# Networked Embedded Applications

**Manoj Kakade**

BITS Pilani

Pilani | Dubai | Goa | Hyderabad

# CS2 : (Wireless Sensor Network)

| | | |
|---|---|---|
| 2 | ➢ Introduction to WSN<br>➢ Application Examples – Long Term & Short Term Monitoring<br>➢ WSN Deployment<br>➢ Network Protocol Stack<br>➢ Importance of Cross Layer Protocol Stack | |

# Sensor Network

- A sensor network is an infrastructure comprised of sensing (measuring), computing, and communication elements that gives an administrator the ability to instrument, observe, and react to events and phenomena in a specified environment.
- The administrator typically is a civil, governmental, commercial, or industrial entity.
- The environment can be the physical world, a biological system, or an information technology (IT) framework.

Four basic components in a sensor network are:

- an assembly of distributed or localized sensors
- an interconnecting network (usually, but not always, wireless-based)
- a central point of information clustering
- a set of computing resources at the central point (or beyond) to handle data correlation, event trending, status querying, and data mining.

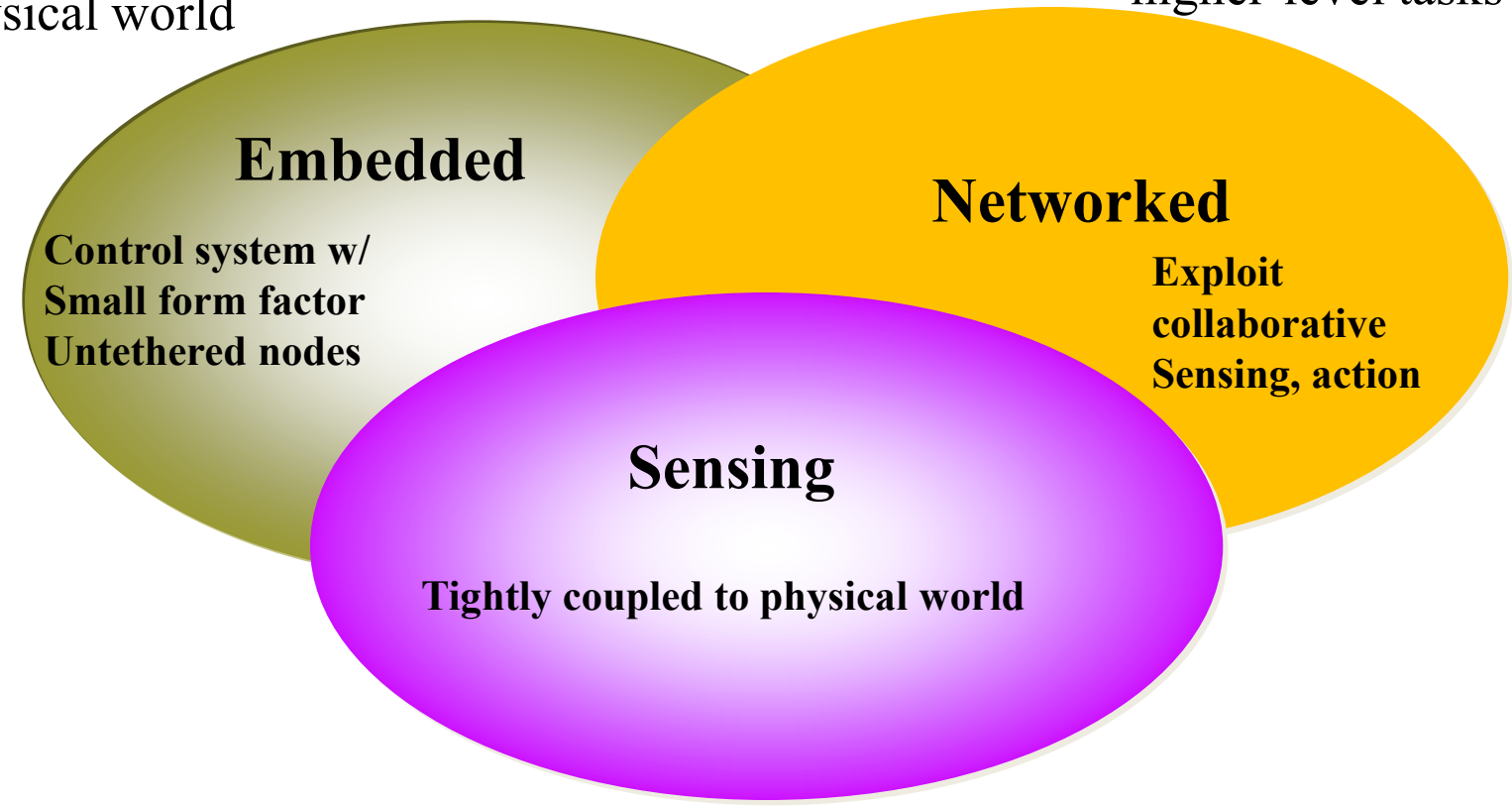
# Wireless Sensor Network

- A collection of devices equipped with a processor, having sensing and communication capabilities and being able to organize themselves into a network created in a ad-hoc manner falls into 'Wireless Sensor Network' category.
- **Sensor Node:**
  - 'Sensor node' or 'mote' is used to describe a tiny device that has a short-range wireless communication capability, a small processor and several sensors attached to it.
  - It may be powered by batteries.
- A wireless sensor network is a network made up of large numbers of **sensor nodes**.
- A WSN is a self-organizing multi-hop ad-hoc networks.

# WSN

Embed numerous distributed devices to monitor and interact with physical world

Network devices to coordinate and perform higher-level tasks

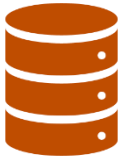



Exploit spatially /temporally dense, in-situ/remote, sensing/actuation

# The Macroscope

- For the first time, sensor networks allow us to:
  - Observe the world at very high spatial resolutions
  - Make these observations continuously
  - Collect the observations in digital form

- This concept as - “ macroscope ” -- a scientific instrument that observes entire systems



# Applications

- Monitoring Space
- Monitoring Objects
- Monitoring Interactions of Objects & Space

# Monitoring Space

- Environmental and Habitat Monitoring
- Precision Agriculture
- Indoor Climate Control
- Military Surveillance
- Intelligent Alarms

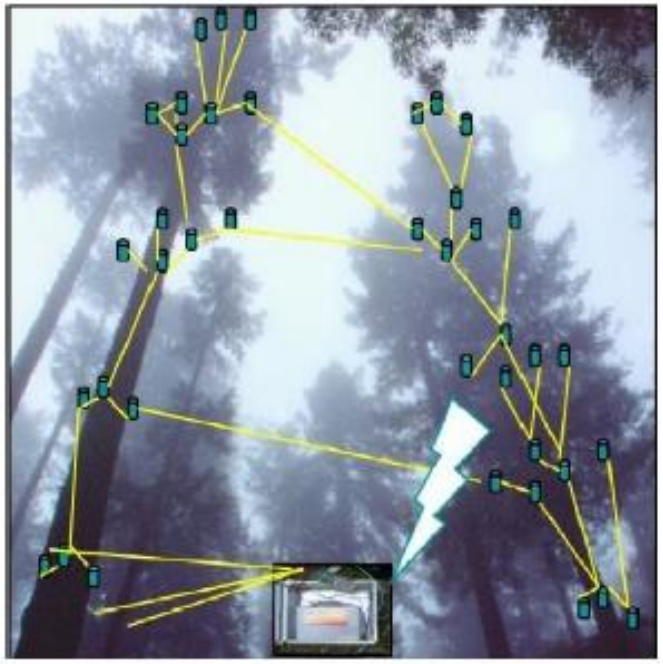
# Monitoring Objects

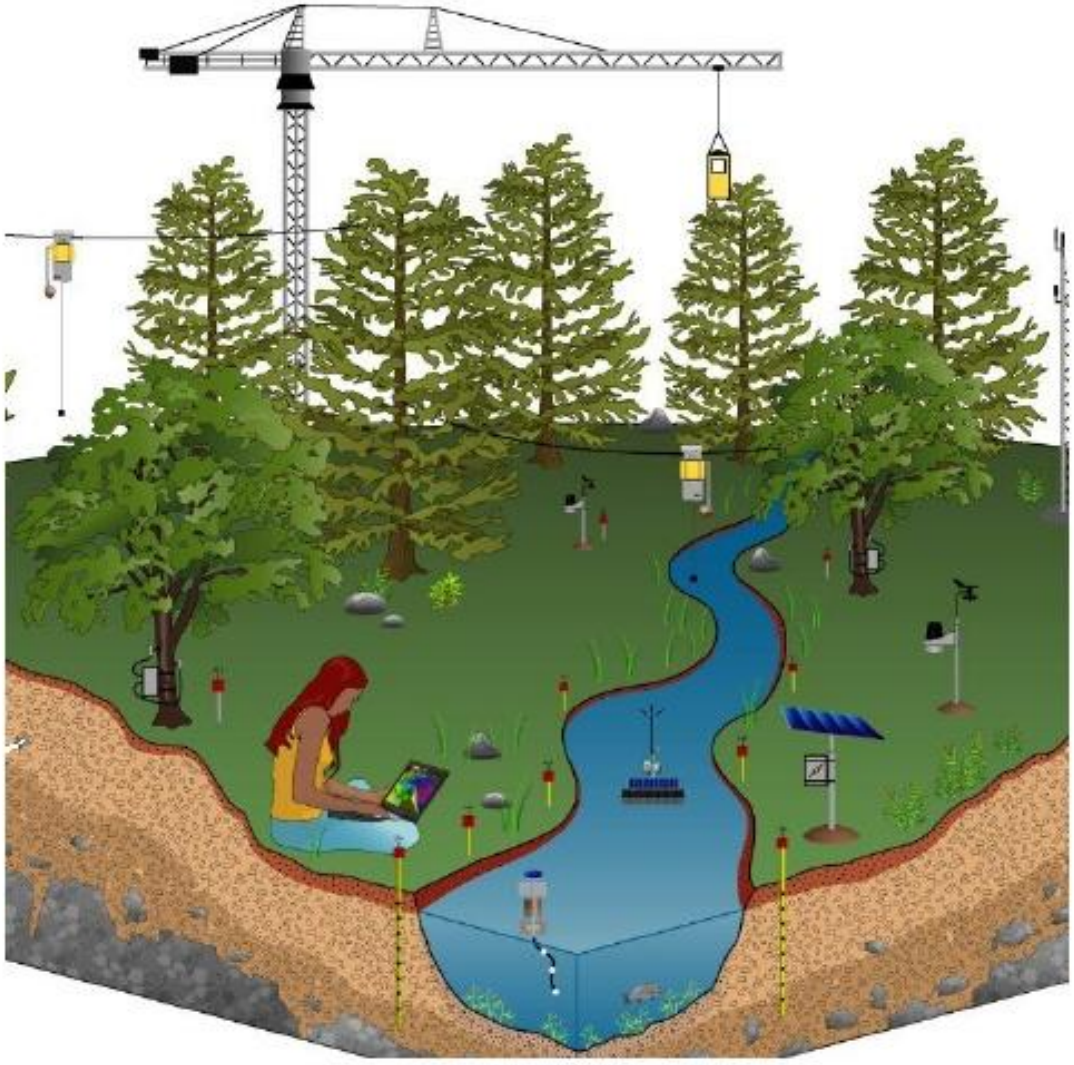
- Structural Monitoring
- Condition-based Maintenance
- Medical Diagnostics
- Urban terrain mapping

# Monitoring interactions between Space & Objects

- Wildlife Habitats
- Disaster Management
- Emergency Response
- Asset Tracking
- Health Care
- Manufacturing Process Flows

# Environmental Monitoring





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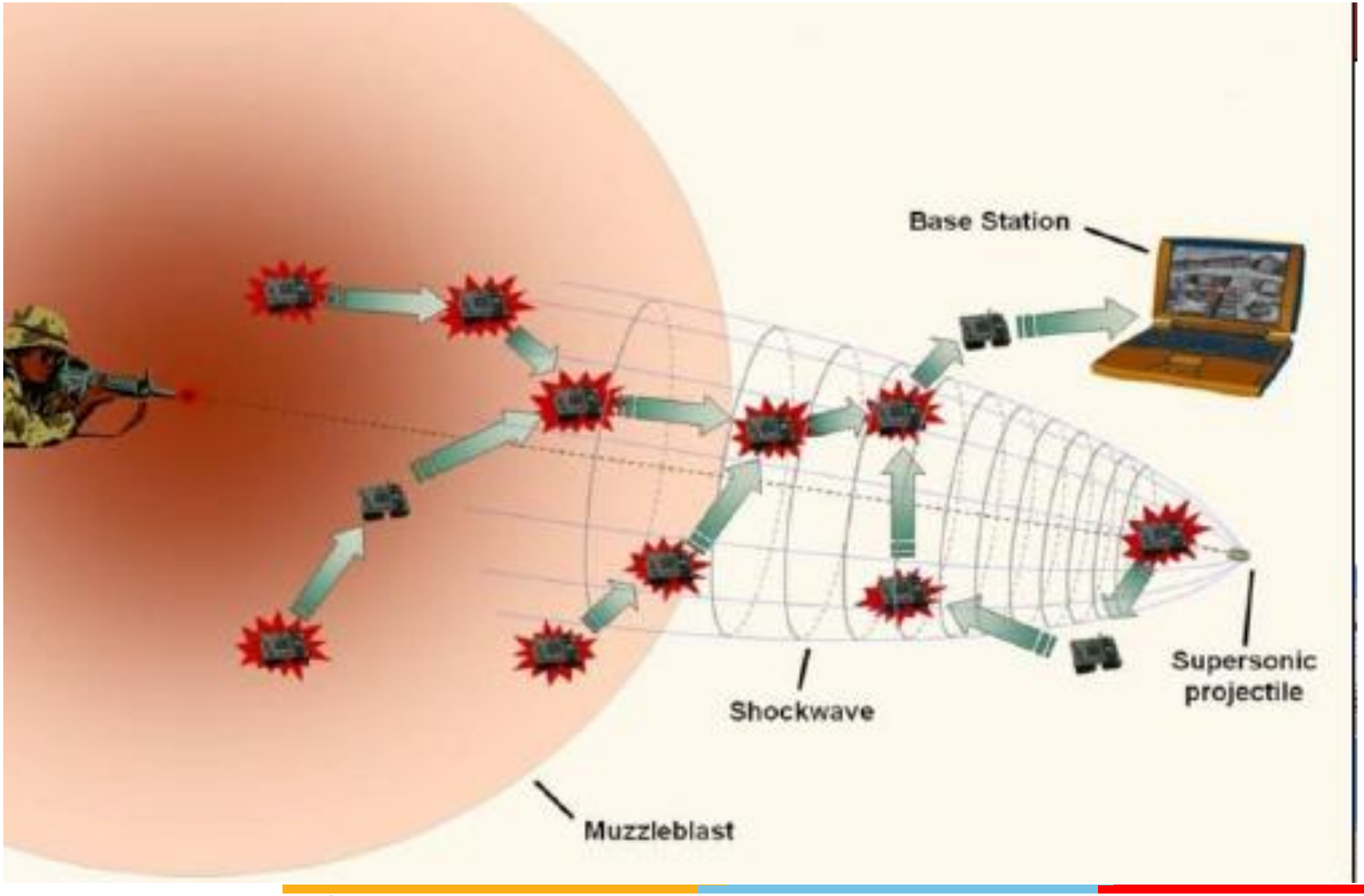
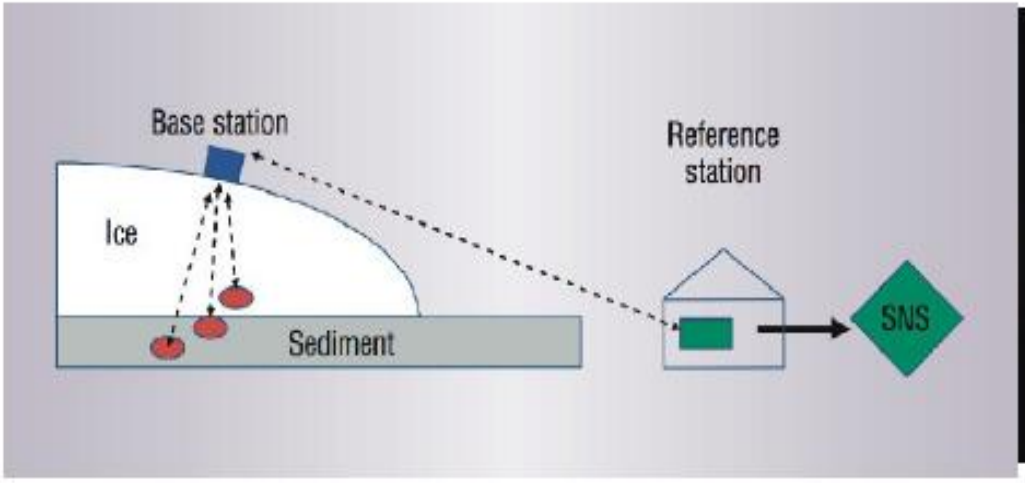
# Gunshot detection



# Volcanic Eruption Monitoring

## Application Examples

# Glacier Monitoring

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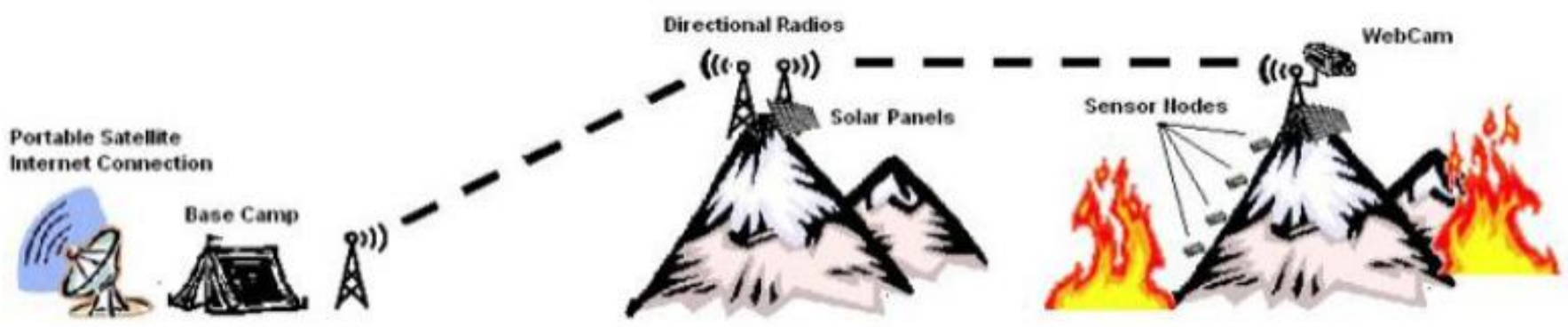
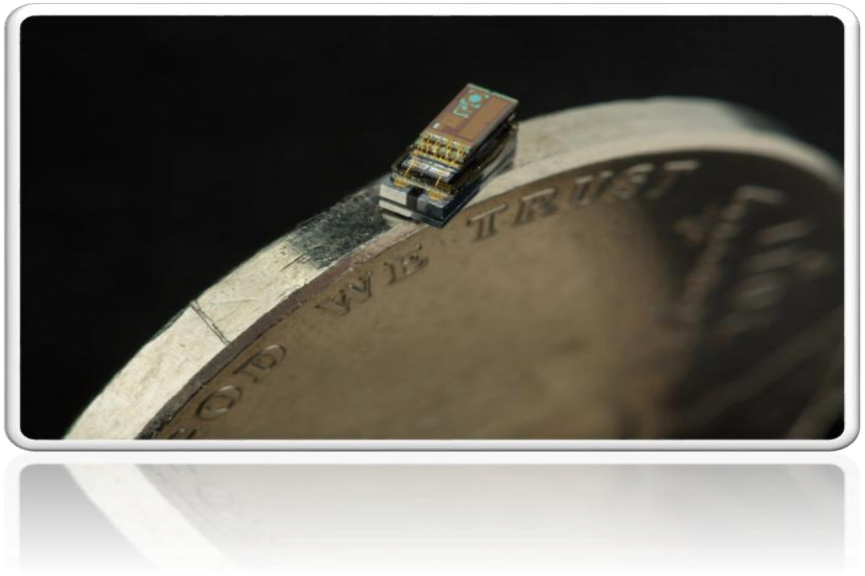
# Forest Fire Monitoring

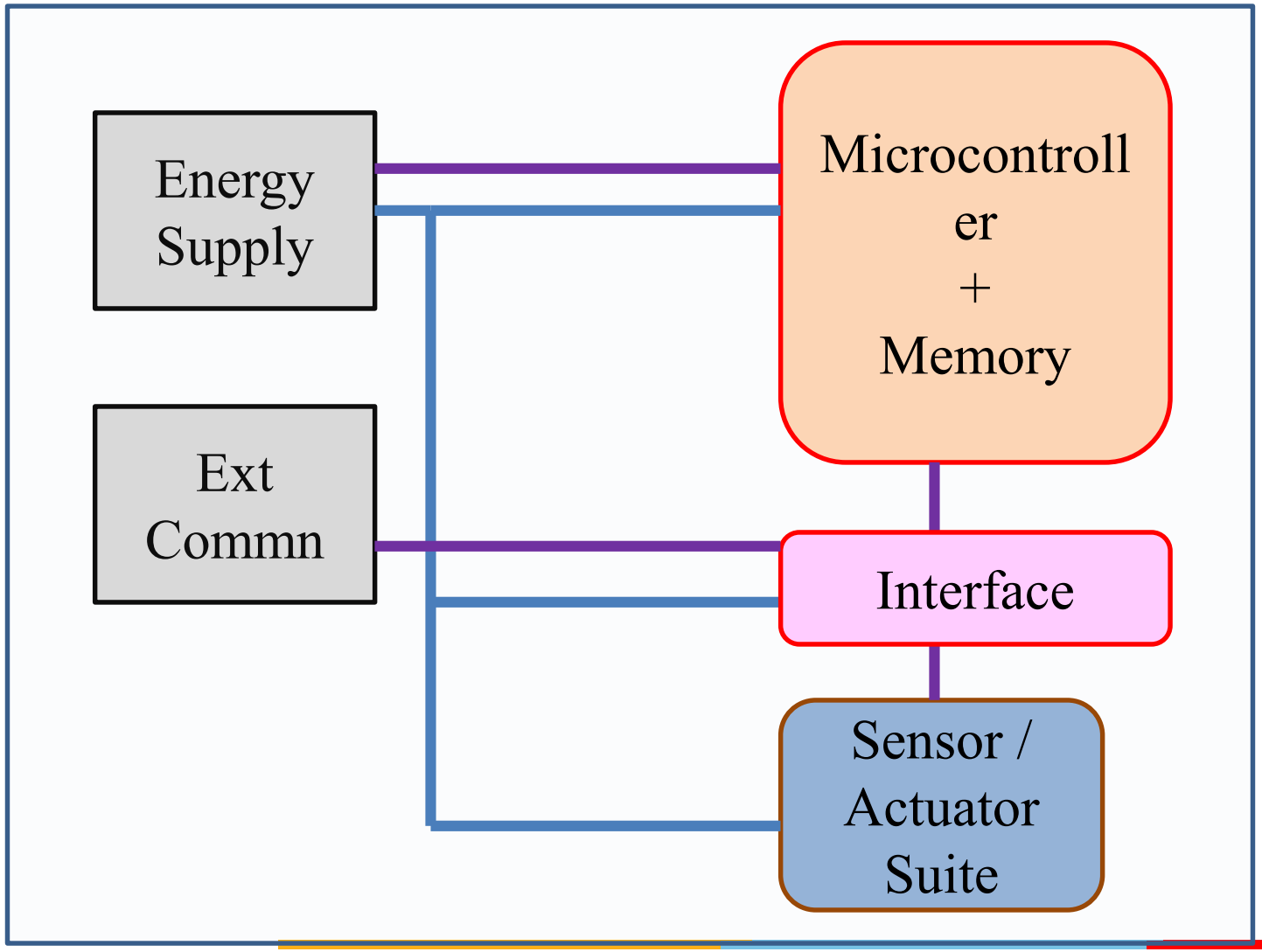



# WSN – Building Blocks

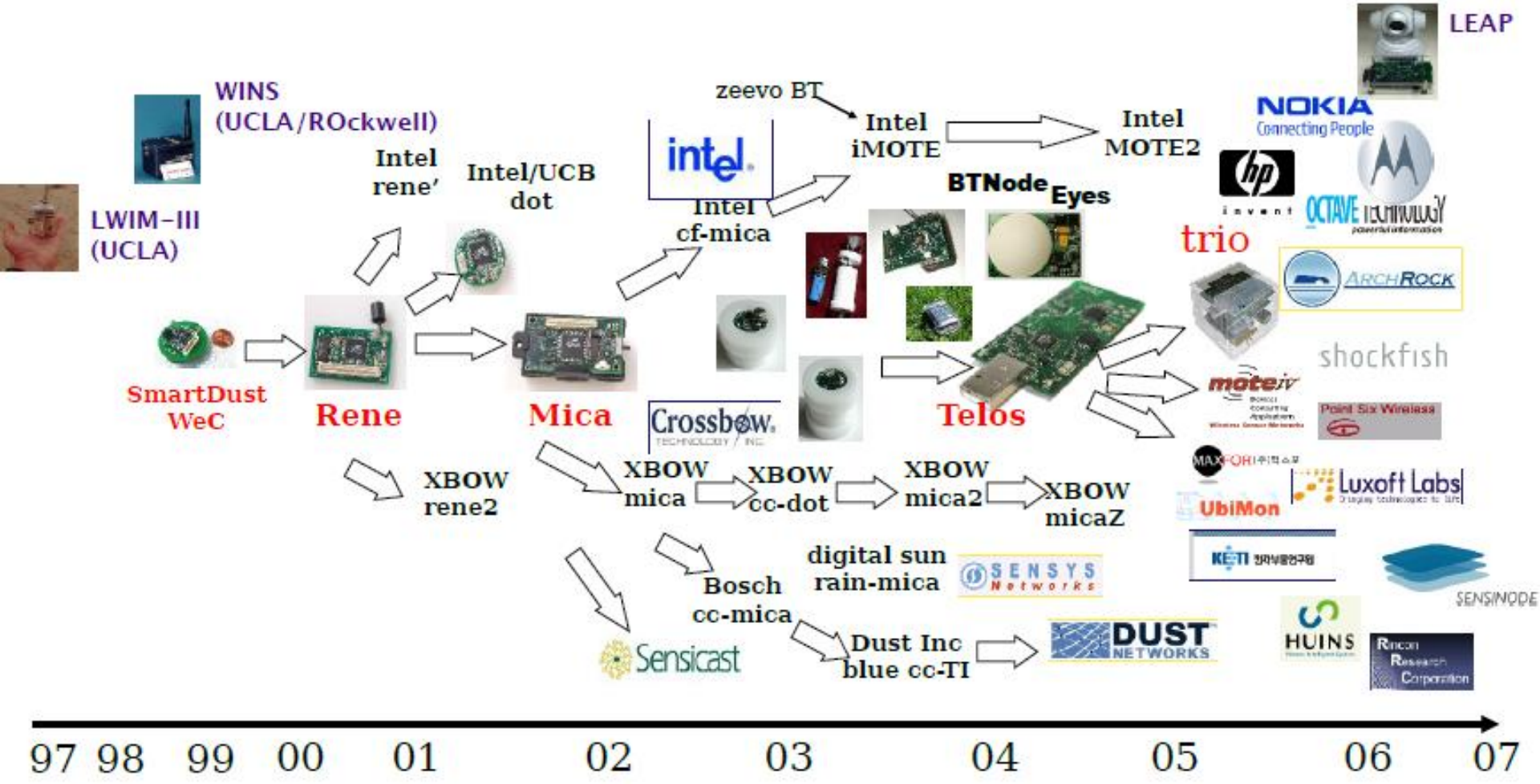


- Motes
- Simplest Intelligent Device
- Small Form Factor
- Michigan Micro Mote –($M^3$) – 2 x 4 x 4 $mm^3$

# WSN – Motes


Energy Supply
Ext Commn
Microcontroller + Memory
Interface
Sensor / Actuator Suite

# WSN – Motes


LEAP
WINS
(UCLA/ROckwell)
zeevo BT
Intel
iMOTE
Intel
MOTE2
NOKIA
Connecting People
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Intel/UCB
dot
intel
BTNode
Eyes
LWIM-III
(UCLA)
Intel
cf-mica
trio
ARCHROCK
shockfish
SmartDust
WeC
Rene
Mica
Crossbow
Telos
XBOW
rene2
XBOW
mica
XBOW
cc-dot
XBOW
mica2
XBOW
micaZ
UbiMon
Luxoft Labs
digital sun
rain-mica
SENSYS
Networks
Bosch
cc-mica
SENSINODE
Sensicast
Dust Inc
blue cc-TI
DUST
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HUINS
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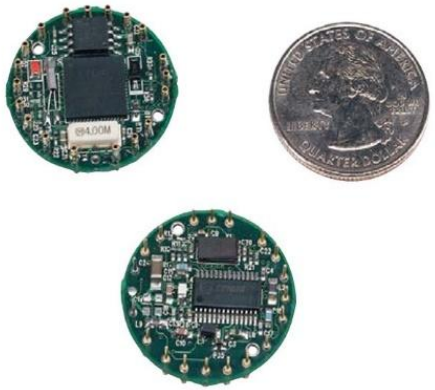
# Sensor Node - Mica

**Mote** : something, especially a bit of dust, that is so small it is almost impossible to see

## **Motes** (Mica2, Mica2dot, MicaZ)

- Developed initially at UC Berkely
- ATMega128L microcontroller
  128KB program flash; 512KB measurement Flash; 4KB EEPROM
- MicaZ uses Zigbee IEEE 802.15.4 Standard
- AA battery
- TinyOS O/S
- Convenient form factor for adding sensors

mica2



mica2dot

micaz

## WSN : Classification based on Complexity

- Intelligent “Warehouses”
- Environmental Monitoring
- Very Large Scale Sensor Network Applications

# Requirements

- **Long Life**
  - Sensor nodes should be able to live as long as possible using its own batteries.
  - So power management is a key design challenge
- **Small Size**
  - Sensor node size should be very small
  - Recently processor and radio were integrated in a chip of size approximately 1 $mm^3$
- **Low Cost**
  - Since large number of sensor nodes are required, their cost should be low.

- Disadvantages like Limited processing power, low-rate unreliable wireless communication, small memory footprints, and low energy, lead to designing new set of protocols.

# Locally Available Resources

- Limited Energy
- Limited Processing power
- Limited Memory
- Limited Bandwidth

# Diversity & Dynamics

- Motes
- Sensors
- Nodes Deployed Randomly – Mobile
- Motes are subject to energy budget
- Motes may die
- Wireless Communication Media – dynamic

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# Dependability

- Harsh Environments
- Wireless Commn Media
- Security

# Wireless Sensor Network – Deployment

- Deployments : Physical distribution of the nodes

- **Deployment Objectives**
  - Coverage
  - Connectivity
  - Topology

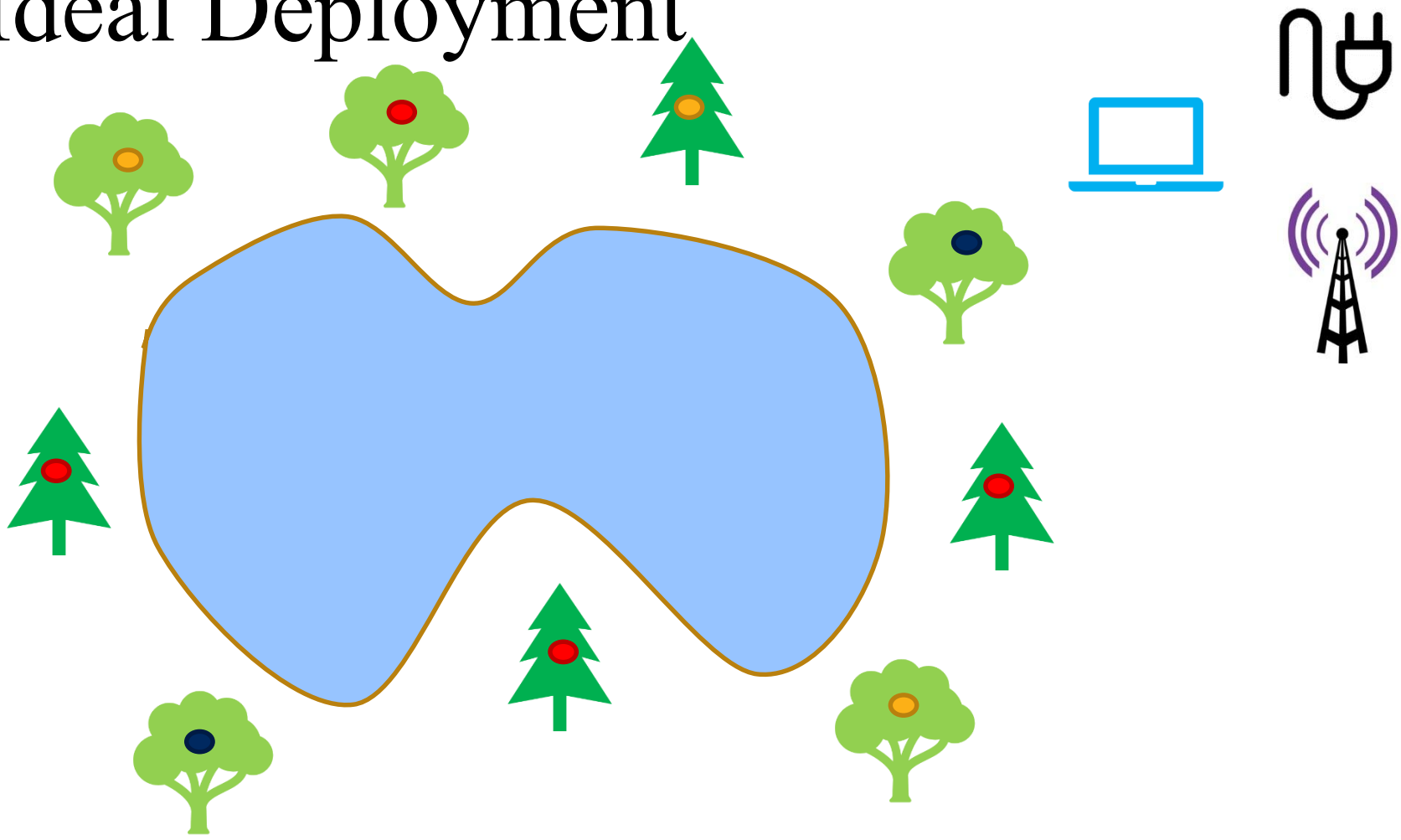
- **Deployment – Issues**
  - Structured Vs Random Deployment
  - Over Deployment Vs Incremental Deployment
  - Network Topology
  - Homogeneous Vs Heterogeneous Deployment

# Wireless Sensor Network – Deployment

- Structured Vs Random Deployment
- The first concerns for deployment are safety, durability, and sturdiness;
- **Random Deployment :**Deploying NES nodes in an arbitrary fashion in the field. Random deployment is useful when the region being monitored is not accessible for precise placement of sensors
- **Structured Deployment :** Placing NES nodes at well-planned points so that the coverage is maximized or to place nodes strategically in a small field of concentration such that these nodes are not easily subjected to natural damages
- If no. of available nodes is small wrt size of operational area and required coverage – a delicate balance has to be struck between how nodes for sensing & nodes for connectivity.

# Wireless Sensor Network – Deployment

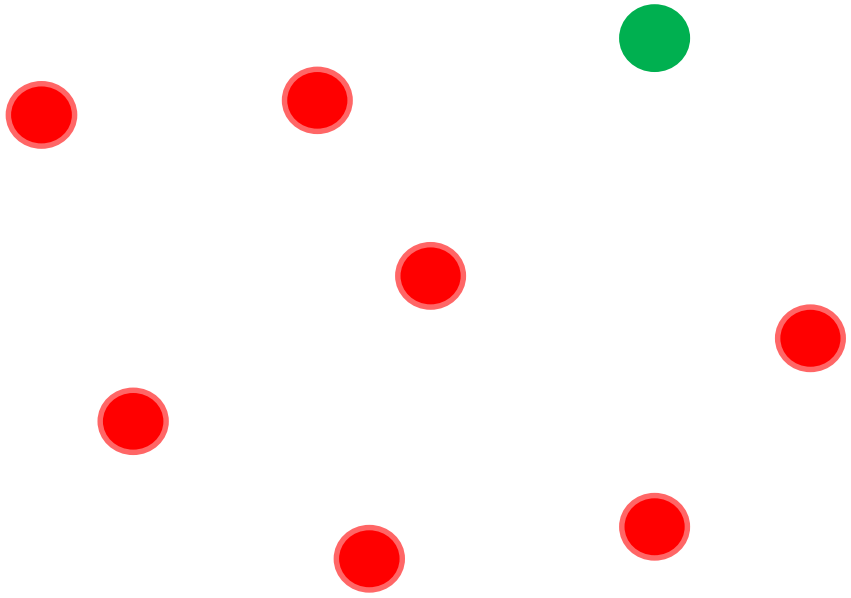
## Ideal Deployment



# Random Deployment

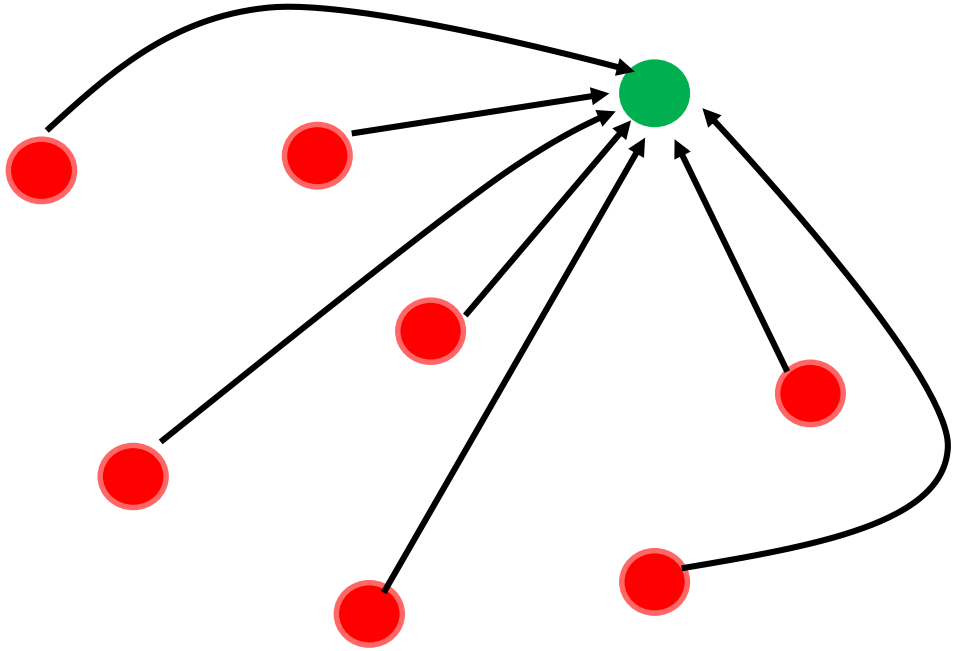
# Wireless Sensor Network – Deployment

## Deployment Patterns



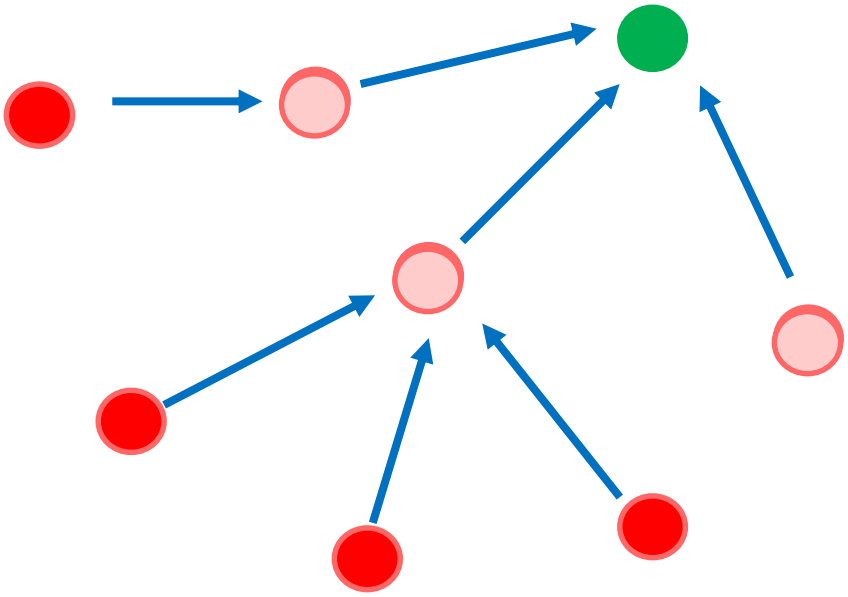
# Wireless Sensor Network – Deployment

## Deployment Patterns - Star

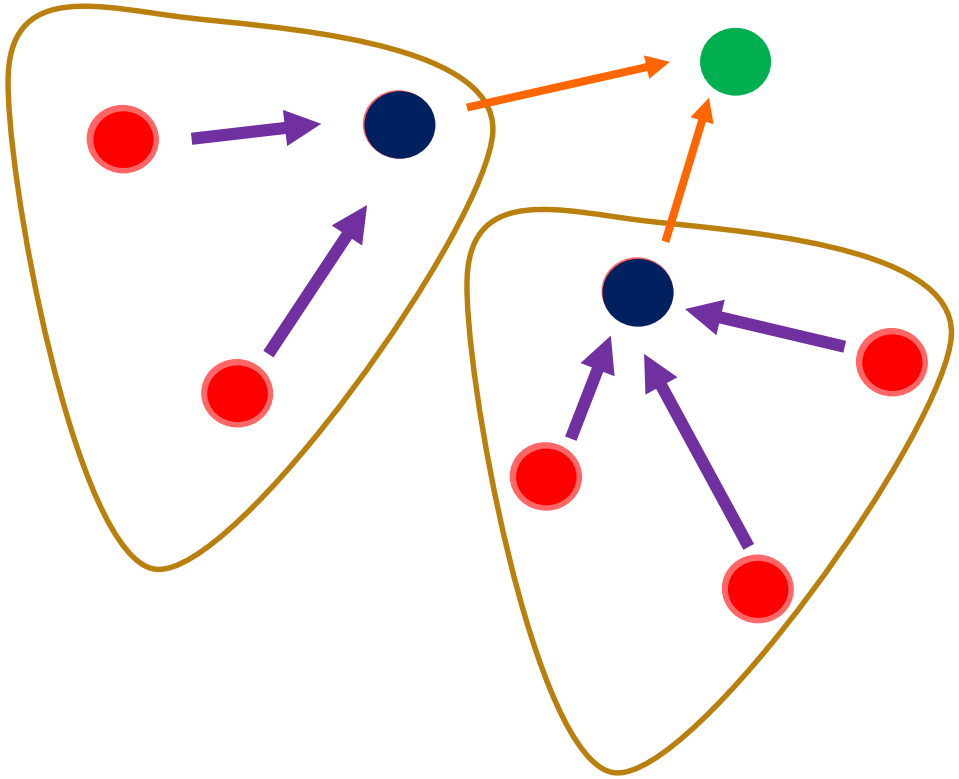


Energy Consumption

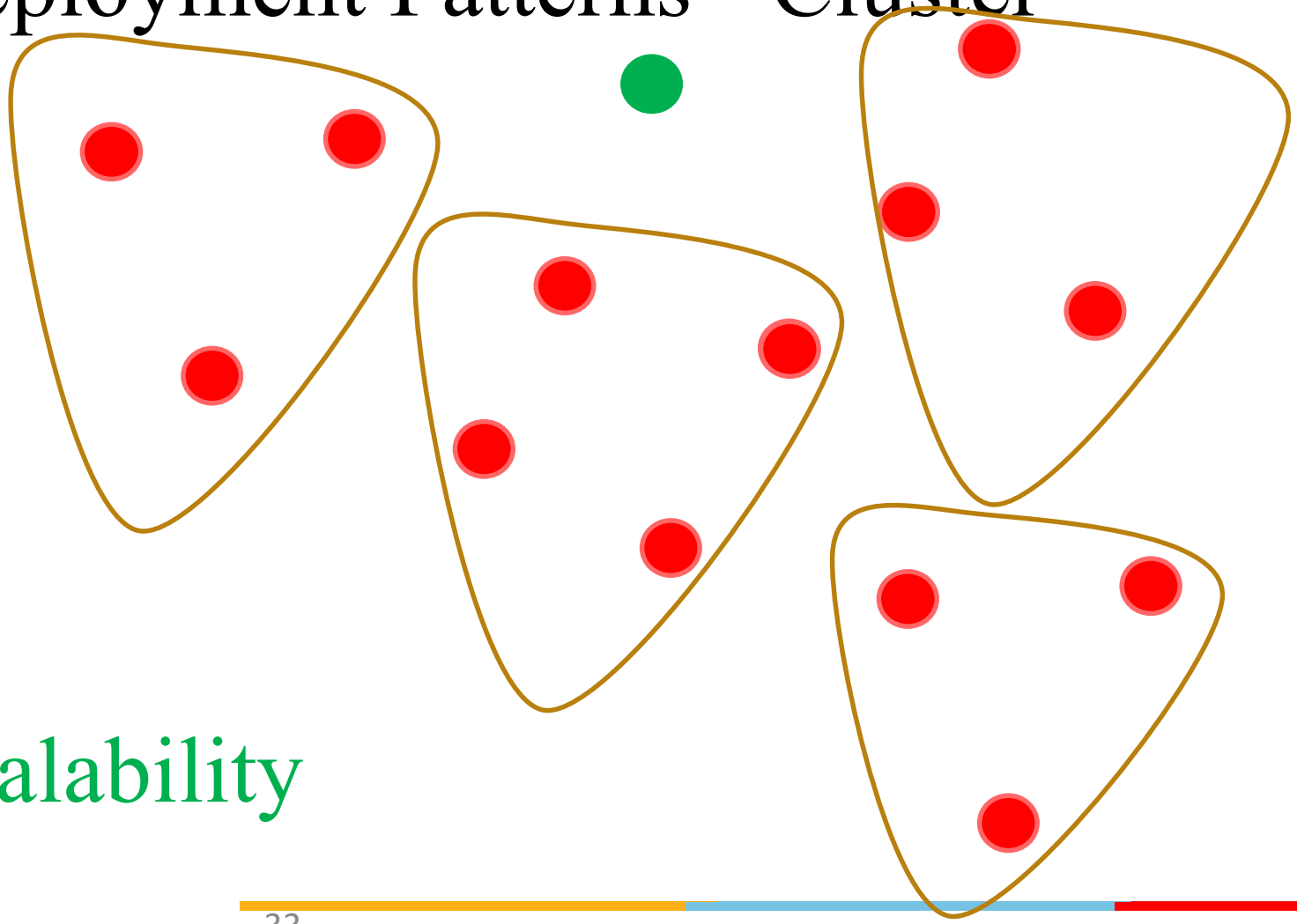
# Deployment Patterns – Multi Hop



# Deployment Patterns - Cluster

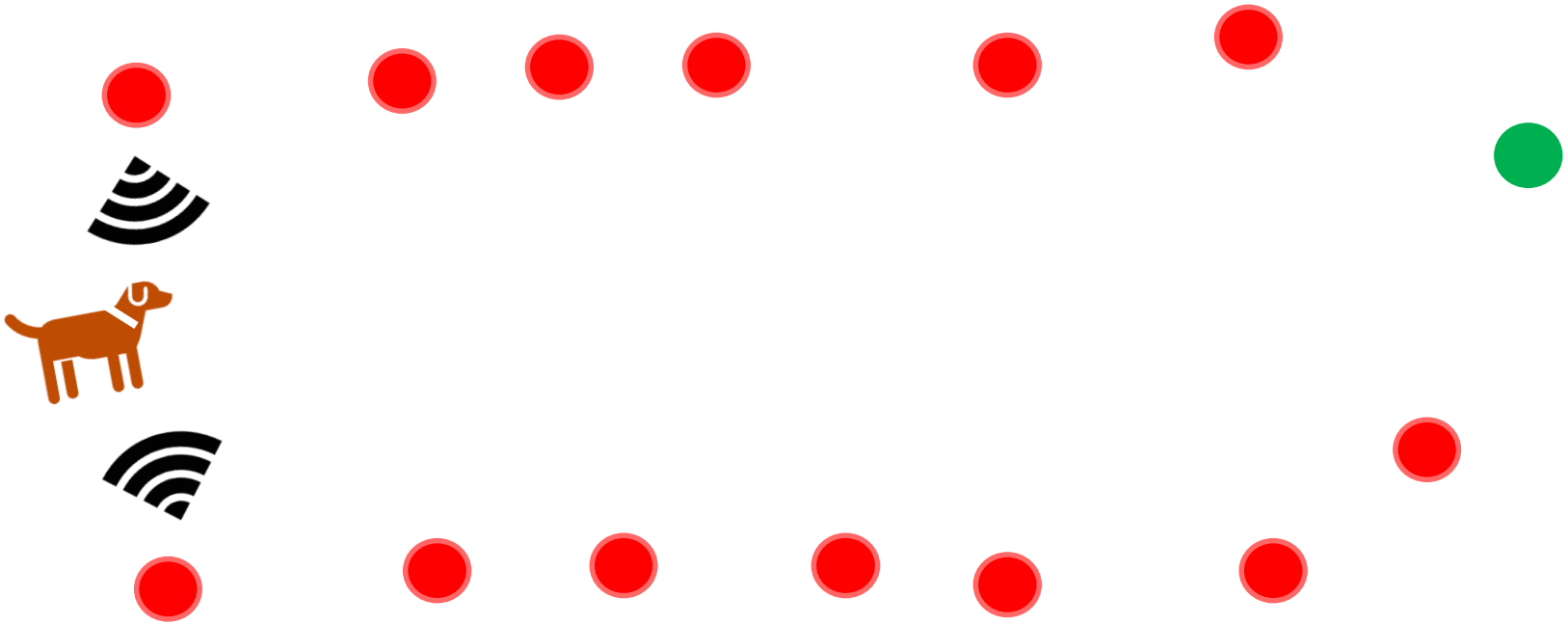


# Deployment Patterns - Cluster



Scalability

# Deployment Patterns – Data Mule



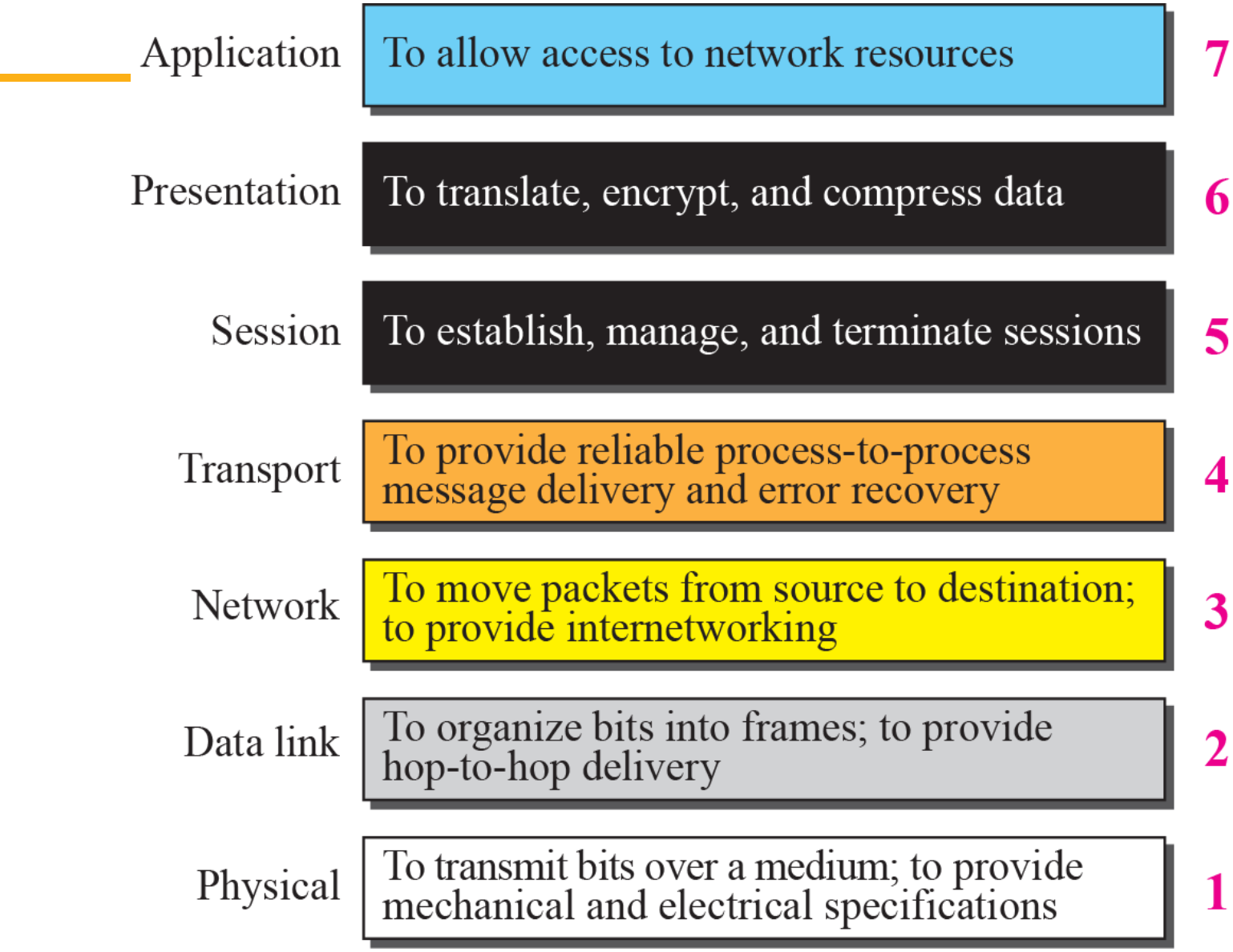
# Network Protocol Stack

- What is Network Protocol Stack ?
- Protocol are the Rules
- Stack is software implementation of the Protocol in layered manner
- Protocol Stack is implementation
- Conceptual Model is called The **Open Systems Interconnection model** (**OSI model**)

# Network Protocol Stack

- The **Open Systems Interconnection model** (**OSI model**) characterizes and standardizes the communication functions of a telecommunication or computing system **without** regard to their underlying internal structure and technology.
- Its goal is the interoperability of diverse communication systems with standard protocols. The model partitions a communication system into seven abstraction layers.

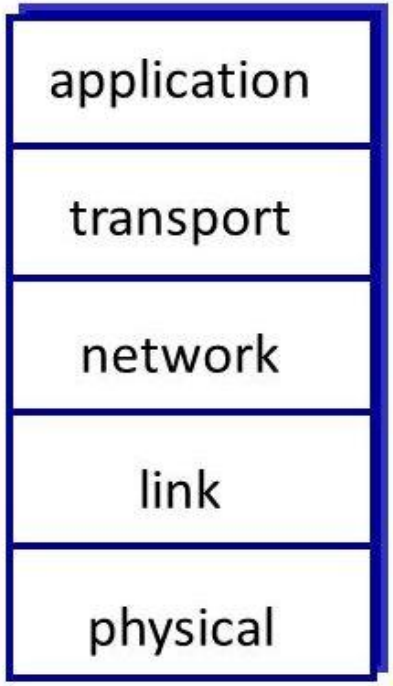
# Network Protocol Stack



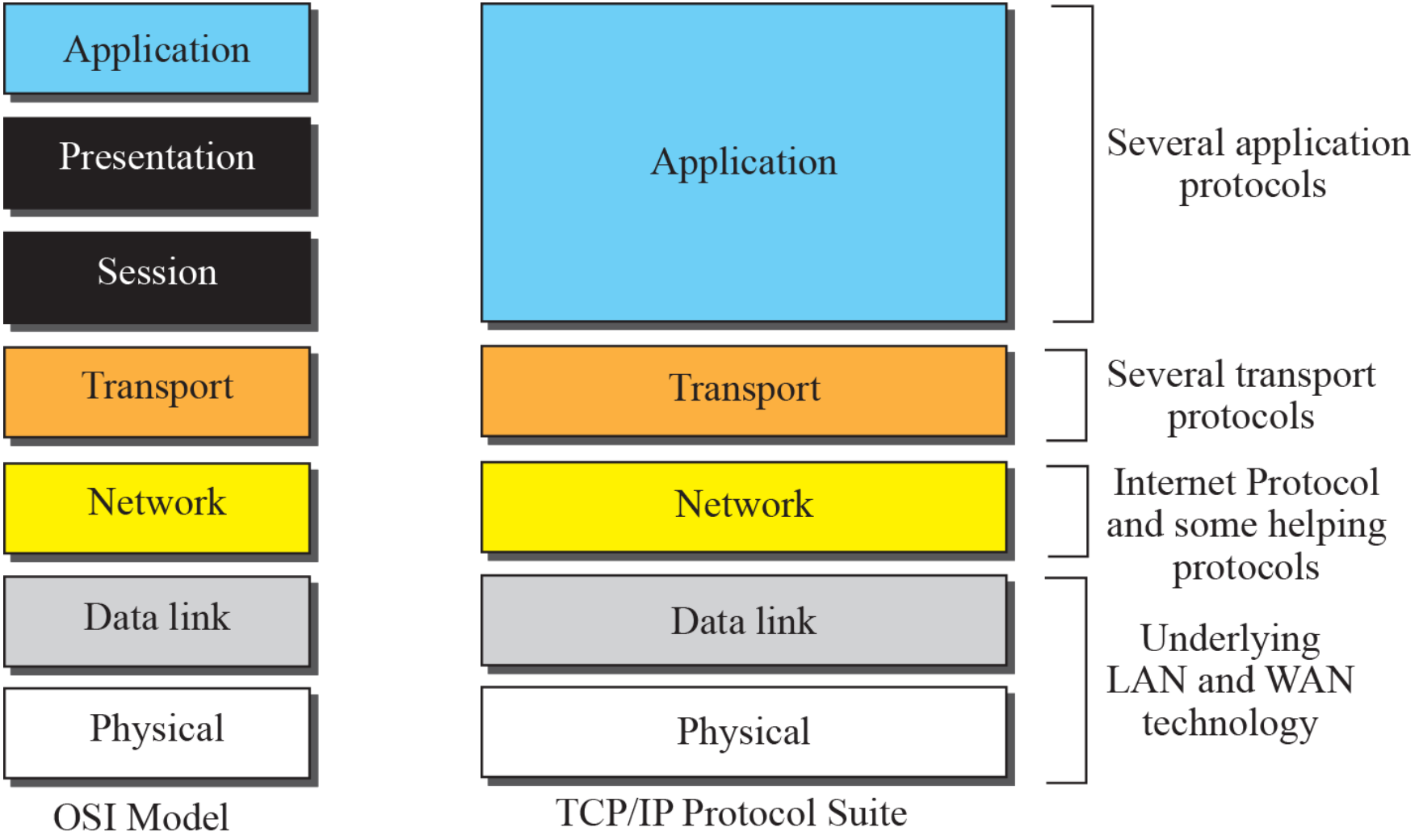
# Network Protocol Stack

## Internet protocol stack

- application: supporting network applications
  - FTP, SMTP, HTTP
- transport: process-process data transfer
  - TCP, UDP
- network: routing of datagrams from source to destination
  - IP, routing protocols
- link: data transfer between neighboring network elements
  - Ethernet, 802.111 (WiFi), PPP
- physical: bits "on the wire"



# TCP/IP and OSI model



# WSN Protocol Stack – Physical Layer

- Responsible for the management of the wireless interface
- Majority assume the use of a radio transceiver
- Unlicensed band is preferred (ISM band – Industrial, Scientific and Medical)

Minimum output power required to transmit a radio signal over a certain distance is directly proportional to the distance raised to the power between two or four

So in order to reduce the energy consumption, it is always beneficial to transmit a signal using multi-hop network

# WSN Protocol Stack – Data-link Layer

- Responsible for managing most of the communication tasks within one-hop
- One of the major task is error control strategies
- For reducing energy consumption, it turns the radio off of sleeping nodes.(radio is the main energy consumer of each sensor node)
- Also creates and maintains the list of neighbouring nodes

# WSN Protocol Stack – Network Layer

- It is responsible for routing the packets in the Sensor Network
- It is one of the most studied area in Sensor Network
- Routing must be done in energy efficient manner.
- Energy efficiency can be achieved by minimizing traffic in the network.
- Solution is data-centric routing.
- Data-centric routing:
  - Each node is assigned a task based on its capability and base station's interest
  - Depending upon the expected amount of traffic and level of events in the sensor network, the base station can broadcast its interest to the sensor nodes, or sensor nodes can advertise their capabilities.
  - So the network layer should be optimized for two operations:
    - Spreading the user queries around the whole network
    - Retrieving the sensed data and sending it to back to the requested node (sink).
  - Individual addressing to sensor node is not important. (why?)
  - Since multiple sensor nodes may collect similar/same data, there is a lot of data redundancy in the network.
  - So optimization is done by eliminating the redundant data and combining the packets.

# WSN Protocol Stack – Transport Layer

- It is responsible for connecting the WSN to the external network (e.g. Internet)
- Protocols needed at this layer require more resources.
- So some designated sensor nodes are made equipped with more resources and they act as the gateways to the external network
- As technology advances and the individual sensor nodes gets equipped with more resources, this layer is likely to get more attention

# WSN Protocol Stack – Application Layer

- It usually links the user applications with the underlying layers
- Usually the protocol stacks for the sensor networks are designed per application basis
- This layer also takes care of activities like sensor management protocol, task management and data advertisement protocol, sensor query and data extraction protocol.

# WSN Protocol Stack

characteristic features which differentiate them from traditional communication networks:

1. The large density of nodes- sensors that are cheap to manufacture and ready to deploy
2. The application diversity, which requires different kinds of application specific sensor devices
3. The tight limitations in energy, processing power and memory, which call for highly optimized and lightweight protocols
4. The collaborative objective for which all the sensor nodes cooperate with one another

# WSN Protocol Stack

| | | |
|---|---|---|
| Unlimited Power | → | Limited Power |
| Wired | → | Wireless |
| Non-RT | → | RT |
| User I/f – Mouse, Screen | → | User I/f – Sensors |
| Fixed Set of Resources | → | Dynamic Set of Resources |
| Location Independent | → | Location Critical |
| Individual Nodes | → | Aggregate Data |

# WSN Protocol Stack

- WSN to have reasonable longevity,
- An aggressive energy-management policy is mandatory-currently the greatest design challenge
- Considering- MICAz mote the energy cost associated with transmitting a byte over the transceiver >>> performing local computation
- Developers must leverage local processing capabilities to minimize battery-draining radio communication.

# WSN Protocol Stack

- Salient Features of Sensor Networks

- Collaborative Objective
- Network Scale
- Many-to-one Communication Paradigm
- Nodes with Limited Capabilities
- Clustering for Scalability

# WSN Protocol Stack

- Several key differences between more traditional ad hoc networks and wireless sensor networks exist
- Sensor networks are prone to frequent topology changes due to several reason
  - hardware failure
  - depleted batteries
  - intermittent radio interference
  - environmental factors
  - addition of sensor node
- applications require a degree of inherent fault tolerance and the ability to reconfigure themselves as the network topology evolves

# WSN Protocol Stack

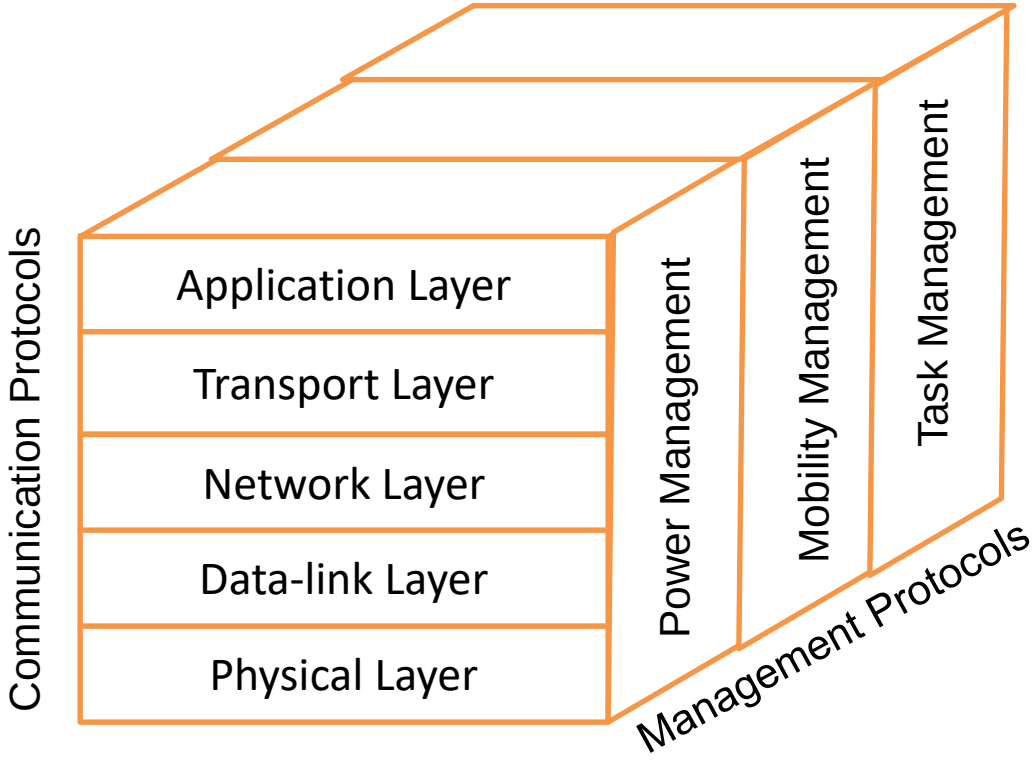
- Even with the limitations individual sensor nodes possess and the design challenges application developers face, several adv exist
- Due to the dense deployment of a greater number of nodes - higher level of fault tolerance is achievable in WSN
- Coverage of a large area is possible through the union of coverage of several small sensors
- Coverage of a particular area and terrain shaped as needed to overcome any potential barriers or holes in the area under observation
- It is possible to incrementally extend coverage of the observed area & density by deploying additional sensor nodes within the region of interest

# WSN Protocol Stack

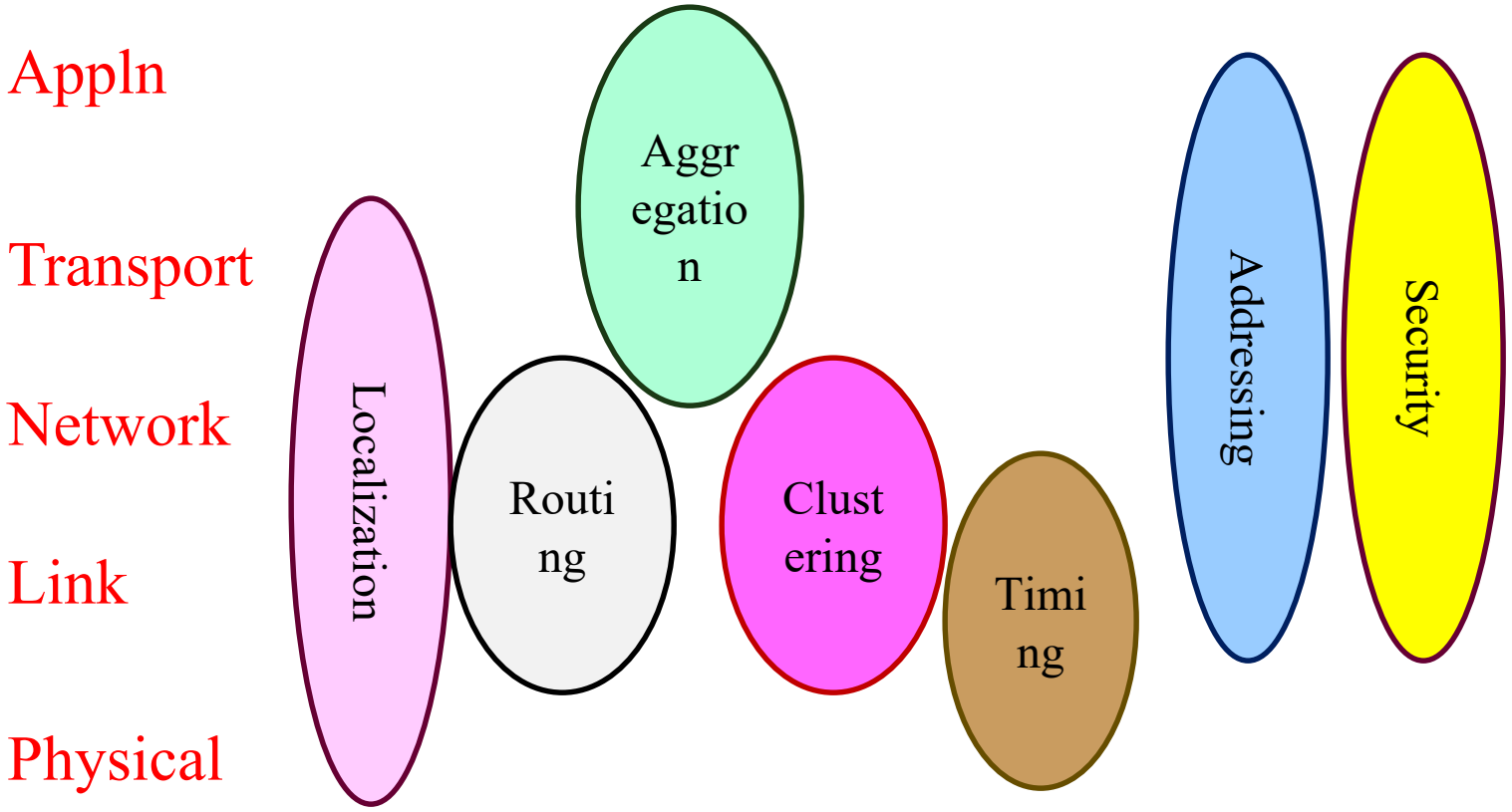
- Even with the limitations individual sensor nodes possess and the design challenges application developers face, several adv exist
- An improvement in sensing quality is achieved by combining multiple, independent sensor readings.
- Local collaboration between nearby sensor nodes achieves a higher level of confidence in observed phenomena.
- Since nodes are deployed in close proximity to the sensed event- this overcomes any ambient environmental factors that might otherwise interfere with observation of the desired phenomenon
- **Each node has two modes in the network**
- **Initializing**
- **Operation**

# Protocol Stack Approach

- Difference between Protocol Stacks of traditional computer network and sensor network: *Blocks need to build sensor network spans across multiple layers*



# Protocol Placement



**Prof. Manoj S Kakade**

Email id: manoj.kakade@pilani.bits-pilani.ac.in

# THANK YOU!!!!!