Wireless sensor network

Unit-1

AKDANIEL

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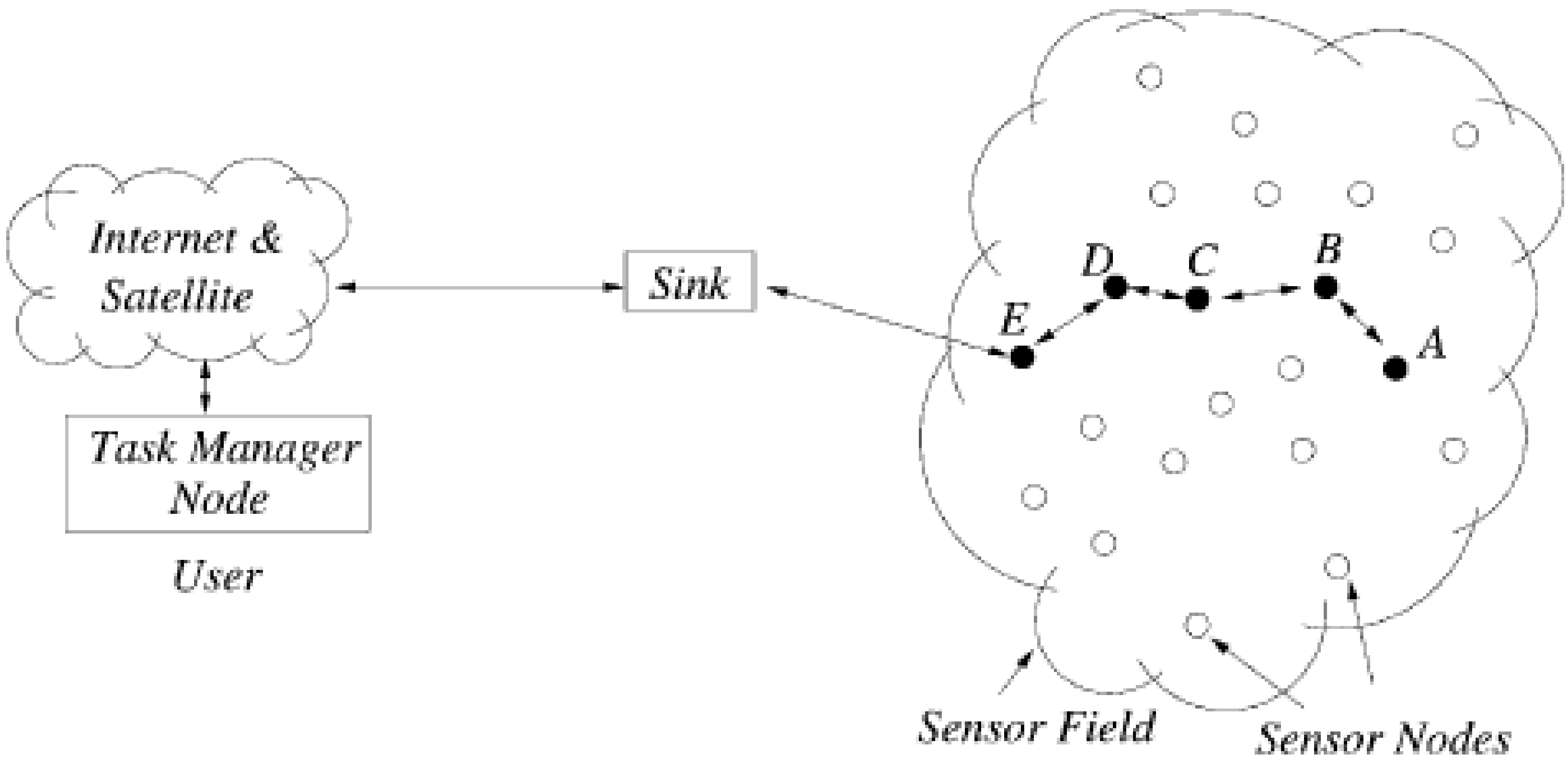
What is WSN

- Wireless Sensor Networks are networks that consists of sensors which are distributed in an ad hoc manner.
- These sensors work with each other to sense some physical phenomenon and then the information gathered is processed to get relevant results.
- Wireless sensor networks consists of protocols and algorithms with self-organizing capabilities.

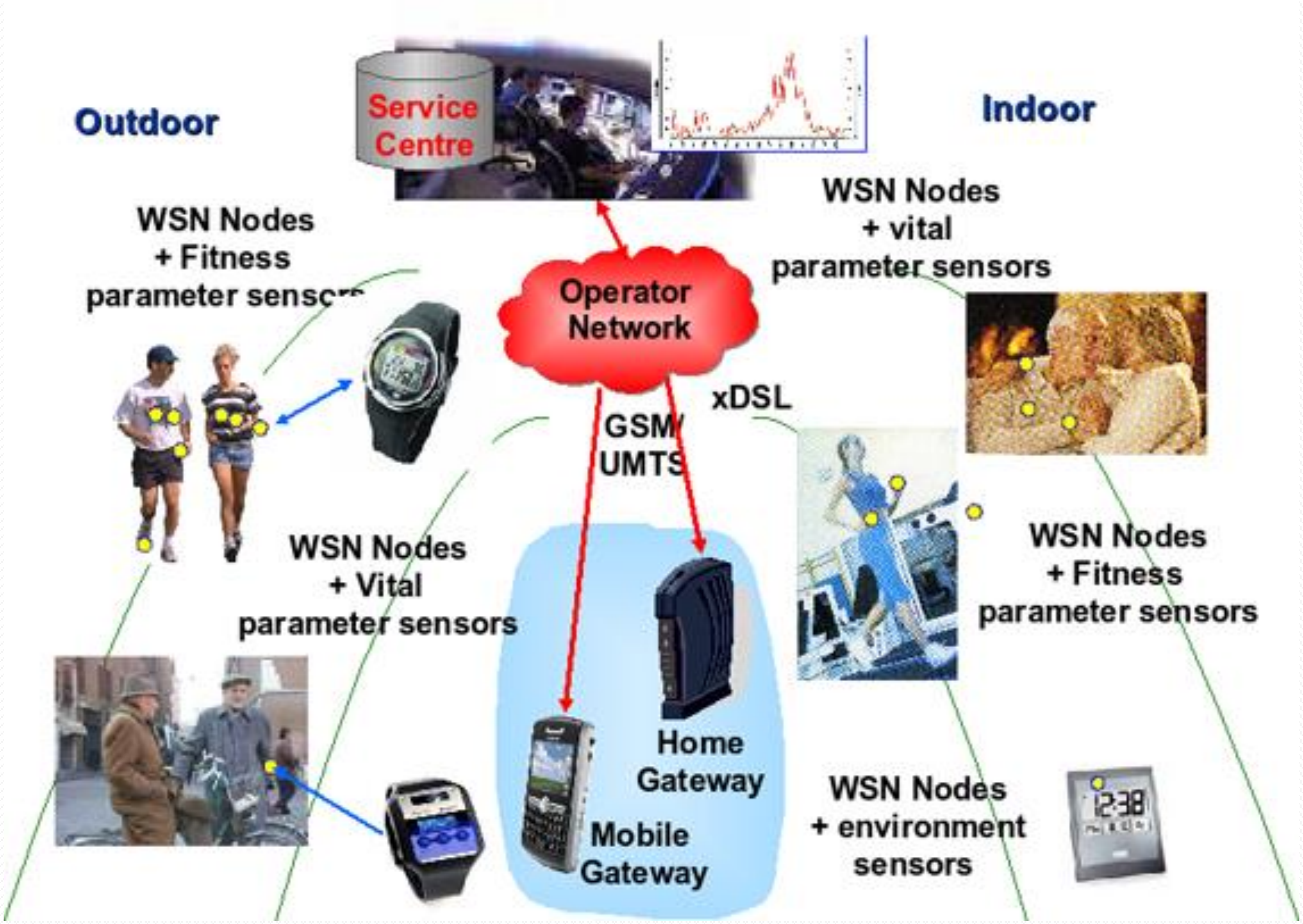
WSN Communication Architecture



Why use a WSN?

- Ease of deployment
  - Wireless communication means no need for a communication infrastructure setup
  - Drop and play
- Low-cost of deployment
  - Nodes are built using off-the-shelf cheap components
- Fine grain monitoring
  - Feasible to deploy nodes densely for fine grain monitoring

Example of WSN



Classifications of WSNs

WSNs can be classified on the basis of their mode of operation or functionality, and the type of target applications

Proactive Networks – The nodes are periodically switch to their target sensors sense data of interest from environment and transmit it

They provide relevant parameters at regular intervals

Classifications of WSNs cont…

- **Reactive Networks** –The nodes react immediately as sudden and drastic changes in the value of the sensed attribute.
- They are well suited for time critical applications.
- **Hybrid Networks** – This is a combination of both proactive and reactive networks where sensor nodes not only send data periodically, but also respond to sudden changes in attribute values

Characteristics of Wireless Sensor Networks

- Wireless Sensor Networks mainly consists of **sensors. Sensors** are -
  - low power
  - limited memory
  - energy constrained due to their small size.

- Wireless networks can also be deployed in **extreme environmental** conditions and may be prone to enemy attacks.

- Although deployed in an ad hoc manner they need to be **self organized** and **self healing** and can face constant reconfiguration.

Challenges in sensor networks

- Nodes are battery powered
- Radio broadcast,
- Limited bandwidth,
- Busty traffic
- False positives
- Pre-configuration inapplicable
- Algorithms should scale well

Challenges in sensor networks

- Energy constraint
- Unreliable communication
- Unreliable sensors
- Ad hoc deployment
- Large scale networks
- Limited computation power
- Distributed /Centralized algorithms
- Difficult to debug & correct it

Comparison with Ad hoc Networks

- Wireless sensor networks mainly use **broadcast** communication while ad hoc networks use **point-to-point** communication.
- Unlike ad hoc networks wireless sensor networks are **limited by sensors** limited power, energy and computational capability.
- Sensor nodes may **not have global ID** because of the large amount of overhead and large number of sensors.

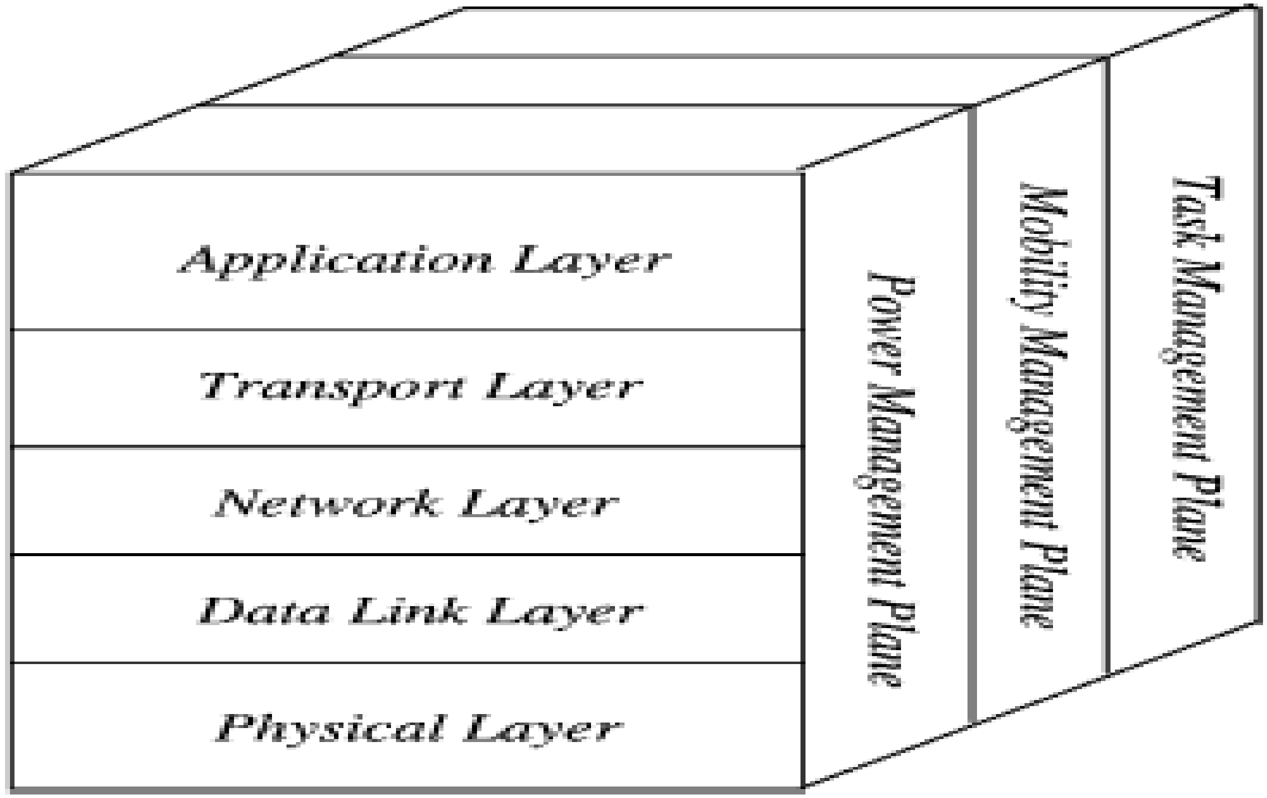
WSN Applications

- Environmental/Habitat monitoring
- Acoustic detection
- Seismic Detection
- Military surveillance
- Inventory tracking
- Medical monitoring
- Smart spaces

WSN Applications cont…

- Forest fire detection
- Bio-complexity mapping of environment
- Flood detection
- Precision Agriculture
- Air and water pollution
- Process Monitoring

WSN Protocol Stack



WSN Operating Systems

- Tiny OS
- Contiki
- MANTIS
- BTnut
- SOS
- Nano-RK

Design Issues

- **Heterogeneity**
  - The devices deployed maybe of various types and need to collaborate with each other.
- **Distributed Processing**
  - The algorithms need to be centralized as the processing is carried out on different nodes.
- **Low Bandwidth Communication**
  - The data should be transferred efficiently between sensors

Design Issues

Cont..

- **Large Scale Coordination**
  - The sensors need to coordinate with each other to produce required results.
- **Utilization of Sensors**
  - The sensors should be utilized in a ways that produce the maximum performance and use less energy.
- **Real Time Computation**
  - The computation should be done quickly as new data is always being generated.

Design Issues Cont..

Application-dependent

- Node deployment:
  - Manual (deterministic): data is routed through predetermined paths
  - Randomized: nodes are scattered randomly, creating an ad hoc routing infrastructure
  - Distribution of nodes is not uniform, optimal clustering becomes necessary

Design Issues

Cont..

- Data Reporting method
  - Time-driven: for application requiring periodic data monitoring
  - Event-Driven: React due to a certain event Occurred (Time-critical application)
  - Query-Driven: Response to a Query (Time-critical application)
  - Hybrid

Design Issues

Cont

- Energy consumption: Use up their limited energy supply to communicate it
- Node/link heterogeneity

  Hierarchical protocols designate
- Fault tolerance

  The failure of sensor nodes should not affect the overall task of the sensor network

Design Issues Cont…

- Scalability
  - Any routing scheme must be able to work with huge number of sensor nodes
- Network dynamics
  - Nodes can be mobile
  - The phenomenon can be mobile
- Transmission media
  - The bandwidth is low(1-100 Kb/s)
  - TDMA based protocols used more energy
  - CSMA based protocol used less energy as TDMA

Design Issues

Cont …

- Connectivity
  - Density in sensor networks
  - Depends on the possibly random distribution of nodes
- Coverage
  - A sensor's view of the environment is limited in both range and accuracy

Design Issues

Cont…

- Data aggregation
  - Sensor nodes may generate significant redundant data
  - To reduce the number of transmissions
- Quality of service
  - Network lifetime often is considered more important
  - Bounded latency for data delivery is a condition for time-constrained applications

Operational Challenges of Wireless Sensor Networks

- Energy Efficiency
- Limited storage and computation
- Low bandwidth and higher error rates
- Errors generate are common due to
  - Wireless communication
  - Noisy measurements
  - Node failure are expected
- Scalability to a large number of sensor nodes
- Survivability in harsh environments
- Experiments are time- and space-intensive

Coverage Problems

- **Coverage:** It is a measure of the Quality of service of a sensor network in a given area
- How well can the network cover the given event area ?

Example Intruder detection, Animal, Fire detection

- Coverage depends upon:
  - Range and sensitivity of sensing nodes
  - Location and density of sensing nodes in given region

Coverage Problems

cont…

- *Worst-Case Coverage*:

  Areas of breach (lowest coverage)

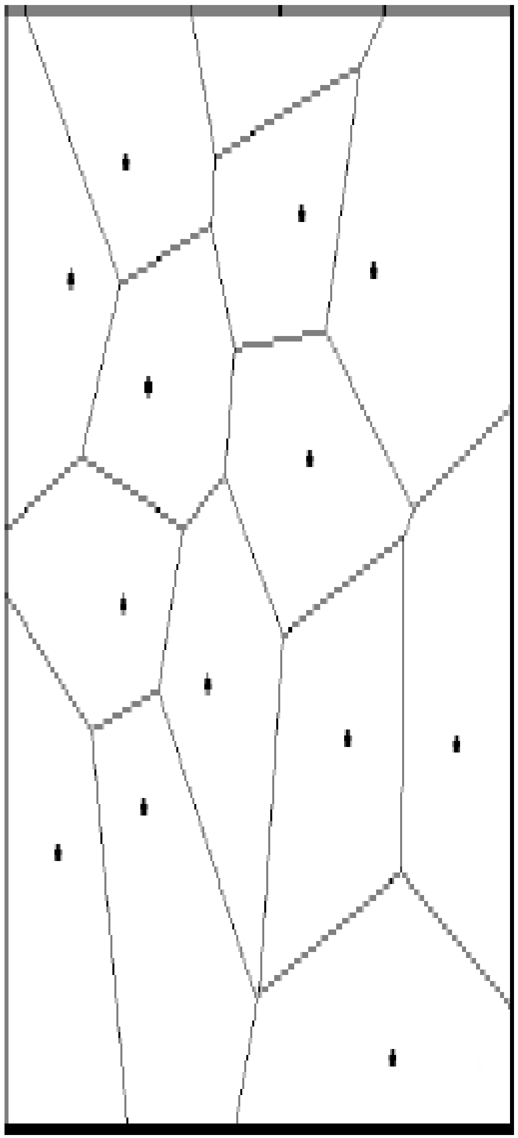
  - Can be used to determine if additional sensors needed
- *Best-Case Coverage*:

  Areas of best coverage

  - Can be used by a friendly user to navigate in given areas

Voronoi diagrams

- In 2D, the Voronoi diagram of a set of points partitions the plane into a set of convex polygons such that:
  - All points inside a polygon are closest to only one site.
  - The polygons have edges equidistant from nearby points.
- Related is Delaunay Triangulation
  - Connect points in V-Diag. whose polygons share a common edge.



Localization problem

- In some applications, it is essential for each node to know its location
- Global Positioning System (GPS) is not always possible
  - GPS cannot work indoors
  - GPS power consumption is very high

Solutions

- Range-based
  - Use exact measurements (point-to-point distance estimate (range) or angle estimates)
  - More expensive
  - Ranging: the process of estimating the distance between the pair of nodes
- Range-free
  - Only need the existences of beacon signals
  - Cost-effective alternative to range-based solutions

Location Information

- It is essential, for some applications, that each node must know its location (position).
  - Sensed data coupled with location position as data for transmission .
  - Need a cheaper , low-power, low-weight, low form-factor, and accurate mechanism device
- Global Positioning System (GPS) not always feasible
  - GPS cannot work indoors, in dense foliage, etc.
  - GPS power consumption is very higher
  - Size of GPS receiver and antenna will increase node form factor

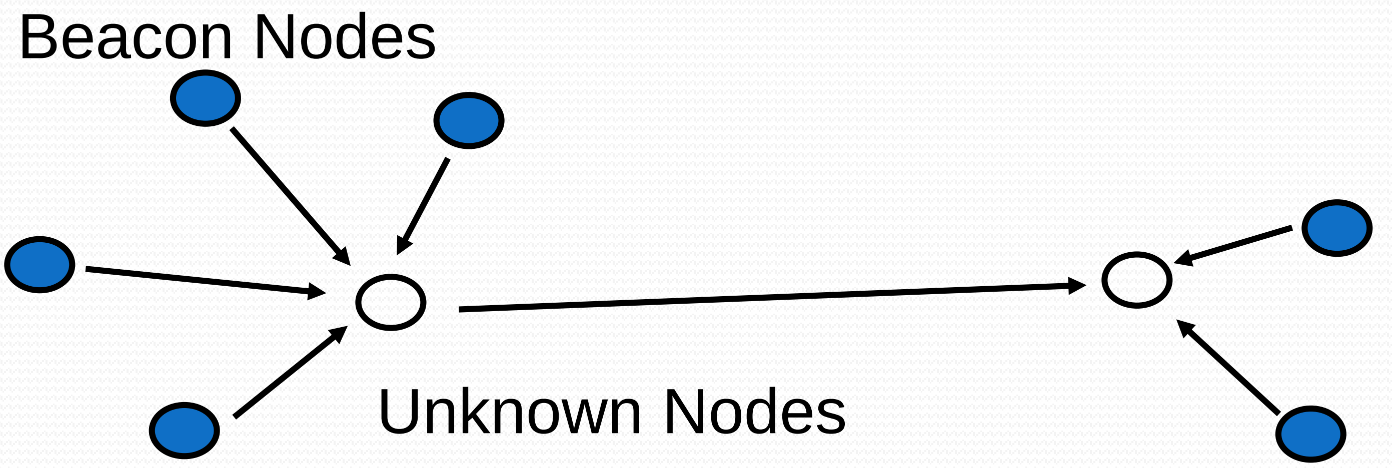
Indoor Localization

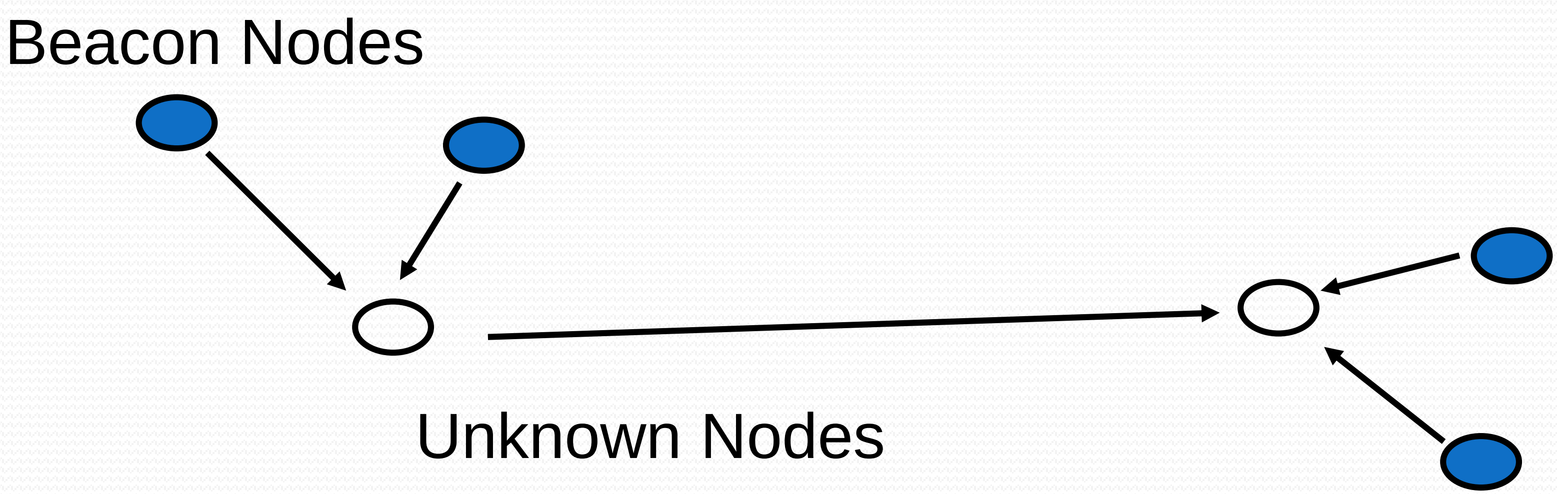
- Use a fixed infrastructure
  - Beacon nodes are strategically placed
- Nodes receive beacon signals and measure:
  - Signal Strength
  - Signal Pattern
  - Time of arrival; Time difference of arrival
  - Angle of arrival
- Nodes use measurements from multiple beacons and use different techniques to estimate locations
- Accuracy of estimate depends on correlation between measured entity and distance

Localization algorithms

- Based on the time diff. of arrival
- Atomic Multi-lateration:
  - If a node receives 3 becaons, it can determine its location (similar to GPS)
- Iterative ML:
  - Some nodes not in direct range of beacons
  - Once an unknown node estimates its location, will send out a beacon
  - Multi-hop approach; Errors propagated
- Collaborative ML:
  - When 2+ nodes cannot receive 3 beacons (but can receive say 2), they collaborate

Multi-lateration examples





Localization Algorithms in WSNs

- *Beacon Nodes* know their locations
- Range-based Algorithms
  - Sensor nodes need to measure physical distance-related properties
  - How to measure distance
    - RSSI (Received Signal Strength Indication)
    - ToA (Time of Arrival)
    - TDOA (Time Difference of Arrival)
  - How to estimate location
    - MMSE (Minimum Mean Square Estimation)
- Range Free Algorithms
  - Do Not involve distance estimation

Aggregation in Sensor Networks

- Redundant Data/events
- Some services are amenable for in-network computations.
  - “The network is the sensor”
- Communication can be more expensive than computation.
- By performing “computation” on data en route to the sink, we can reduce the amount of data traffic in the network.
- Increases energy efficiency as well as scalability
  - The bigger the network, the more computational resources.

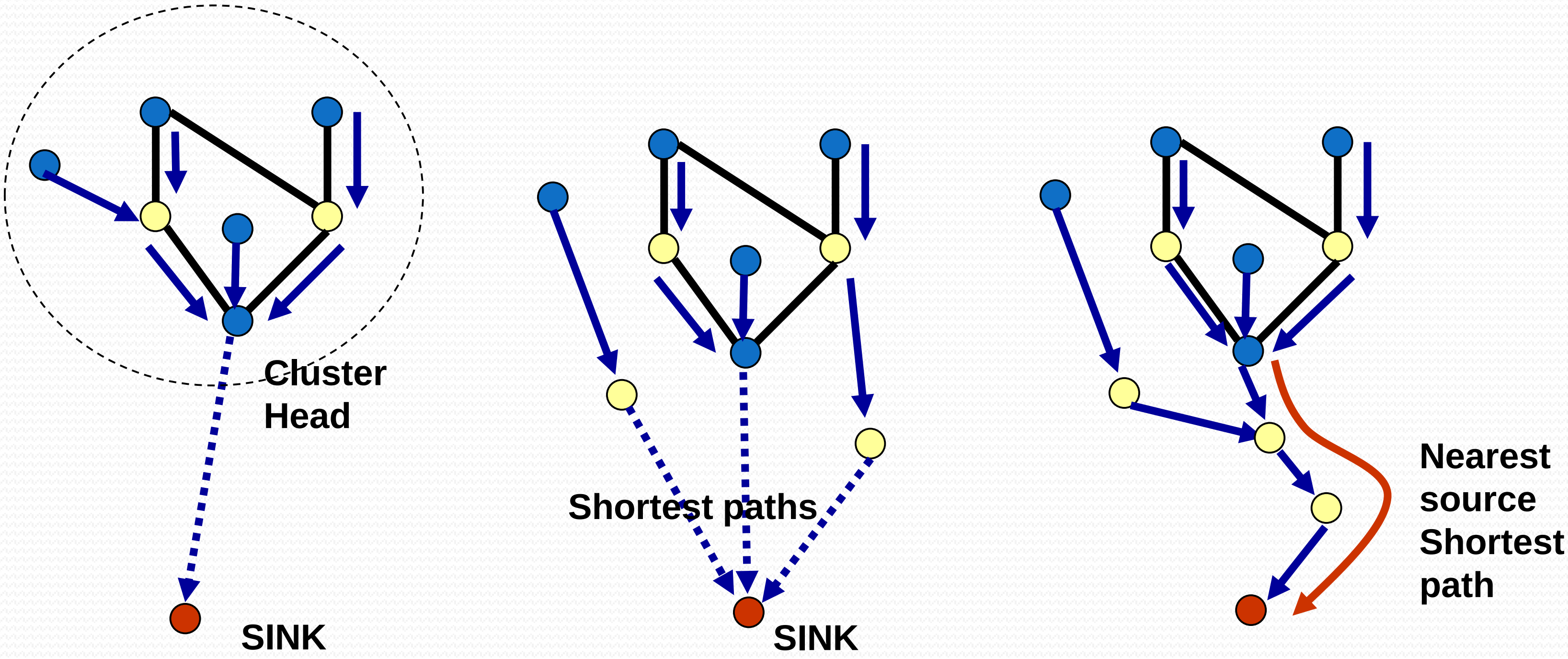
Aggregation Techniques

- Center at Nearest Source (CNSDC): All sources send the information first to the source nearest to the sink, which acts as the aggregator.

- Shortest Path Tree (SPTDC): Opportunistically merge the shortest paths from each source wherever they overlap.

- Greedy Incremental Tree (GITDC): Start with path from sink to nearest source. Successively add next nearest source to the existing tree.

Aggregation Techniques



a) Clustering based CNS

b) Shortest Path Tree

c) Greedy Incremental