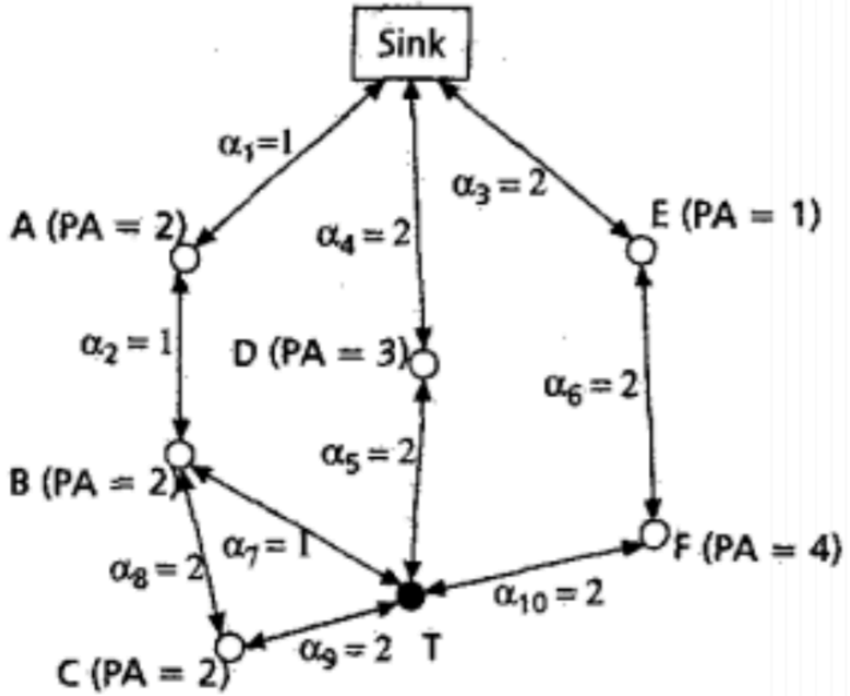
- Power efficiency routing
- Routing paths(PA : Available power, α : required power)
  - Route 1 : T–B–A–Sink (PA : 4, α : 3)
  - Route 2 : T–C–B–A–Sink (PA : 6, α : 6)
  - Route 3 : T–D–Sink (PA : 3, α : 4)
  - Route 4 : T–F–E– Sink (PA : 5, α : 6)



- Maximum PA route

Network Layer

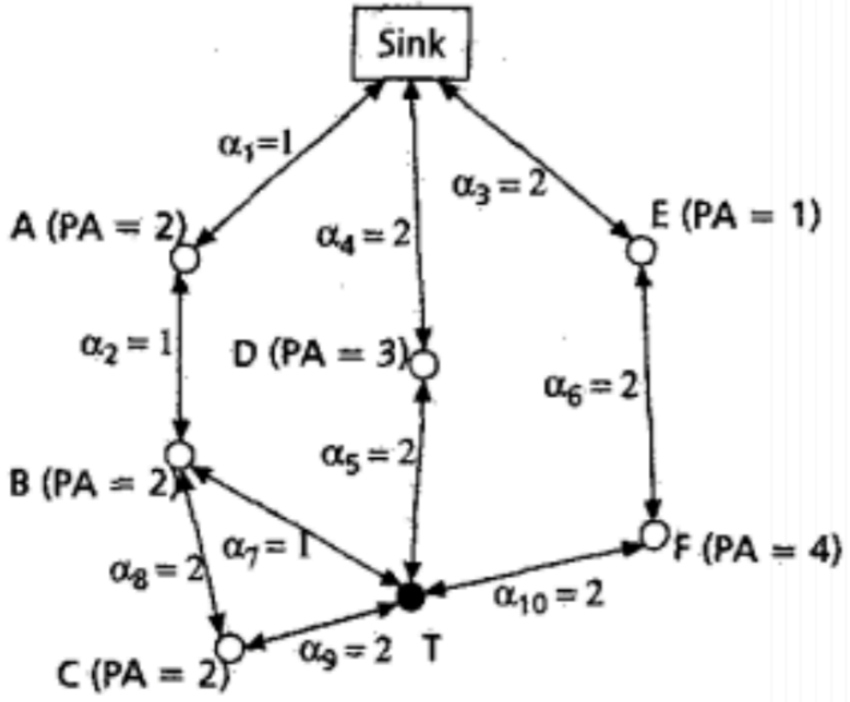
- Power efficiency routing
- Routing paths(PA : Available power, α : required power)
  - Route 1 : T–B–A–Sink (PA : 4, α : 3)
  - Route 2 : T–C–B–A–Sink (PA : 6, α : 6)
  - Route 3 : T–D–Sink (PA : 3, α : 4)
  - Route 4 : T–F–E– Sink (PA : 5, α : 6)



- Minimum energy(α) route

Network Layer

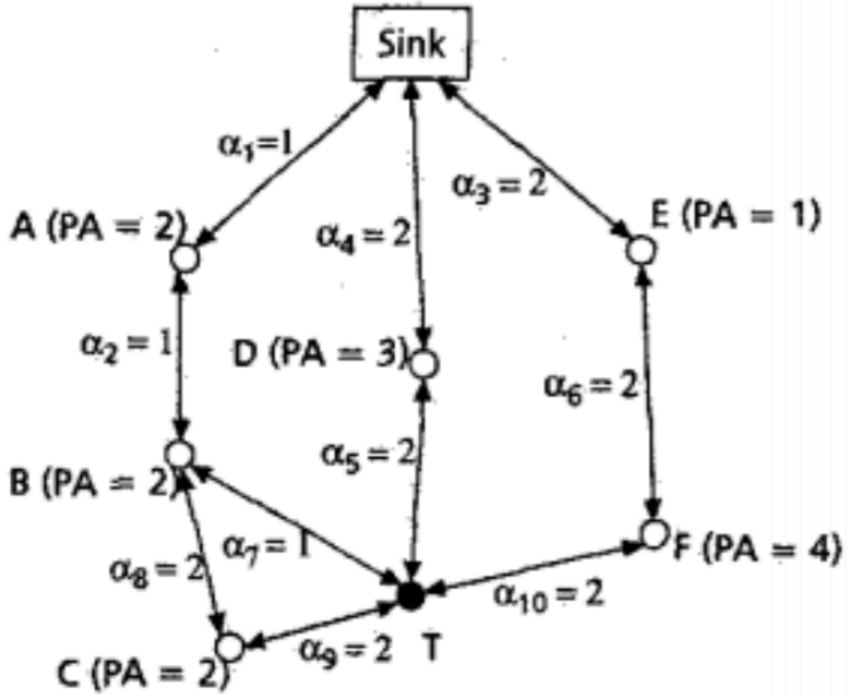
- Power efficiency routing
- Routing paths(PA : Available power, α : required power)
  - Route 1 : T–B–A–Sink (PA : 4, α : 3)
  - Route 2 : T–C–B–A–Sink (PA : 6, α : 6)
  - Route 3 : T–D–Sink (PA : 3, α : 4)
  - Route 4 : T–F–E– Sink (PA : 5, α : 6)



- Minimum hop(node) route

Network Layer

- Power efficiency routing
- Routing paths(PA : Available power, α : required power)
  - 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)



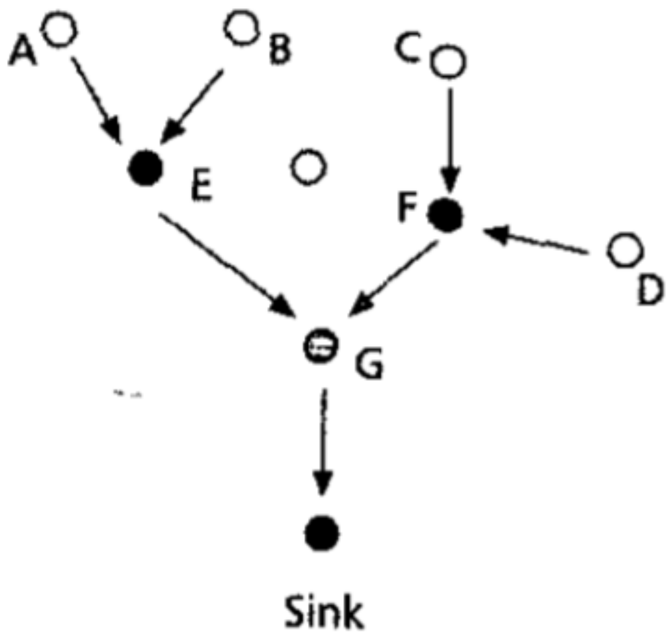
- Maximum 'minimum PA' route

Network Layer

- Data Centric Routing
  - Interest dissemination from sink nodes
  - Advertise available data from sensor nodes

Network Layer

- Data aggregation
  - To avoid implosion and overlap



Network Layer

- Sensor network schemes
  - SMECN
  - FLOODING
  - GOSSIPING
  - SPIN
  - SAR
  - LEACH
  - Directed Diffusion

Network Layer

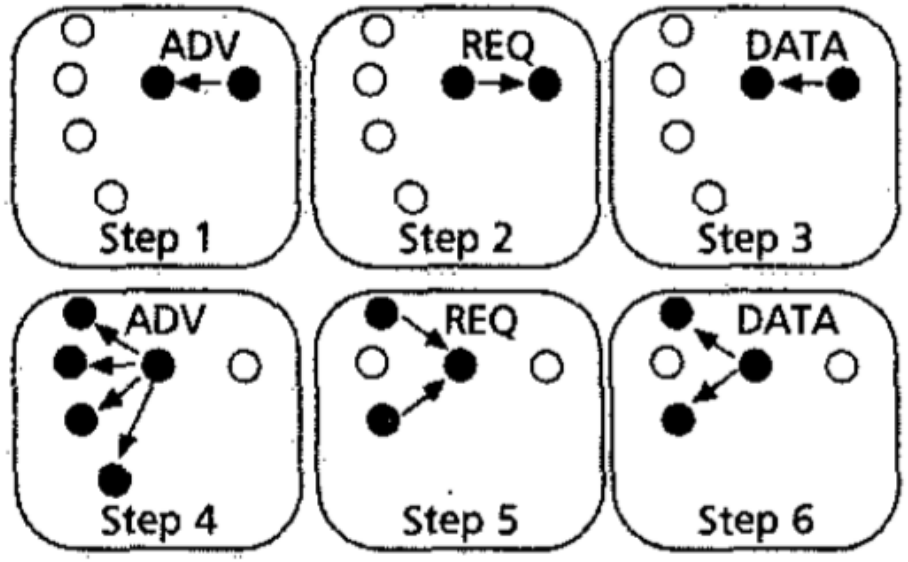
- SMECN(Small Minimum Energy Communication Network)
  - Creates a subgraph of the sensor network that contains the minim um energy path

Network Layer

- FLOODING
  - Old technique, broadcast data to all neighbor nodes regardless if t hey receive before or not
  - Implosion, Overlap, Resource blindness problem
- GOSSIPING
  - Sends data to one random neighbor node
  - Avoid implosion problem, low performance

Network Layer

- SPIN(Sensor Protocols for Information via Negotiation)
  - Sends data to sensor nodes only if they are interested
  - 3 types of message; ADV, REQ, DATA



Network Layer

- SAR(Sequential Assignment Routing)
  - Creates multiple trees where the root of each tree is a one hop nei ghbor from the sink
  - Trees grow outward from the sink
  - Choose path based on energy resources, additive QoS metric, pack et's priority level.

Network Layer

- LEACH(Low-Energy Adaptive Clustering Hierarchy)
  - Forms clusters to minimize energy dissipation
  - Randomly select sensor nodes as cluster heads
  - High energy dissipation in communicating with the base station is spread to all sensor nodes
  - Two phases

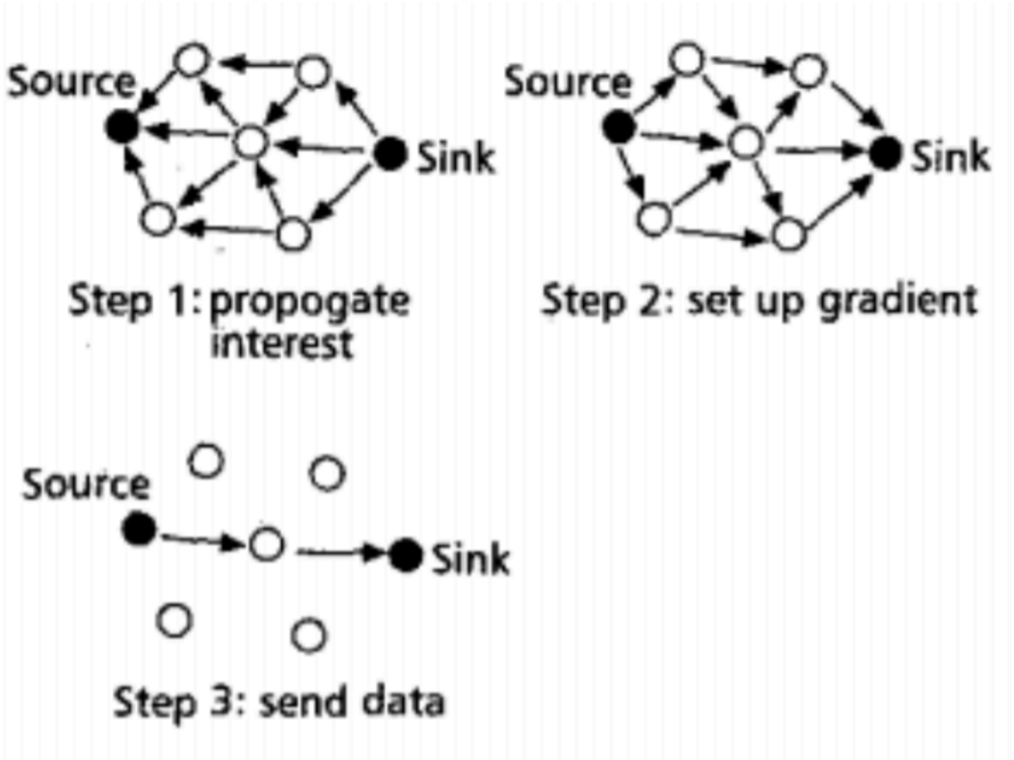
Network Layer

- LEACH(Low-Energy Adaptive Clustering Hierarchy)
  - Setup Phase
    - Cluster heads are selected randomly
    - Each sensor node is associated with its cluster head
  - Steady Phase
    - Sensor nodes begin sensing and sending data to head
    - Cluster heads aggregate data and send it to the base station

Network Layer

- Directed Diffusion
  1. Sink sends interest
  2. Gradients are set up
  3. Source sends the data
  4. Sink refreshes and reinforces the interest

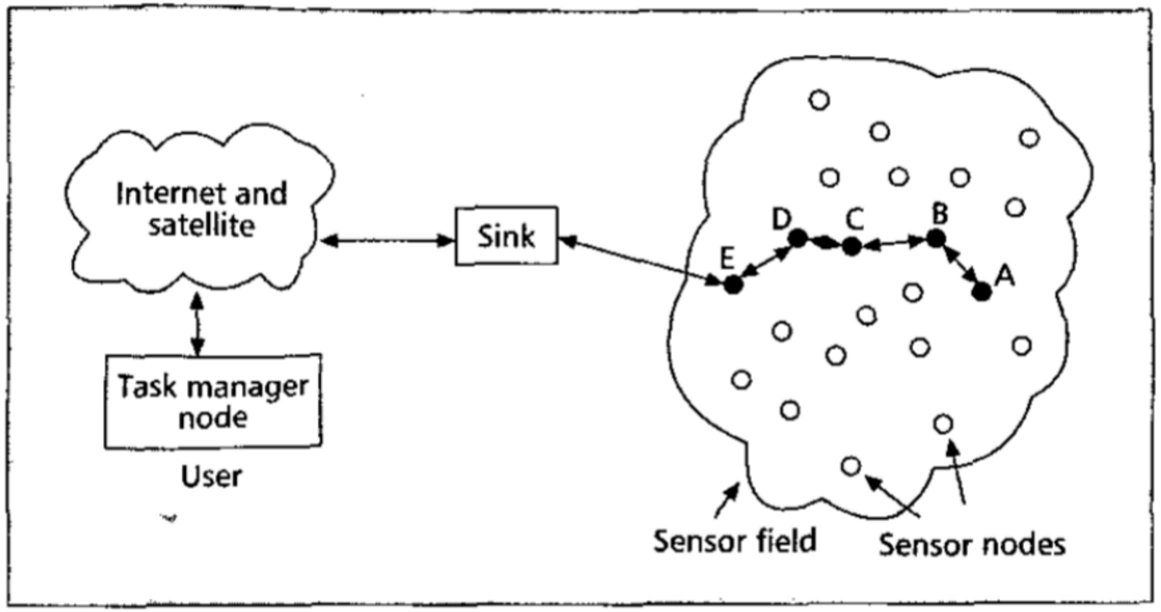
- Based on data centric routing



Contents

Transport Layer

- Access to Internet or other external network
- Hybrid approach
  - TCP(sink – internet) + UDP(sink – sensor nodes)



Contents

- Introduction
- Sensor Networks Communication Architecture
- Protocol Stack
  - Physical Layer
  - Data Link Layer
  - Network Layer
  - Transport Layer
  - Application Layer
    - Largely unexplored region
    - Application layer protocols
- Conclusion

Application Layer

- Largely unexplored region
- Application layer protocols
  - SMP
  - TADAP
  - SQDDP

Application Layer

- SMP(Sensor Management Protocol)
  - System admin interacts with sensor networks
  - Administrative tasks
    - Introducing rules about data aggregation, attribute based naming and clustering t o sensor nodes
    - Exchanging data related to the location finding algorithms
    - Time synchronization
    - Moving sensor nodes
    - Turning sensor nodes on/off
    - Querying network configuration, nodes` status
    - Reconfiguring sensor networks
    - Authentication, security

Application Layer

- TADAP(Task Assignment and Data Advertisement Protocol)
  - Efficient interest dissemination interface
    - Interest dissemination by users
    - Data advertisement by sensor nodes
  - Helps data-centric routings in lower layers

Application Layer

- SQDDP(Sensor Query and Data Dissemination Protocol)
  - Provides user applications with interfaces to issue query, respond t o queries and collecting incoming replies
  - Attribute, location based querying

Contents

Conclusion

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