21ES614 – Internet of Things

Sivraj P, Asst. Professor,
Dept. of EEE, Amrita School of Engineering
Amrita Vishwa Vidyapeetham

Syllabus

Unit 1

Introduction to IoT - Definitions, frameworks and key technologies. Functional blocks of IoT systems: hardware and software elements- devices, communications, services, management, security, and application. Challenges to solve in IoT

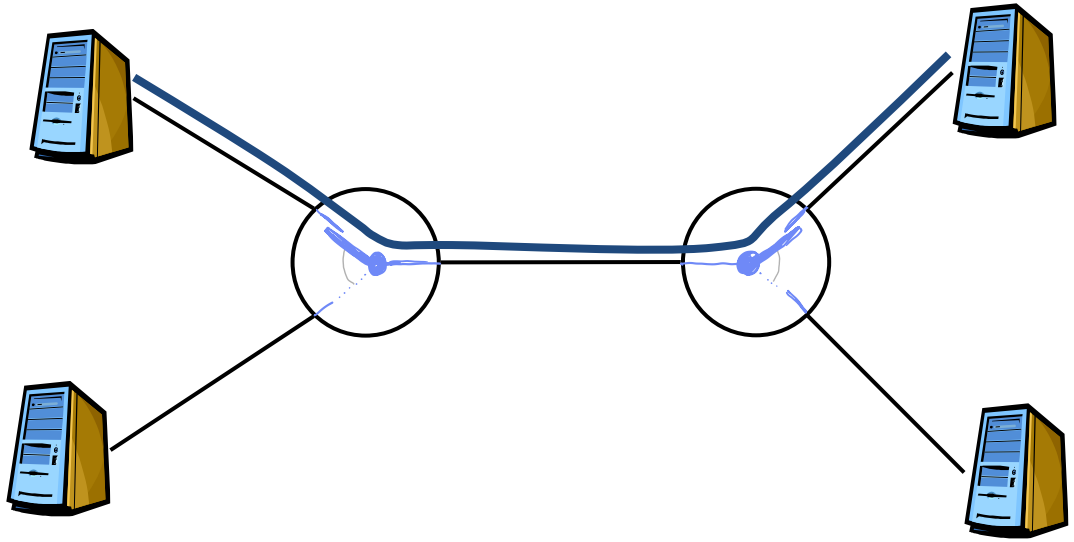
Unit 2

Basics of Networking & Sensor Networks - Applications, challenges - ISO/OSI Model, TCP/IP Model, Sensor network architecture and design principles, IoT technology stack, Communication models. Communication Protocols - Overview of protocols in each layer, Application protocols for the transfer of sensor data, Infrastructure for IoT: LoRa-Wan, 6LoWPAN, 5G and Sigfox.

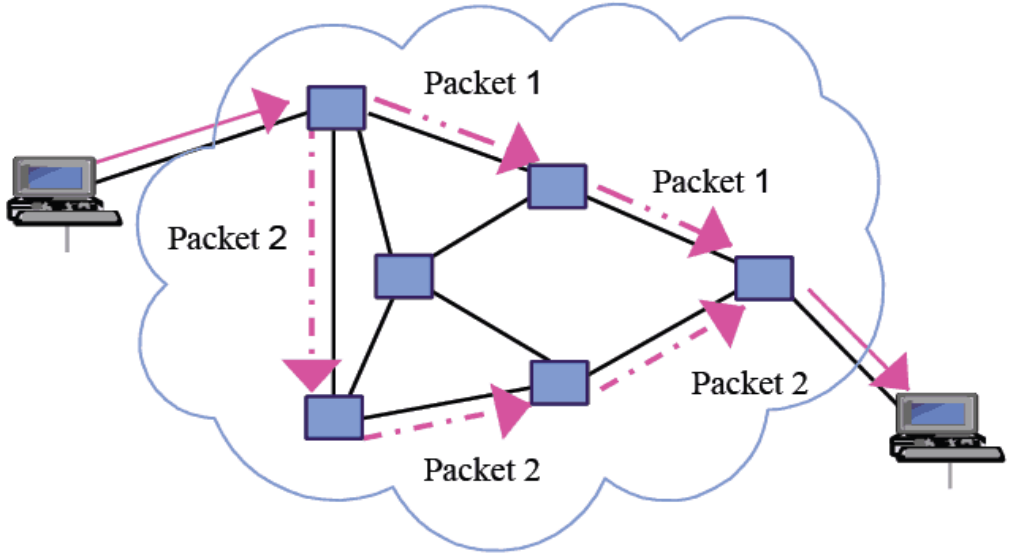
Unit 3

Introduction to Cloud, Fog and Edge Computing. Modern trends in IoT – Industrial IoT, Wearable. Applications of IoT - Smart Homes/Buildings, Smart Cities, Smart Industry, and Smart Medical care, Smart Automation etc.

Network Evolution



Circuit Switching



Packet Switching

Ref: https://www.geeksforgeeks.org/difference-between-circuit-switching-and-packet-switching/

Sensor Networks

Sensor

- Real world interface
- First step of being intelligent
- Awareness about the surroundings

Networks

- Interconnected devices
- Data / information exchange
- Distributed system

A networked system for automating a real world application using smart devices that can communicate.

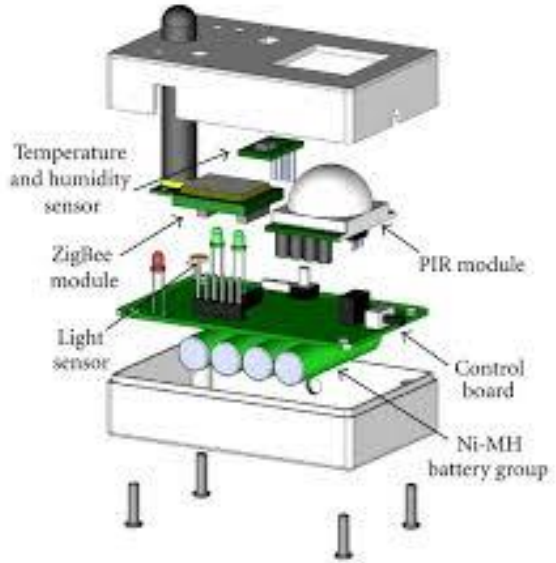
If not a network of Sensors, then what???

- Yes, sensor is an important module of sensor networks
- Yes, it is a networked system

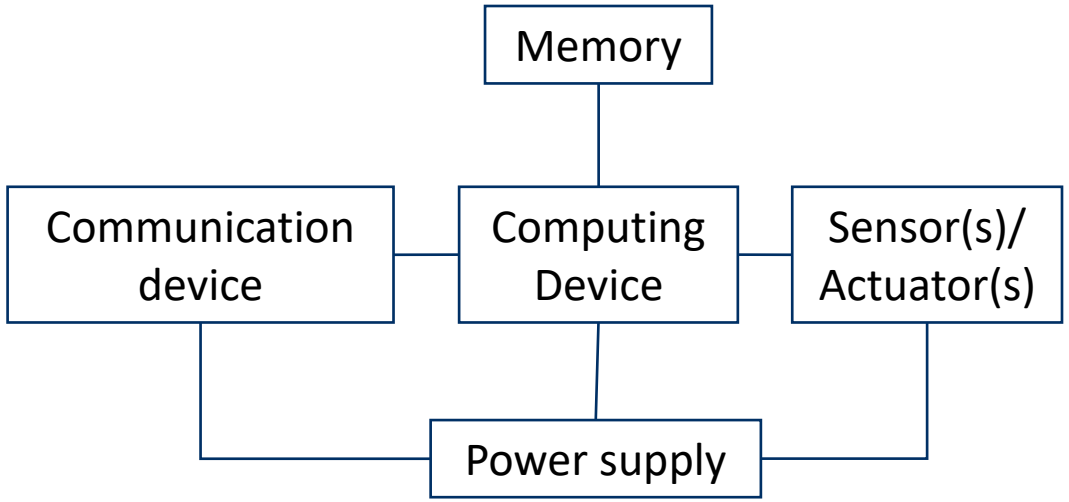
- A network of sensor nodes.

- Sensor Node = Sensor + ... ?? + Communication modem

Sensor Node

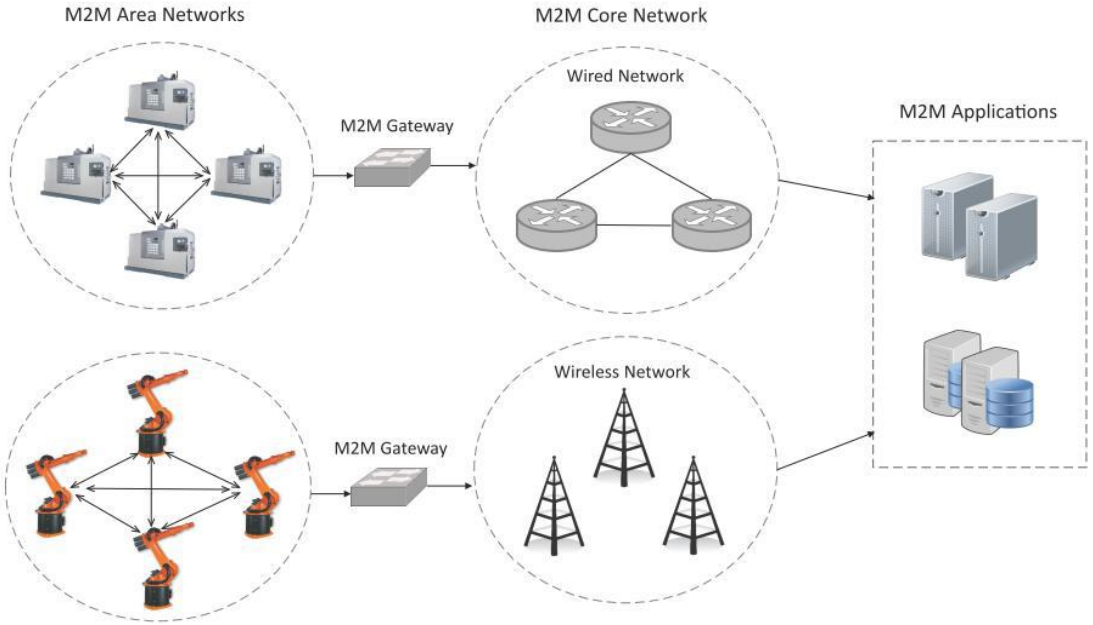


- Main components of a WSN node
  - ✓Controller
  - ✓Communication device(s)
  - ✓Sensors/actuators
  - ✓Memory
  - ✓Power supply



Machine-to-Machine (M2M) Network

- Machine-to-Machine (M2M) refers to networking of machines (or devices) for the purpose of remote monitoring and control and data exchange.



Ref: Arshdeep Bahga and Vijay Madisetti, “Internet of Things: A Hands-on Approach”, Universities Press, 2015.

Real World Applications Scenarios

- Monitoring
- Survilence and Tracking
- Smart Environments

Harsh environment, Short sensor range, Large area, High temporal/spatial variability, Event detection

WSN Application Examples

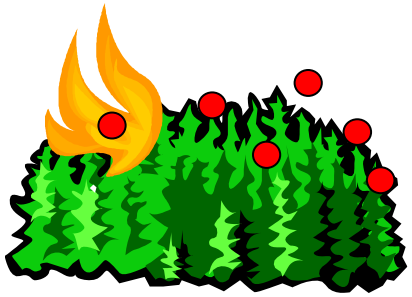
- Facility management
  - ✓ Intrusion detection into industrial sites
  - ✓ Control of leakages in chemical plants, …
- Machine surveillance and preventive maintenance
  - ✓ Embed sensing/control functions into places no cable has gone before
  - ✓ E.g., tire pressure monitoring

- Precision agriculture
  - ✓ Bring out fertilizer/pesticides/irrigation only where needed
- Medicine and health care
  - ✓ Post-operative or intensive care
  - ✓ Long-term surveillance of chronically ill patients or the elderly

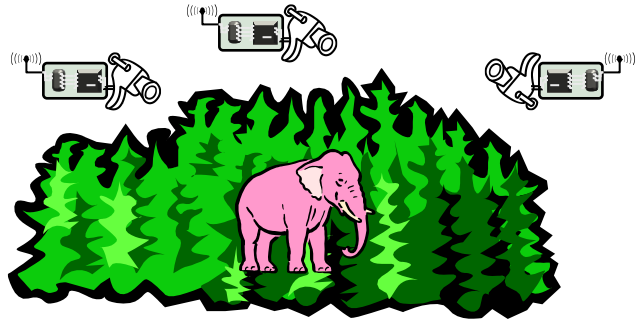
WSN Application Scenarios

- Logistics
  - ✓ Equip goods (parcels, containers) with a sensor node
  - ✓ Track their whereabouts – ***total asset management***
  - ✓ Note: passive readout might suffice – compare RF IDs

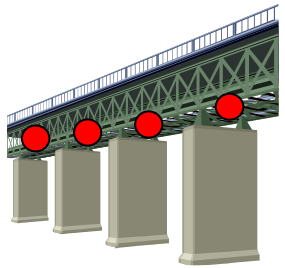
- Vehicle Telematics
  - ✓ Provide better traffic control by obtaining finer-grained information about traffic conditions
  - ✓ ***Intelligent roadside***
  - ✓ Cars as the sensor nodes
- Disaster relief operations
  - ✓ Drop sensor nodes from an aircraft over a wildfire
  - ✓ Each node measures temperature
  - ✓ Derive a “temperature map”

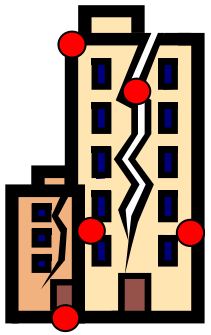


WSN Application Scenarios



- Biodiversity mapping
  - ✓ Use sensor nodes to observe wildlife
- Tracking of wild animals
  - ✓ e.g. Zebras, black storks
- Intelligent buildings (or bridges)
  - ✓ Reduce energy wastage by proper humidity, ventilation, air conditioning (HVAC) control
  - ✓ Needs measurements about room occupancy, temperature, air flow, …
  - ✓ Monitor mechanical stress after earthquakes
- Environmental Measuring
  - ✓ E.g. currents in the Gulf stream





WSN Application Scenarios

- Oceanographic WSN
  - ✓ Deploy oceanographic buoys to perform measurements far from the coastline
  - ✓ E.g., EEZ-WSN project
- Underwater WSNs
  - ✓ Employ Acoustic communications
  - ✓ Pollution detection in shallow waters
  - ✓ Measurement seismic activity on the sea bed
  - ✓ Anti-submarine warfare

Characteristic Requirements for WSNs

- Type of service of WSN
  - ✓ Not simply moving bits like another network
  - ✓ Rather: provide ***answers*** (not just numbers)
- Quality of service
  - ✓ Traditional QoS metrics do not apply
  - ✓ Still, service of WSN must be “good”: Right answers at the right time
- Fault tolerance
  - ✓ Be robust against node failure (running out of energy, physical destruction, …)
- Lifetime- Typically, severely energy constrained
  - ✓ The network should fulfill its task as long as possible – definition depends on application
  - ✓ Energy sources – Batteries
  - ✓ Tradeoff between performance and lifetime.

Characteristic Requirements for WSNs

- Scalability
  - ✓ Support large number of nodes
- Wide range of densities
  - ✓ Vast or small number of nodes per unit area, very application-dependent
- Programmability
  - ✓ Re-programming of nodes in the field might be necessary, improve flexibility
- Maintainability
  - ✓ WSN has to adapt to changes, self-monitoring, adapt operation
  - ✓ Incorporate possible additional resources, e.g., newly deployed nodes

Characteristic Requirements for WSNs

- Self-organizing and self-healing.
  - ✓ Remote deployments.
- Heterogeneity.
  - ✓ Devices with varied capabilities.
  - ✓ Different sensor modalities.
  - ✓ Hierarchical deployments.
- Adaptability.
  - ✓ Adjust to operating conditions and changes in application requirements.
- Security and privacy.
  - ✓ Potentially sensitive information.
  - ✓ Hostile environments.

Why cant we simply adapt Internet protocols, "end to end" architecture?

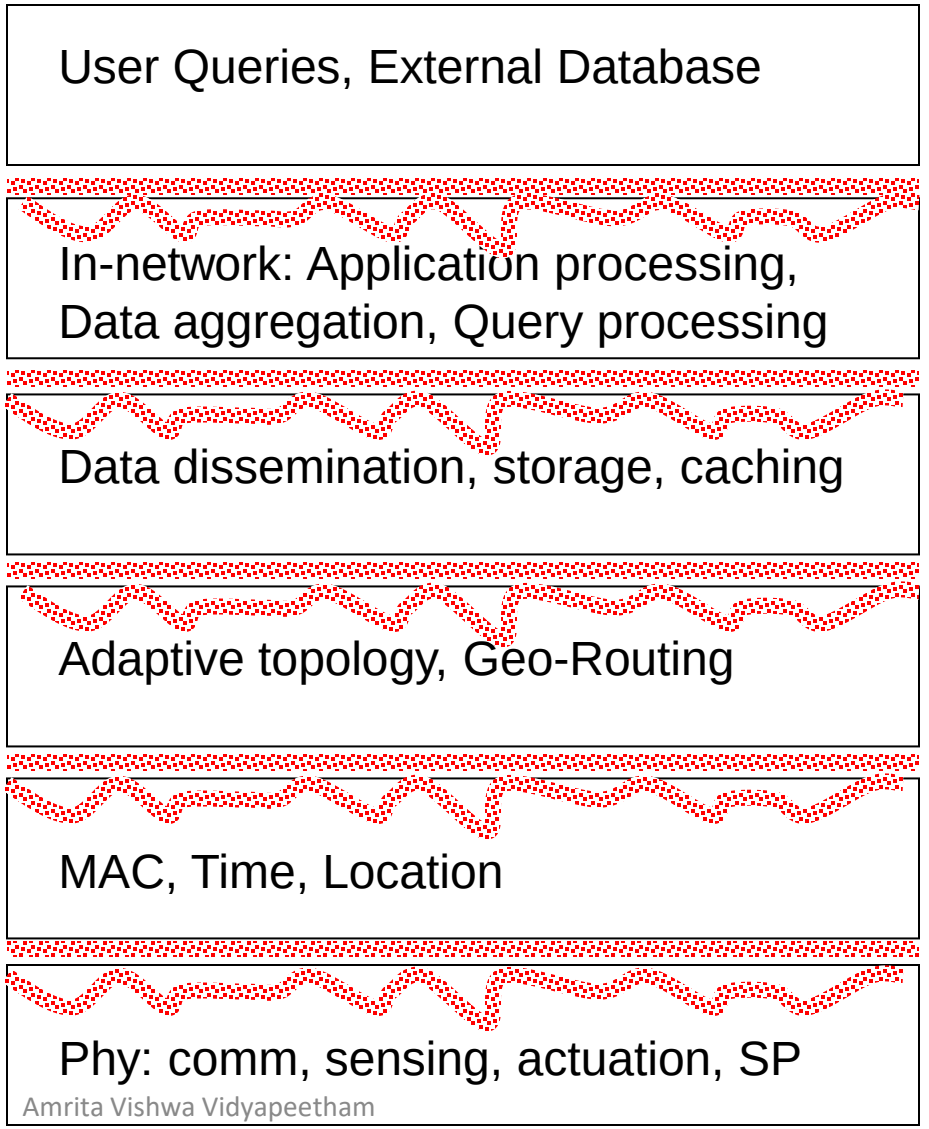
- Internet routes data using IP Addresses in Packets and Lookup tables in routers
  - ✓humans get data by "naming data" to a search engine
  - ✓many levels of indirection between name and IP address
  - ✓embedded, energy-constrained (un-tethered, small-form-factor), unattended systems cant tolerate communication overhead of indirection
- special purpose system function(s): don't need the Internet general purpose functionality designed for elastic applications.

Sample Layered Architecture

Resource constraints call for more tightly integrated layers

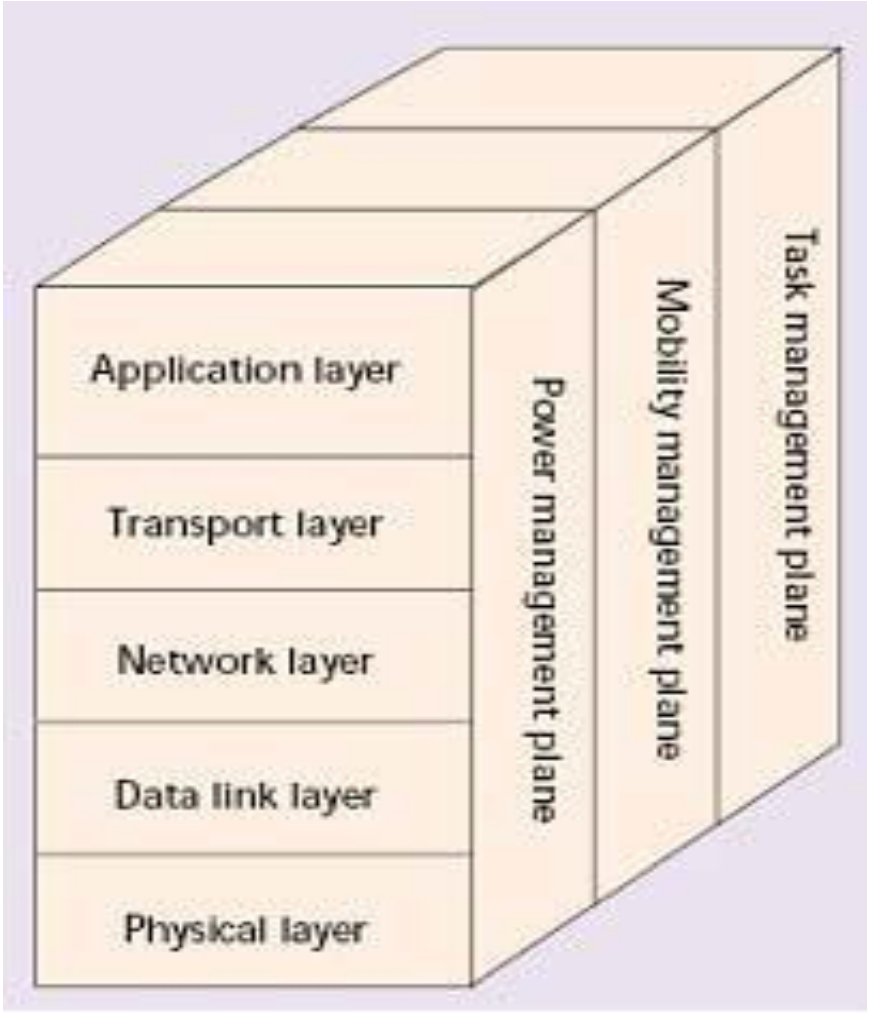
Open Question:

What are defining Architectural Principles?



Sensor Protocol Stack

- Combines power and routing awareness
- Integrates data with networking protocols
- Manages power efficiently across wireless medium
- Promotes cooperative efforts of sensor nodes



Power Management Plane

- Manages how the sensor node uses it power, e.g. the node may turn off if its receiver after getting a message from its neighbours, to avoid getting duplicate messages
- Also when the power of the node is low, the node may broadcast to its neighbours that it cannot participate in routing, the remaining power is reserved for sensing.

Task Management Plane

- Balances and schedules the sensing task given to a specific region. Not all nodes are required to perform sensing in the same region and can be turned off.
- Balances and schedules sensing tasks of a specific region of nodes, cooperative sensing

Mobility Management Plane

- Detects and registers the movement of sensor nodes, so route back to the sink is always maintained and the sensor nodes can keep track of who their neighbours are.

Design Principles for WSNs

- Distributed organization
- In-network processing
- Adaptive fidelity and accuracy
- Data centricity
- Location information
- Activity patterns
- Heterogeneity
- Component-based protocol stacks and cross-layer optimization

Distributed Organization

- Organizing the network in a distributed fashion
- No centralized entity in charge
- Self-organization
- Use centralized principles in a localized fashion

In - Network Processing

- Communication expensive when power and bandwidth are limited
- Perform (data) processing in network
  - ✓ close to (at) data
  - ✓ forward fused/synthesized results
  - ✓ e.g., find max. of set of data
- Distributed data, distributed computation
  - ✓Aggregation
  - ✓Distributed source coding and distributed compression
  - ✓Distributed and collaborative signal processing
  - ✓Mobile code/Agent-based networking

Adaptive Fidelity and Accuracy

- Application dependent.
- Keep an eye on energy constraints.
- For
  - ✓sensing,
  - ✓computation,
  - ✓communication and
  - ✓operation

Data Centricity

- Address data, not nodes
- Implementation options for data-centric networking
  - ✓Overlay networks and distributed hash tables
  - ✓Publish/Subscribe
  - ✓Databases

Location Information

- Position of member nodes.
- Location of an event – may be crucial.
- Location based addressing.
- Focus on data.

Activity Patterns

- Data burst or no data.
- Activity follows uncertain pattern.
- Dynamic or adaptable behavior.

Heterogeneity

- By construction,
  - ✓ larger batteries,
  - ✓ farther-reaching communication devices, or
  - ✓ more processing power.
- By evolution,
  - ✓ all nodes started from an equal state, but because some nodes had to perform more tasks during the operation of the network, they have depleted their energy resources, or
  - ✓ Other nodes had better opportunities to scavenge energy from the environment.
- Boon and bane.

Component-based protocol stacks and cross-layer optimization

- Component based vs. layered.
- The set of components that is active on a sensor node can be complex, and will change from application to application.
- Components interact by
  - ✓simple exchange of data packets.
  - ✓exchange of cross-layer information.

Thank You…

Holger Karl and Andreas Willig, “Protocols and Architectures for Wireless Sensor Networks”, John Wiley and Sons Ltd., 2005.