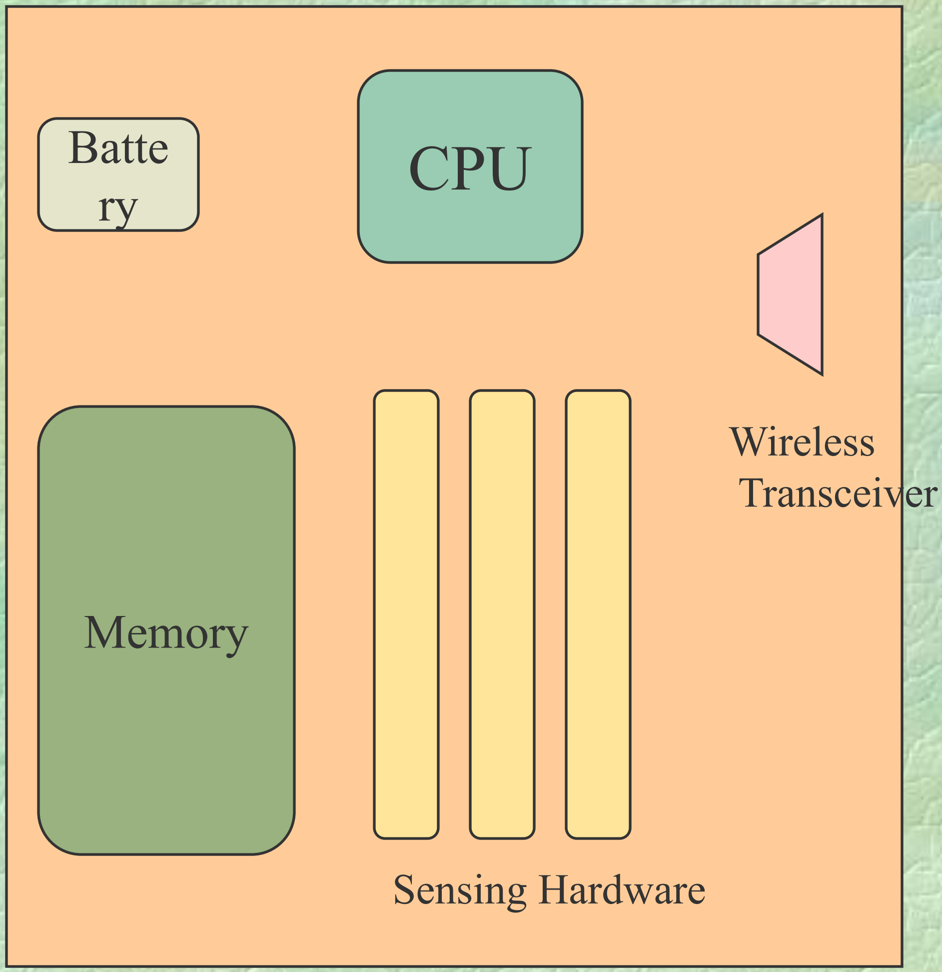
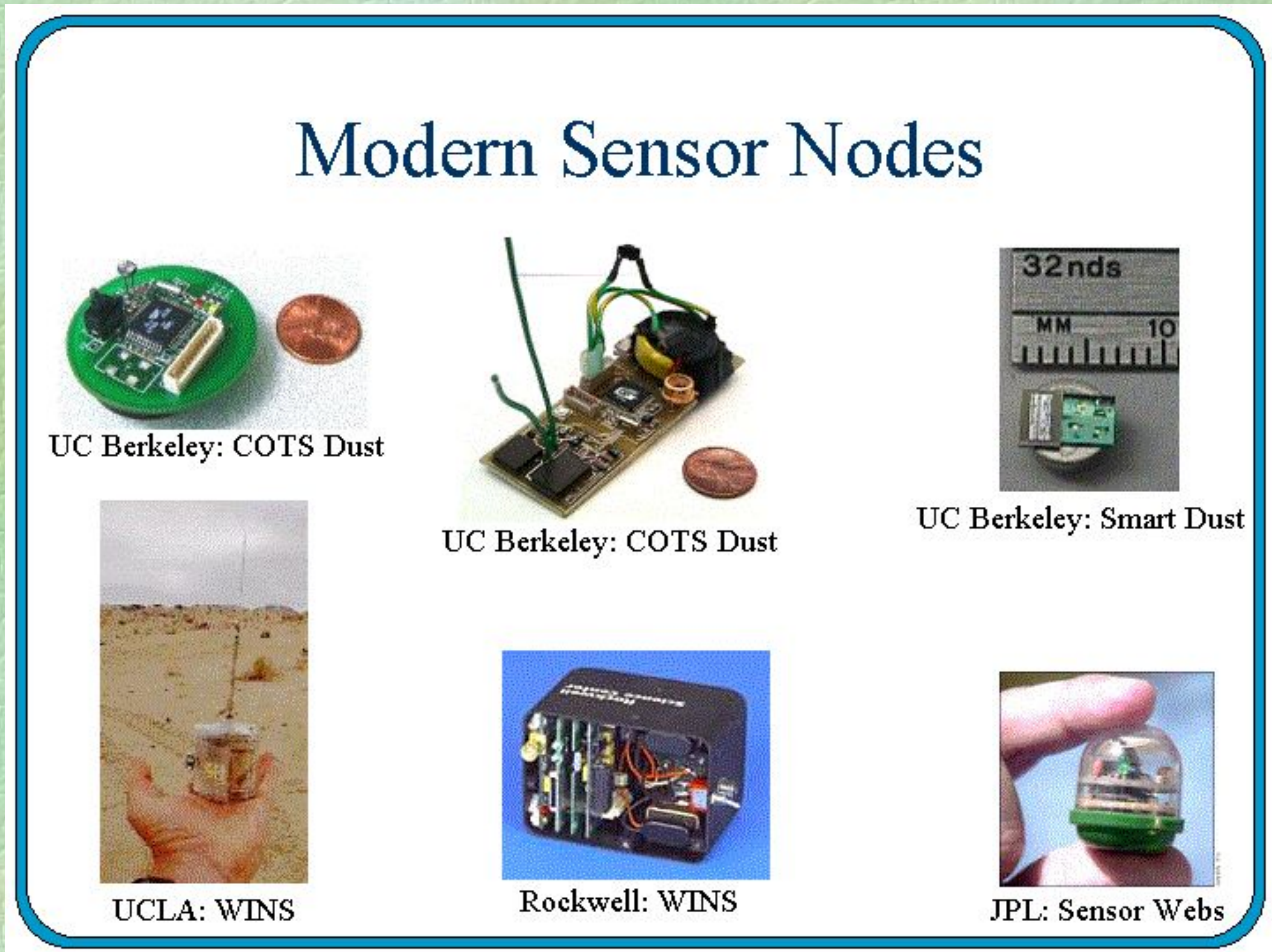
Introduction to WSN

Background , contd.

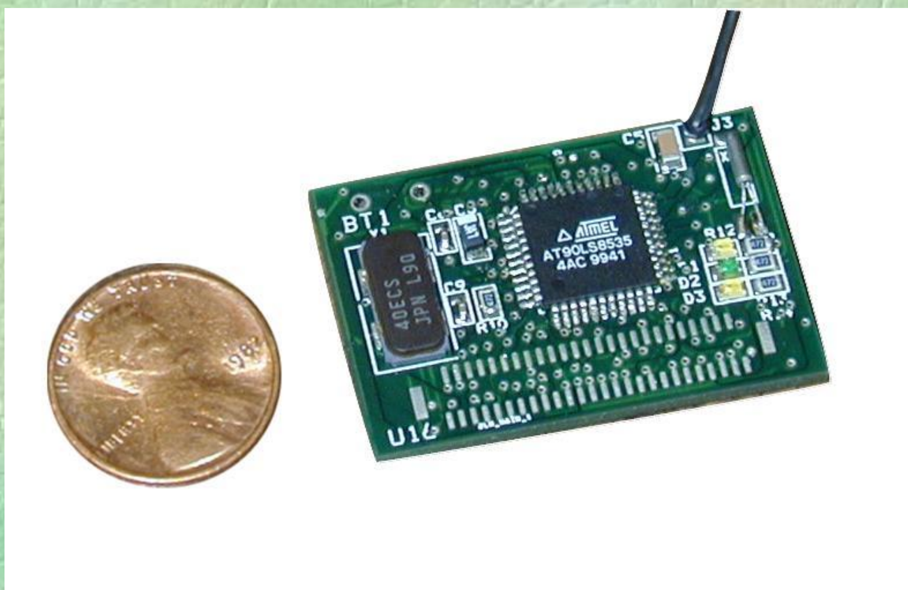


- Sensors
  - Enabled by recent advances in MEMS technology
  - Integrated Wireless Transceiver
  - Limited in
    - Energy
    - Computation
    - Storage
    - Transmission range
    - Bandwidth

Background, contd.



Sensor Nodes, contd.



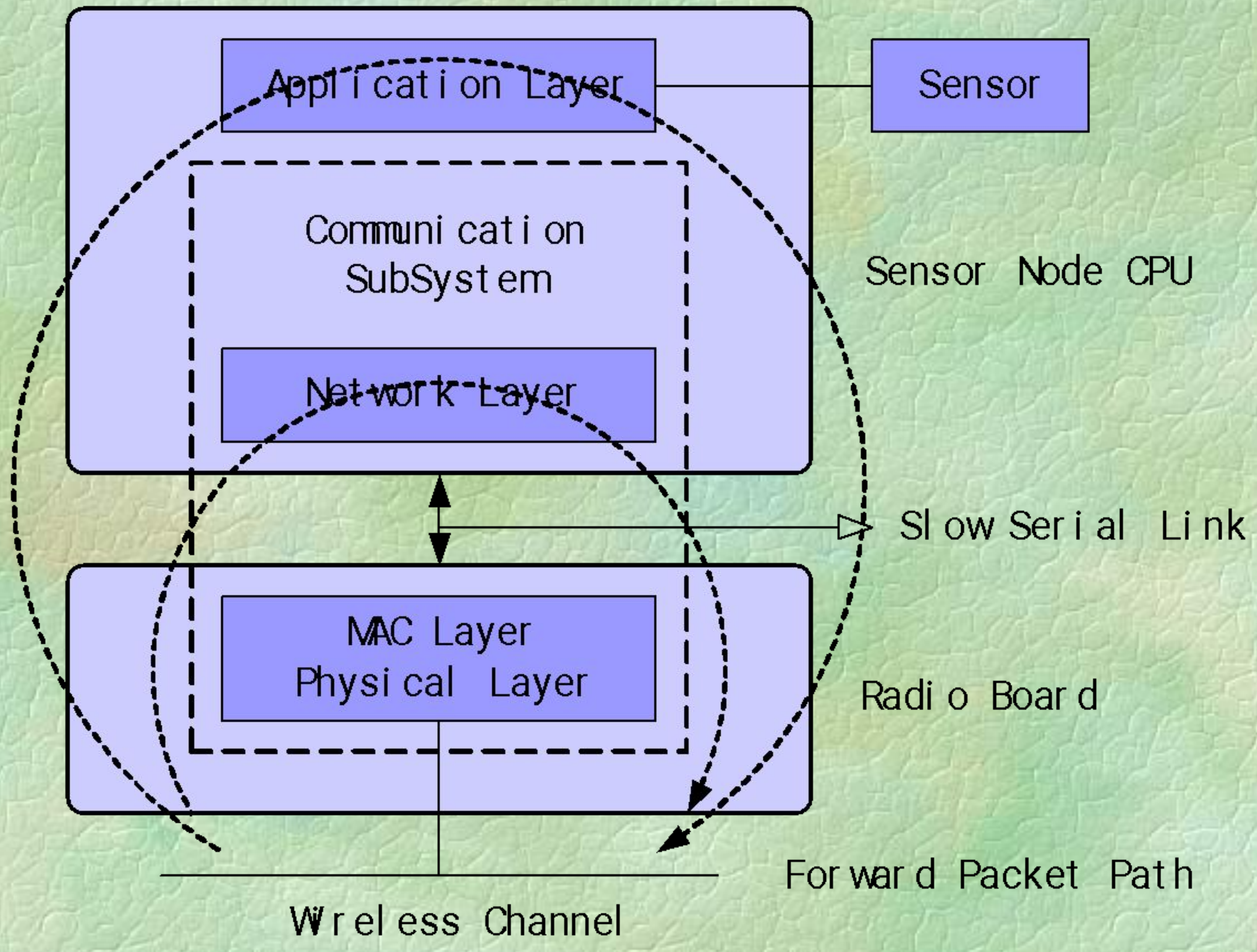
Sensors (contd.)

- The overall architecture of a sensor node consists of:
  - The sensor node processing subsystem running on sensor node main CPU
  - The sensor subsystem and
  - The communication subsystem
- The processor and radio board includes:
  - TI MSP430 microcontroller with 10kB RAM
  - 16-bit RISC with 48K Program Flash
  - IEEE 802.15.4 compliant radio at 250 Mbps
  - 1MB external data flash
  - Runs TinyOS 1.1.10 or higher
  - Two AA batteries or USB
  - 1.8 mA (active); 5.1uA (sleep)

Crossbow Mote

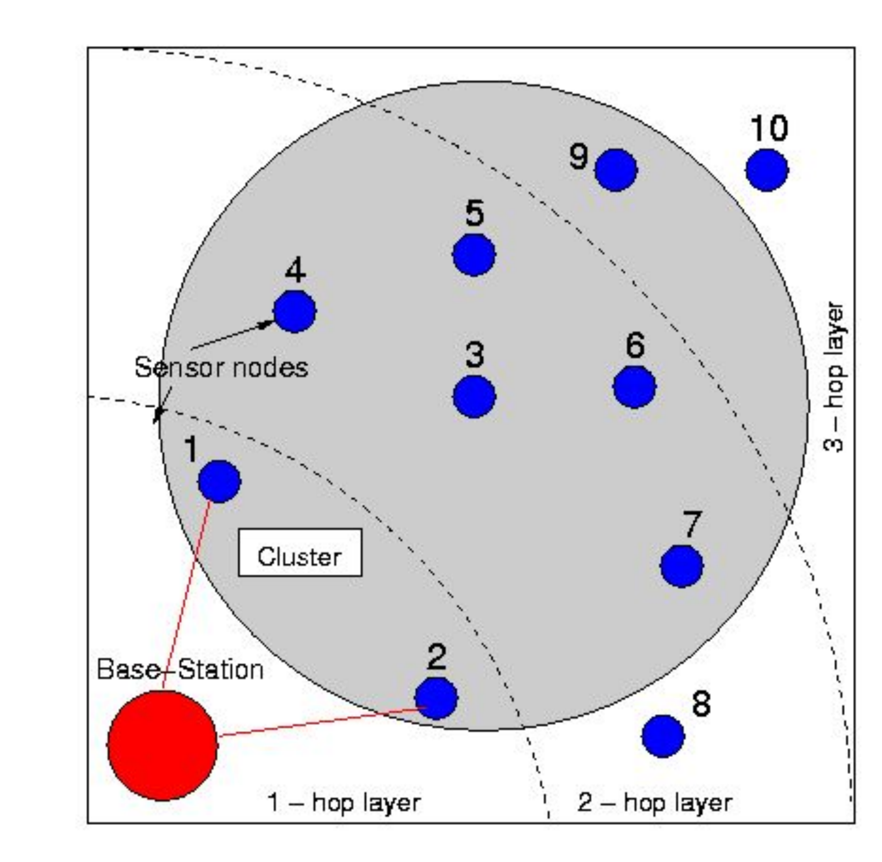
TPR2400CA-TelosB

Overall Architecture of a sensor node



Wireless Sensor Networks (WSN)

- Distributed collection of networked sensors



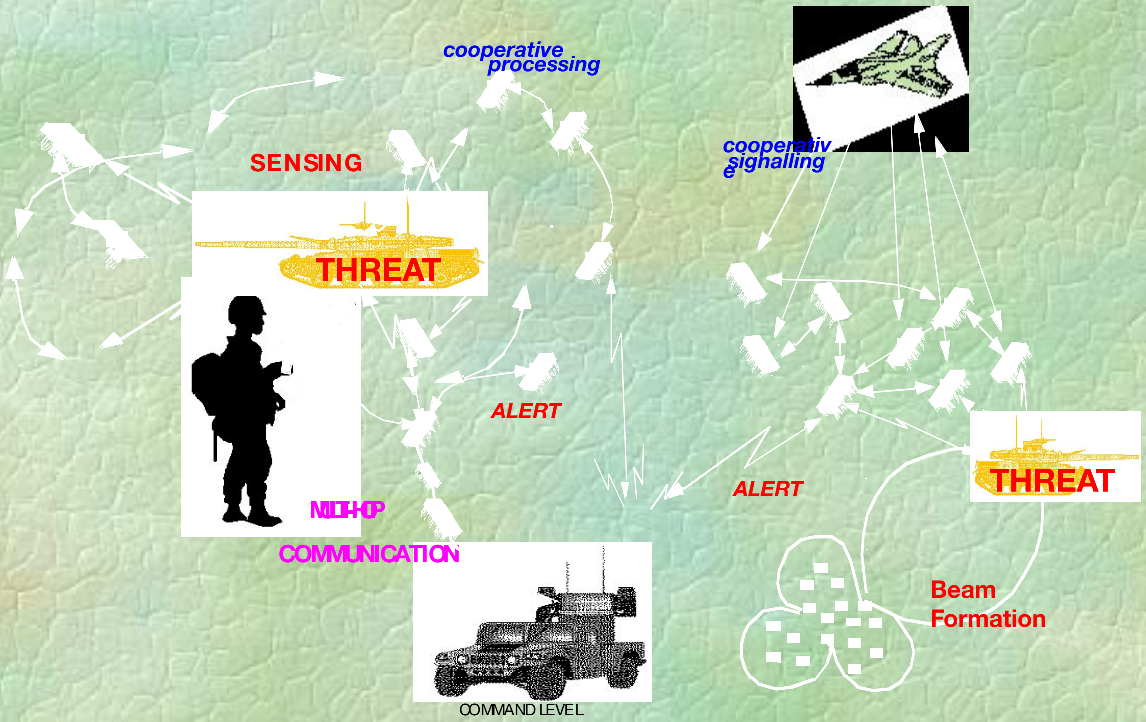
Networked vs. individual sensors

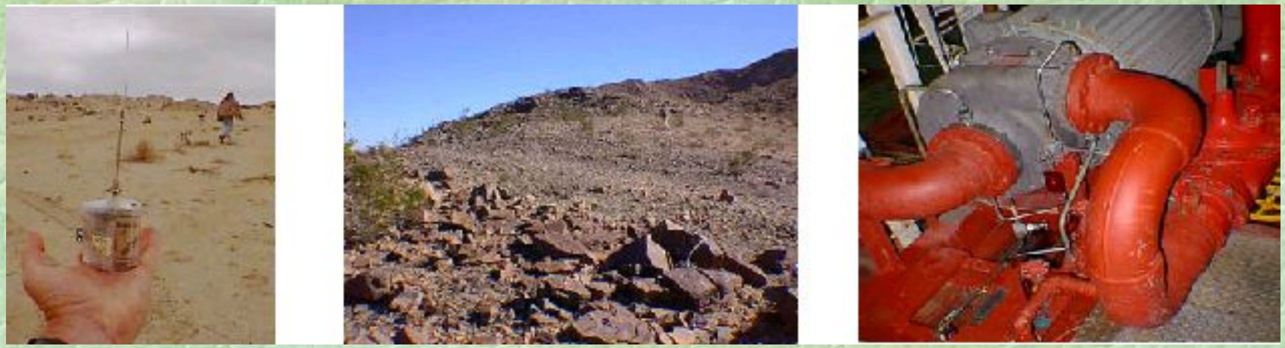
- Extended range of sensing:
  - Cover a wider area of operation
- Redundancy:
  - Multiple nodes close to each other increase fault tolerance
- Improved accuracy:
  - Sensor nodes collaborate and combine their data to increase the accuracy of sensed data
- Extended functionality:
  - Sensor nodes can not only perform sensing functionality, but also provide forwarding service.

Applications of sensor networks

- Physical security for military operations
- Indoor/Outdoor Environmental monitoring
- Seismic and structural monitoring
- Industrial automation
- Bio-medical applications
- Health and Wellness Monitoring
- Inventory Location Awareness
- Future consumer applications, including smart homes.

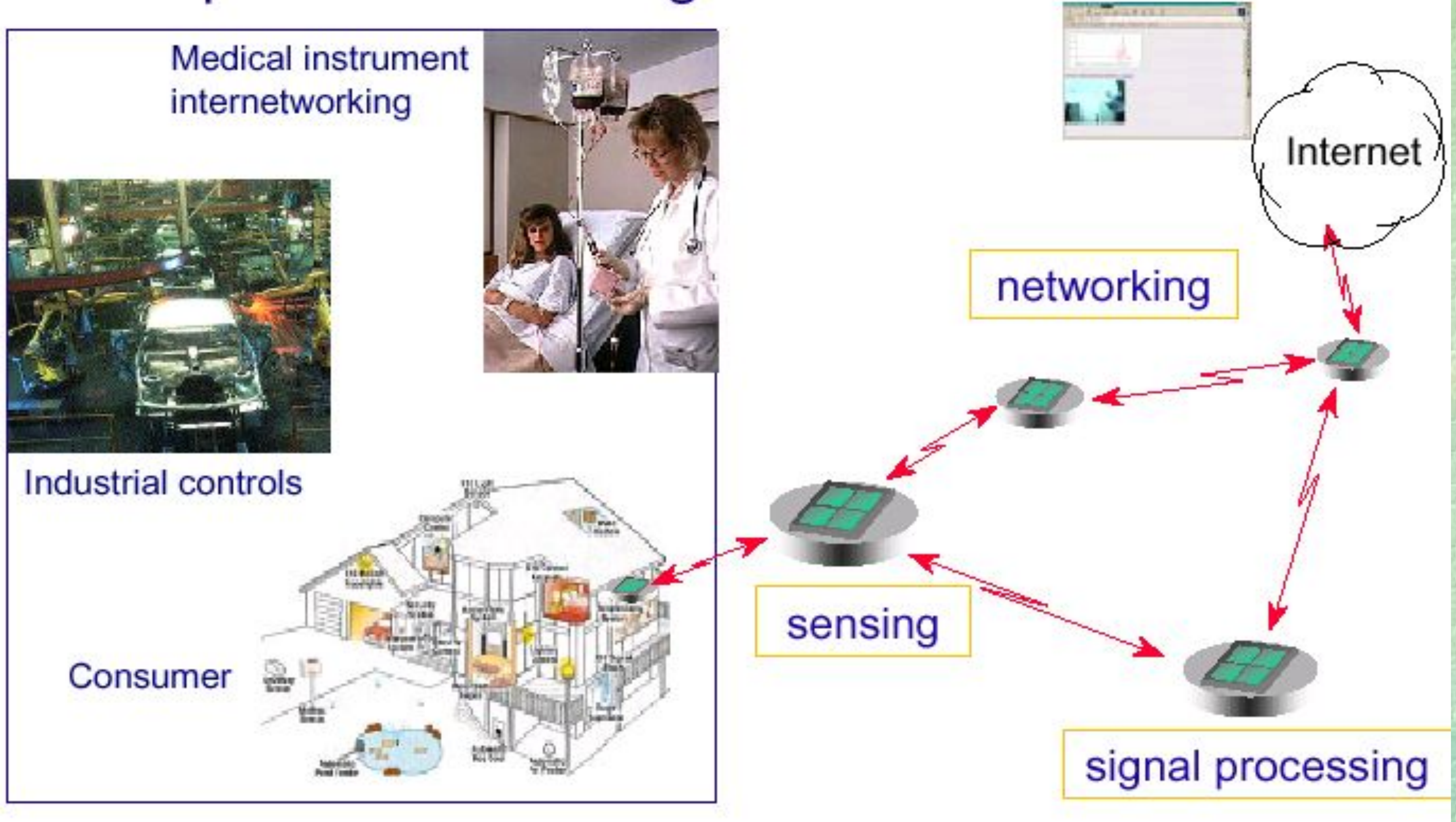
Applications, contd.





Applications, contd.

- Low-power Networking



Characteristics and challenges

- Deeply distributed architecture: localized coordination to reach entire system goals, no infrastructure with no central control support
- Autonomous operation: self-organization, self-configuration, adaptation, exception-free
  - TCP/IP is open, widely implemented, supports multiple physical network, relatively efficient and light weight, but requires manual intervention to configure and to use.
- Energy conservation: physical, MAC, link, route, application
- Scalability: scale with node density, number and kinds of networks
- Data centric network: address free route, named data, reinforcement-based adaptation, in-network data aggregation

Challenges, contd.

- Challenges
  - Limited battery power
  - Limited storage and computation
  - Lower bandwidth and high error rates
  - Scalability to 1000s of nodes
- Network Protocol Design Goals
  - Operate in self-configured mode (no infrastructure network support)
  - Limit memory footprint of protocols
  - Limit computation needs of protocols -> simple, yet efficient protocols
  - Conserve battery power in all ways possible

WSN vs. MANET

- Wireless sensor networks may be considered a subset of Mobile Ad-hoc NETworks (MANET).
- WSN nodes have less power, computation and communication compared to MANET nodes.
- MANETs have high degree of mobility, while sensor networks are mostly stationary.
  - Freq. node failures in WSN -> topology changes
- Routing protocols tend to be complex in MANET, but need to be simple in sensor networks.
- Low-power operation is even more critical in WSN.
- MANET is address centric, WSN is data centric.

Why not port Ad Hoc Protocols?

- Ad Hoc networks require significant amount of routing data storage and computation
  - Sensor nodes are limited in memory and CPU
- Topology changes due to node mobility are infrequent as in most applications sensor nodes are stationary
  - Topology changes when nodes die in the network due to energy dissipation
- Scalability with several hundred to a few thousand nodes not well established
- GOAL: Simple, scalable, energy-efficient protocols

Focus: Radio Transceiver Usage

- The wireless radio transceiver is typically in three modes:
  - Transmit – Maximum power consumption
  - Receive
  - Idle
  - Turned off – Least power consumption
- Sensor node exists in three modes: Active, standby, and battery dead
- Turnaround time: Time to change from one mode to another (esp. important is time from sleep to wakeup and vice-versa)
- Protocol design attempts to place node in these different modes depending upon several factors
- Sample power consumption from 2 sensor nodes shown next

Rockwell Node (SA-1100 proc)

MCU Mode	Sensor Mode	Radio Mode	Power(mW)
Active	On	Tx(36.3mW)	1080.5
		Tx(13.8mW)	942.6
		Tx(0.30mW)	773.9
Active	On	Rx	751.6
Active	On	Idle	727.5
Active	On	Sleep	416.3
Active	On	Removed	383.3
Active	Removed	Removed	360.0
Sleep	On	Removed	64.0

UCLA Medusa node (ATMEL CPU)

MCU Mode	Sensor	Radio(mW)	Data rate	Power(mW)
Active	On	Tx(0.74,OOK)	2.4Kbps	24.58
		Tx(0.74,OOK)	19.2Kbps	25.37
		Tx(0.10,OOK)	2.4Kbps	19.24
		Tx(0.74,OOK)	19.2Kbps	20.05
		Tx(0.74,ASK)	19.2Kbps	27.46
		Tx(0.10,ASK)	2.4Kbps	21.26
Active	On	Rx	-	22.20
Active	On	Idle	-	22.06
Active	On	Off	-	9.72
Idle	On	Off	-	5.92
Sleep	Off	Off	-	0.02

Energy conservation

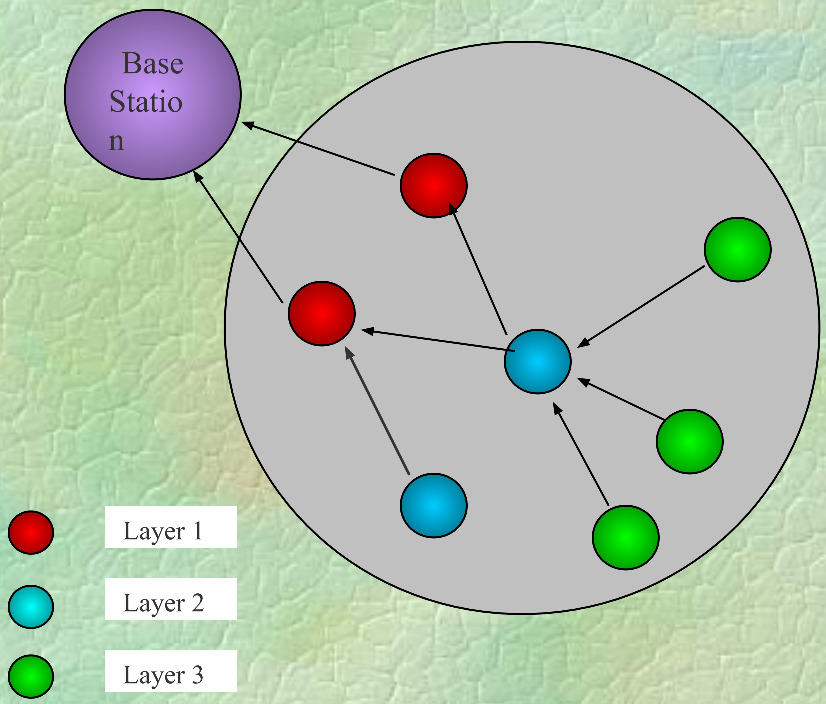
Physical layer	• Low power circuit(CMOS, ASIC) design • Optimum hardware/software function division • Energy effective waveform/code design • Adaptive RF power control
MAC sub-layer	• Energy effective MAC protocol • Collision free, reduce retransmission and transceiver on-times • Intermittent, synchronized operation • Rendezvous protocols
Link layer	• FEC versus ARQ schemes; Link packet length adapt.
Network layer	• Multi-hop route determination • Energy aware route algorithm • Route cache, directed diffusion
Application layer	• Video applications: compression and frame-dropping • In-network data aggregation and fusion

See Jones, Sivalingam, Agrawal, and Chen survey article in ACM WINET, July 2001;
See Lindsey, Sivalingam, and Raghavendra book chapter in Wiley Handbook of Mobile Computing,
Ivan Stojmenovic, Editor, 2002.

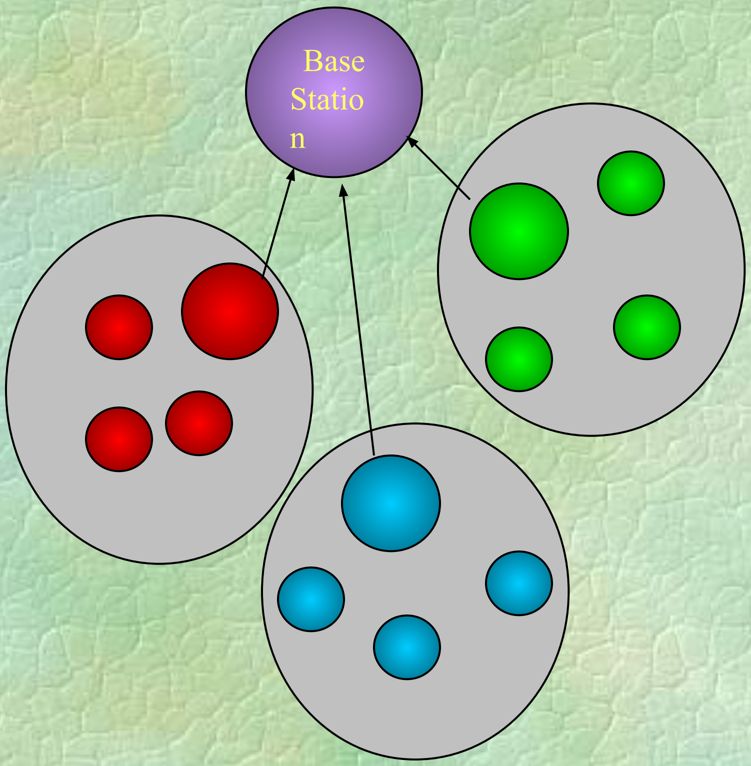
Network Architectures

Network Architectures

Layered Architecture



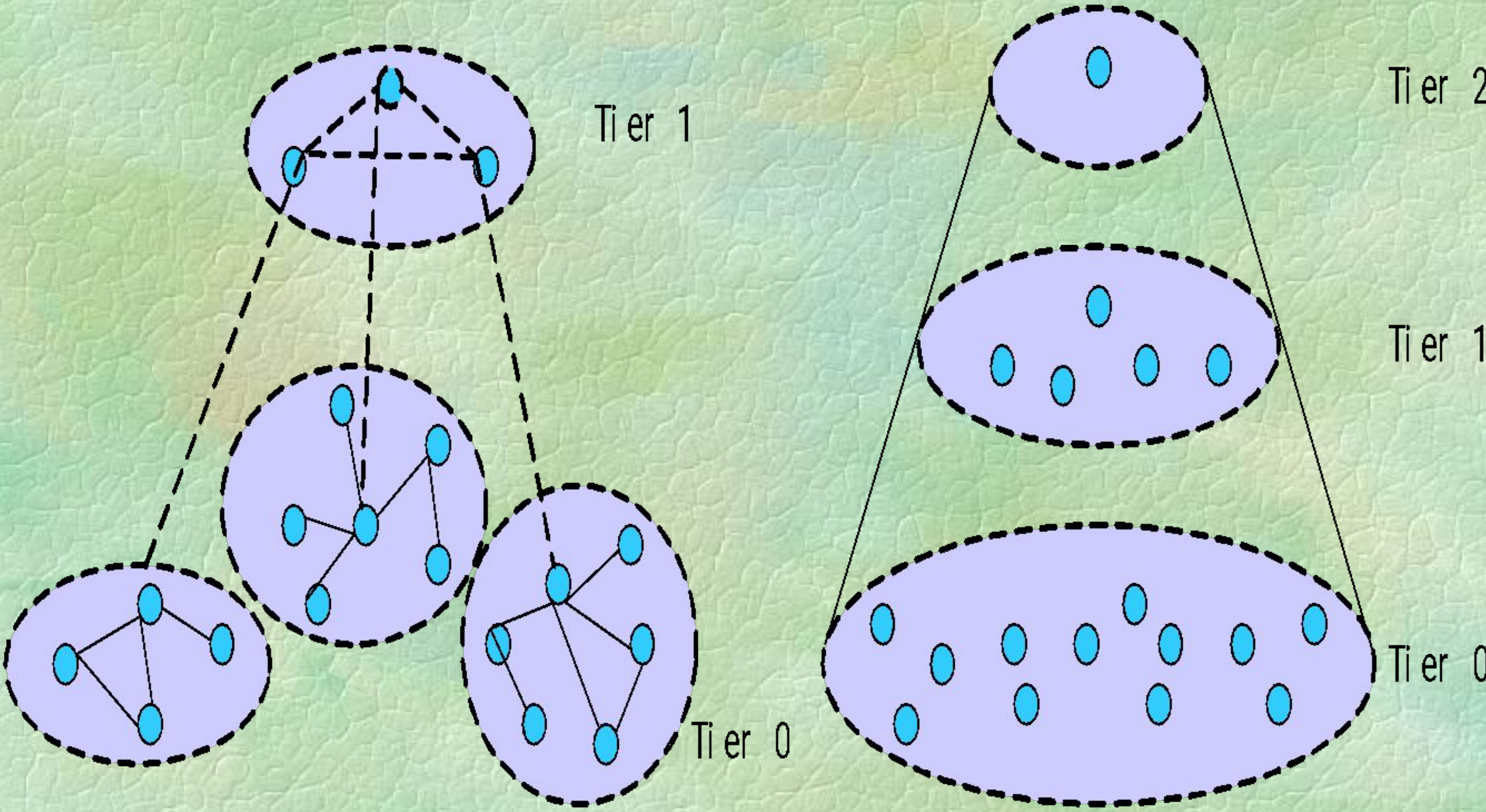
Clustered Architecture



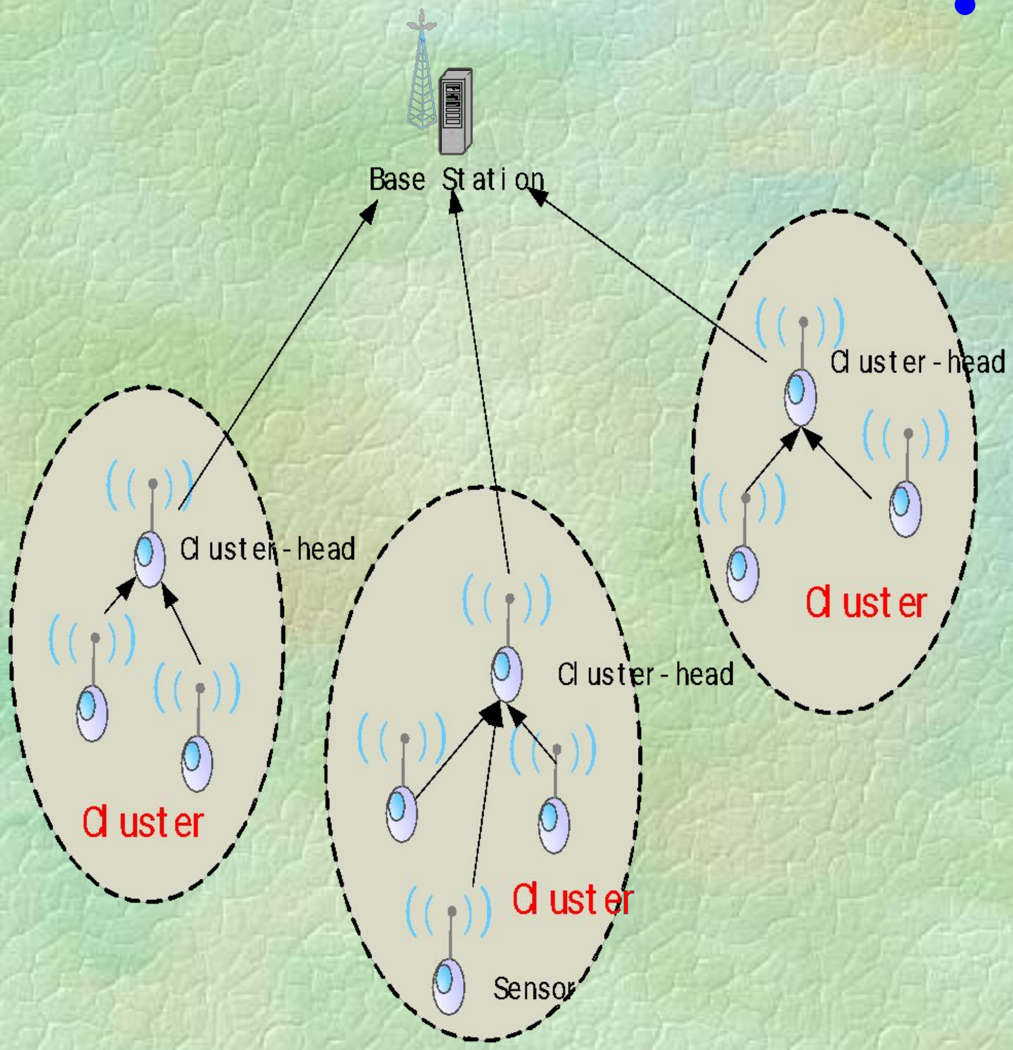
Larger Nodes denote Cluster Heads

Clustered network architecture

- Sensor nodes autonomously form a group called clusters.
- The clustering process is applied recursively to form a hierarchy of clusters.

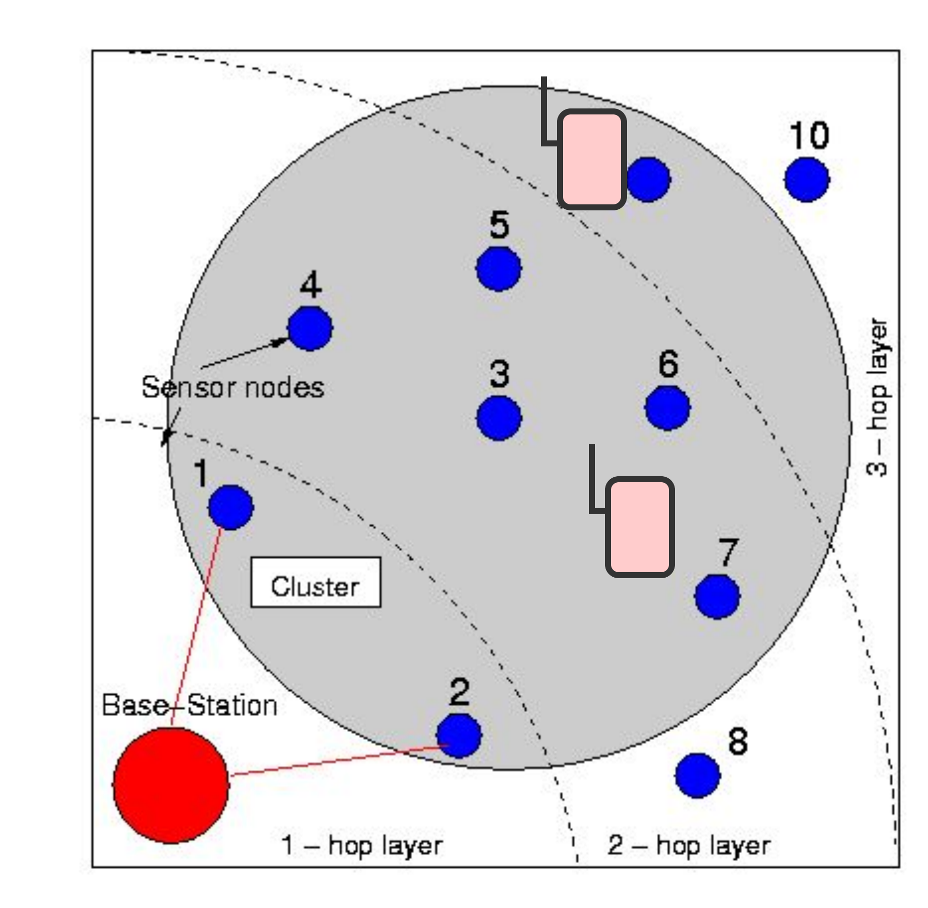


Cluster architecture (contd.)



- Example - LEACH protocol
  - It uses two-tier hierarchy clustering architecture.
  - It uses distributed algorithm to organize the sensor nodes into clusters.
  - The cluster-head nodes create TDMA schedules.
  - Nodes transmit data during their assigned slots.
  - The energy efficiency of the LEACH is mainly due to data fusion.

Layered Network Architecture



A 10 node sensor network depicting cluster of node 3; there are 2 mobile nodes

- A few hundred sensor nodes (half/full duplex)
- A single powerful base-station
- Network nodes are organized into concentric ***Layers***
- ***Layer:*** Set of nodes that have the same hop-count to the base-station
- Additional Mobile Nodes traversing the network
- Wireless Multi-Hop Infrastructure Network Architecture (MINA)

MINA, contd.

- Set of wireless sensor nodes create an infrastructure – provide sensing and data forwarding functionality
- Mobile soldiers with hand-held units access the sensors for data and also to communicate with a remote BS
- BS is data gathering, processing entity and communication link to larger network
- Shorter-range, low-power transmissions preferred for covert operations and to conserve power