Corso di Reti mobili

Reti ad hoc & Reti di Sensori

Susanna Pelagatti & Stefano Chessa

Informazioni generali

- Introduzione (2 ore, Chessa)
- Reti di sensori (8 ore, Chessa)
  - Tecnologie
  - Paradigmi
  - Routing
  - Tabelle Hash geografiche
  - Localizzazione
- Standard per reti di sensori (6 ore, S. Chessa)
  - IEEE 802.15.4
  - Zigbee
  - ZigBee Cluster Library
- Reti ad hoc (4 ore, Pelagatti)
  - Standard IEEE 802.11
  - Protocolli di Accesso al Mezzo
  - Protocolli di Routing
  - Bluetooth e 6LowPan

Informazioni generali

- TinyOs, NesC (2 ore, C. Vairo)
- Arduino (4 ore, R. Pucci & F. Potortì)
- Mobile social networks (2 ore, M. Girolami)
- Organizzazione dei progetti (4+ ore, S. Chessa)
- Seminari conclusivi (4+ ore)

Informazioni generali

- Orario di ricevimento (Chessa)
  - Lunedì 10-12
- Materiale didattico:
  - Lucidi delle lezioni
  - Articoli scaricabili dal sito web del corso
- Testi di consultazione
  - Wireless Sensor Networks – an information processing approach, F. Zhao e L. Guibas, Morgan Kauffman & Elsevier, 2004
  - Ad Hoc Networking, C. Perkins
  - Ad Hoc Mobile Wireless Networks: Protocols and Systems, C.K.Toh
  - Topology Control in Wireless Ad Hoc and Sensor Networks, P. Santi, Wiley, 2005
- Sito Web
  - http://www.cli.di.unipi.it/doku/doku.php/rhs/start

Informazioni generali

Orario delle lezioni

- Mercoledì 9-11, aula C
- Venerdì 9-11, aula N1

Modalità di Esame

- Progetto da presentare a fine corso (seminario in alternativa)
- In alternativa un esame orale

Mobile Ad Hoc Networks (MANETs)

Mobile Ad Hoc Networks

- Autonomous system of mobile hosts connected by wireless links
  - The nodes are autonomous and independent
    - Battery powered
    - Mobile
    - Nodes communicate by exchanging packets via radio waves
    - Cooperate in a peer-to-peer fashion
  - No fixed network infrastructure
    - Pure distributed system
    - No centralized coordinators
    - The network can be (re-)configured on-the-fly

Mobile Ad Hoc Networks

- Features
  - Rapidly deployable
  - Easily configurable
  - Robust
  - Heterogeneous

Mobile Ad Hoc Networks

- Potential drawbacks
  - Distributed control
  - Neighbor knowledge
    - node should detect the presence of other nodes (and behave accordingly)
  - Mobility is a challenge
    - Frequent link/node failures
  - Management of network heterogeneity
    - Different capabilities/power:
      - Battery, processing, storage capacity
      - Laptops, handheld, sensors, etc.

Mobile Ad Hoc Networks

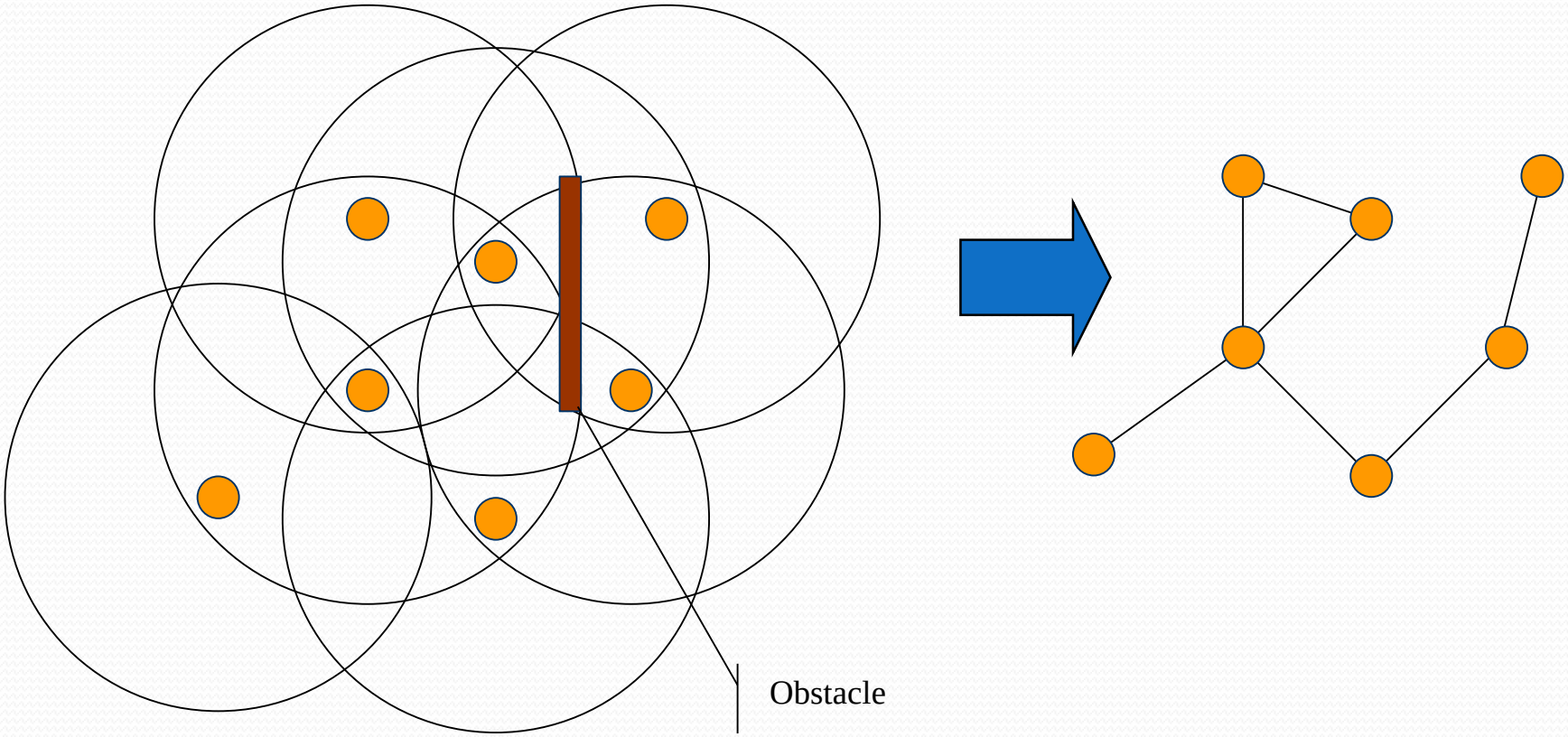
- Applications:
  - communication in remote or hostile environments
  - management of emergencies
  - disaster recovery
  - ad hoc commercial installations
  - sensor networks

Mobile Ad Hoc Networks

- Wireless communications:
  - Transmission range of the nodes is limited
  - Obstacles may prevent direct communication between a pair of nodes

- Point-to-point Network
  - Communication between non-adjacent nodes must be supported by other nodes

Mobile Ad Hoc Networks

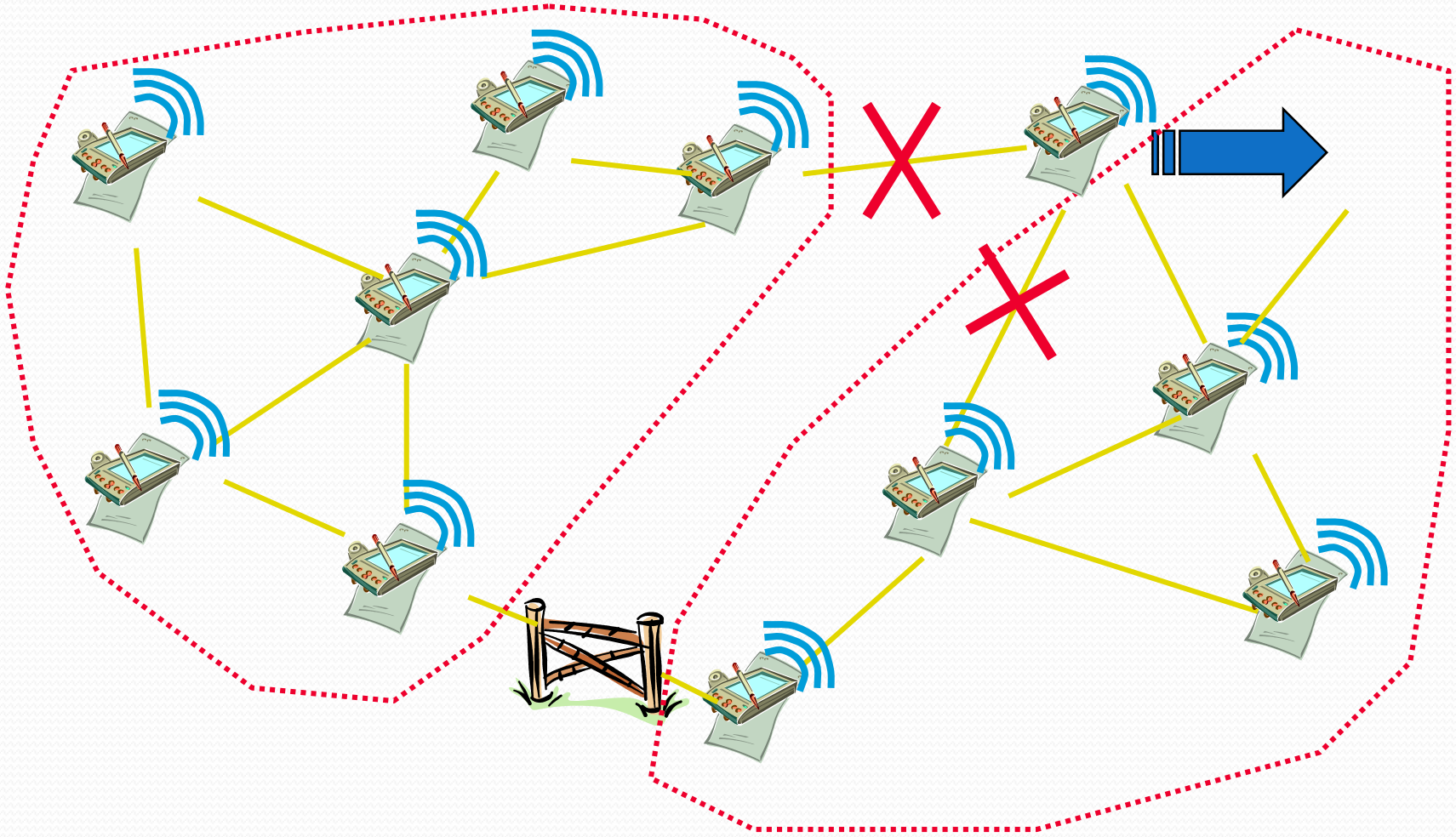


Mobile Ad Hoc Networks

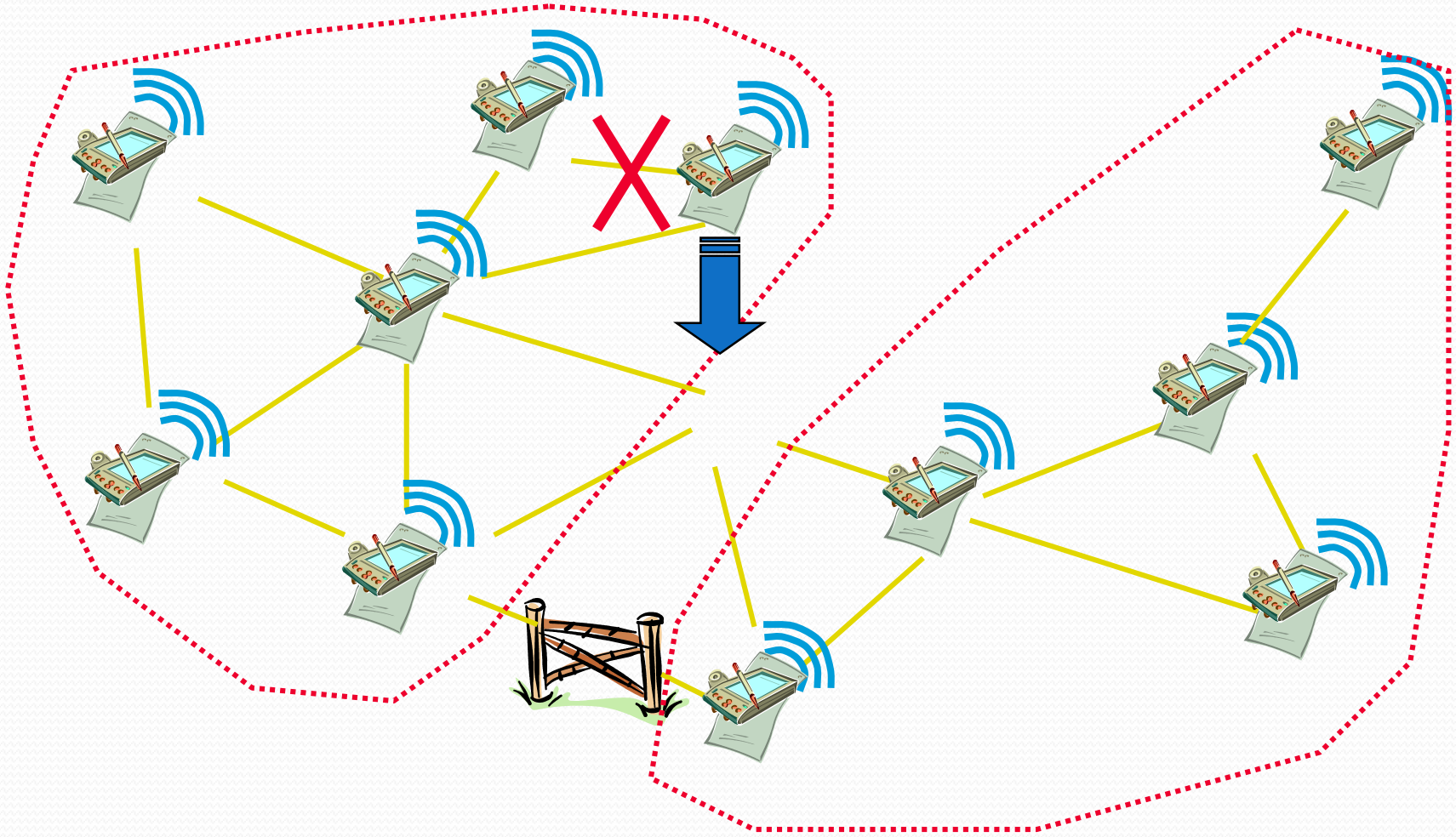
Communication issues:

- Access to the shared wireless channel
  - requires a (wireless) Media Access Control (MAC)
- Mobility / Failures of mobiles (limited power supply)
  - makes the network topology change arbitrarily
  - Produce nodes disconnections/network partitioning
- Limited transmission range:
  - The network is multi hop
  - Need for a multihop routing protocol
- Wireless communication:
  - Eavesdropping of ongoing communications
  - Security issues

Mobile Ad Hoc Networks

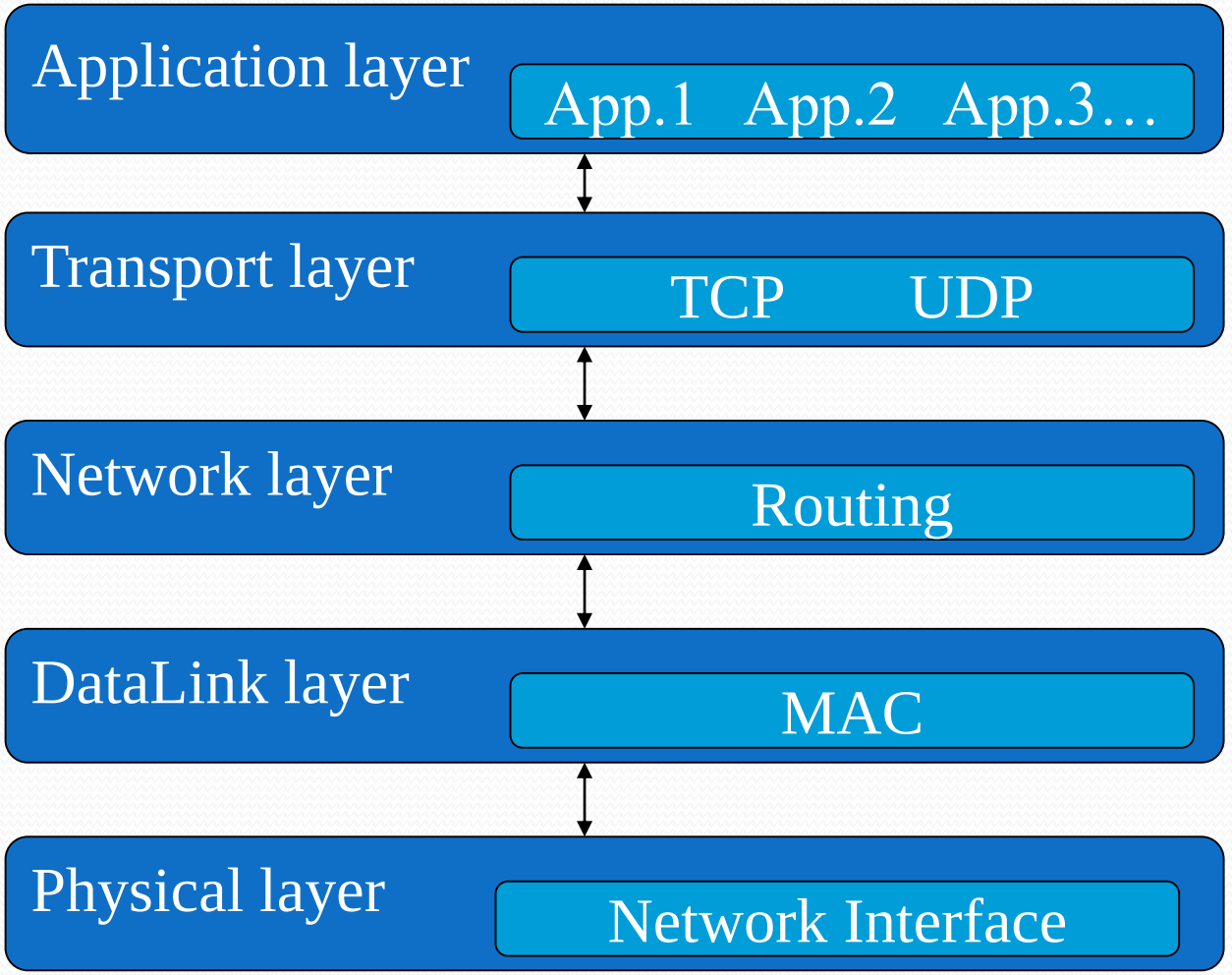


Mobile Ad Hoc Networks



Mobile Ad Hoc Networks

- Typical protocol stack



Mobile Access Control Issues

- Due to physical layer properties
  - No definite boundaries for radio waves
  - High Bit Error Rate (BER)
  - Asymmetric channel qualities
- Concept of “neighbors:” nodes within each other transmission range: only neighbors detect the carrier on the channel
- Attenuation of signal strength depending on node distance

Mobile Issues

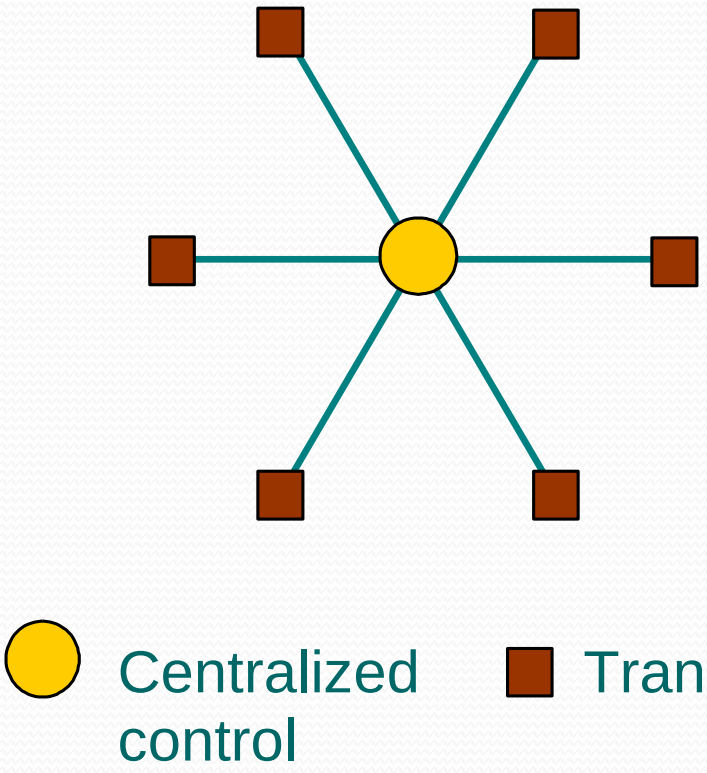
- Nodes are also routers:
  - Need for a multihop routing protocol
- Nodes are mobile, the network topology changes frequently
  - Routes may fail frequently
  - Need for fast route update
  - Need for dynamic routing
- Energy may be important in some applications

Wireless Sensor Networks

(WSN)

Environmental monitoring with sensors

- Conventional approach:
  - The sensors are just transducers
  - Connected by a cable to a centralized control device
- Examples
  - Sensors in automotive
  - Sensors in industrial plants
  - House alarms



Wireless Sensor Networks

- Differences with the conventional model:
  - The sensors are “intelligent”
    - Microsystems (processor, memory, transducers,…)
    - Can process sensed data
  - The sensors communicate via wireless technologies
    - Radio
    - Optical
  - The sensors build a network
    - Not just direct communication transducer-centralized control
  - Network easily deployable
    - No need for fixed infrastructure

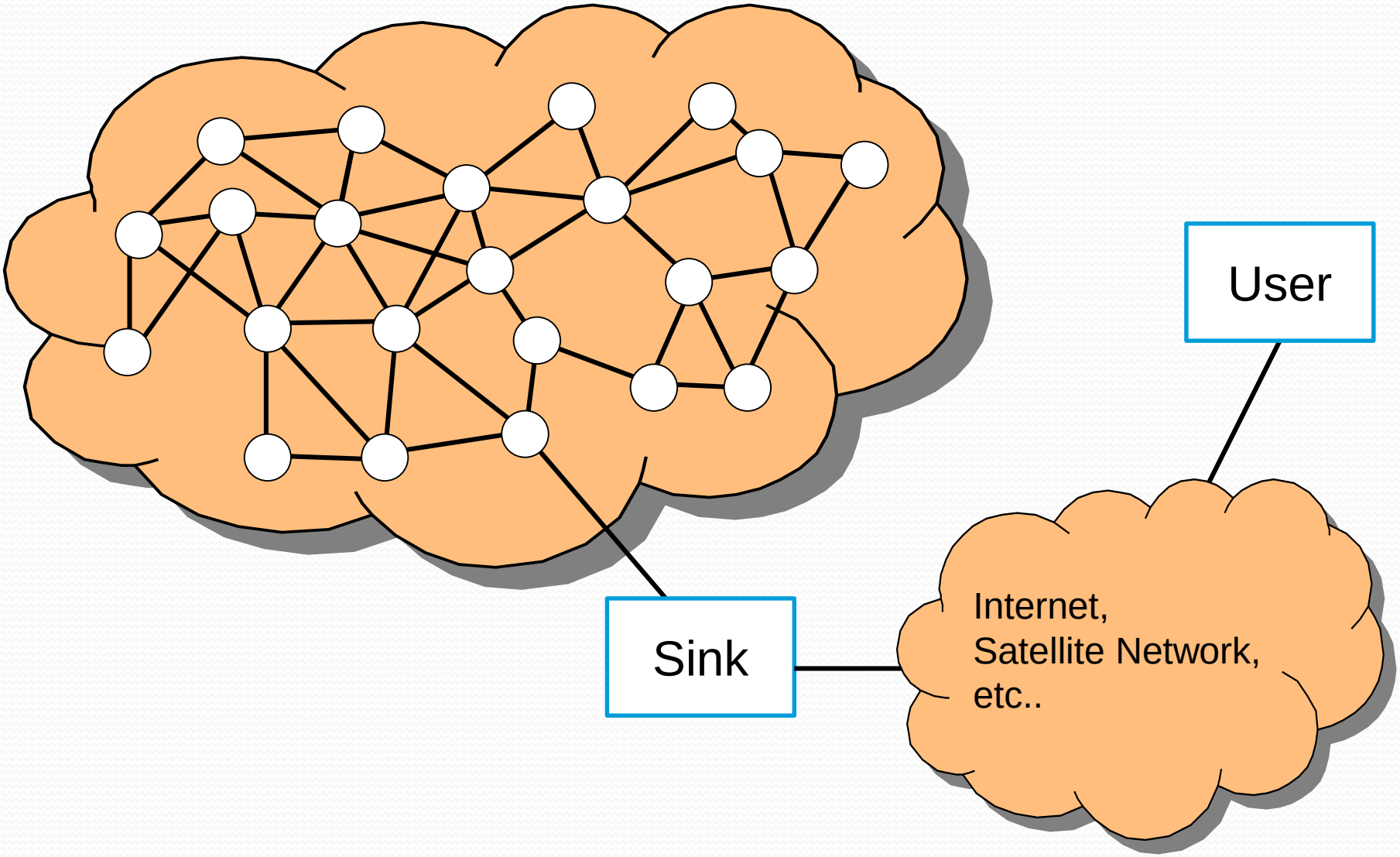
Wireless Sensor Networks

- A typical configuration comprises:
  - One (or more) sink nodes
    - Interface the WSN with the external world
  - A set of wireless sensors
- Each sensor :
  - Low power, low cost system
  - Small
  - Autonomous
- Sensors equipped with:
  - Processor
  - Memory
  - Radio Transceiver
  - Sensing devices
    - Acceleration, pressure, humidity, light, acoustic, temperature, GPS, magnetic, …
  - Battery, solar cells, …

Wireless Sensor Networks

- Sensors are deployed in the *Sensing Field*
- Each sensors samples environmental parameters
  - Produces streams of data
  - data streams can be pre-processed locally and then forwarded to a sink
- The sinks might be temporarily unavailable
  - The network operates autonomously
  - Pre-process and store sensed data
  - Sensors may implement a database

Wireless Sensor Networks



Advantages of WSN

- Sensor network deployment is easy and cheap
  - No need for cables
  - The network is self-configurable
  - The number of sensors can scale up
  - The sensors can be redundant (fault-tolerance)
- The sensors can be mobile
  - For instance sensors on a person or an animal
- No need for centralized control
- The sensors can filter/process data
  - The network can be programmed dynamically

Differences with Ad Hoc Networks

- Number of sensor nodes can be several orders of magnitude higher
- Sensor nodes are strongly constrained in power, computational capacities, and memory
- Sensor network are denser and sensors are prone to failures
- The topology of a sensor network changes mainly due node failures (and mobility?)
- Sensors may not have individual IDs
- Need for a tight integration with sensing tasks

Relationship of WSN with other technologies

WSN Applications

- Environmental
  - Tracking animals, …
  - Pollution control, …
- Disaster recovery
  - Monitor disaster areas,
  - Fire/flooding detection, …
  - Meteorological research
- Security
  - Nuclear, Biological and Chemical (NBC) attack detection
  - Monitoring battlefield,
  - Surveillance, …
- Health
  - Diagnostics
  - Monitoring
  - Support to disabled
- Commercial
  - Inventory management
  - Vehicle tracking
  - Toys
  - Domotics
- Art
- Space exploration
- …

WSN, barcode and RFIDs

- Bar codes:
  - Extremely cheap (the complexity is in the reader)
  - Deep user involvement
  - Short range (a few centimeters)

- RFID (Radio Frequency Identifiers):
  - Cheap technology (the complexity is in the reader)
  - User involvement
  - Short range (a few meters)
    - RFID tags give their identifier to the reader
  - Passive tags (powered by the reader)
    - Can provide TAG ID and a few sampled data to the reader
  - Active tags (battery powered)
    - No network, just TAG and reader
- Wireless Sensor Networks
  - No need for user involvement
  - Medium range (10-100 meters)
    - Range can be extended with multihop communications
  - Active sensors (battery powered)
  - Can interoperate with RFID tags

An example: user localization

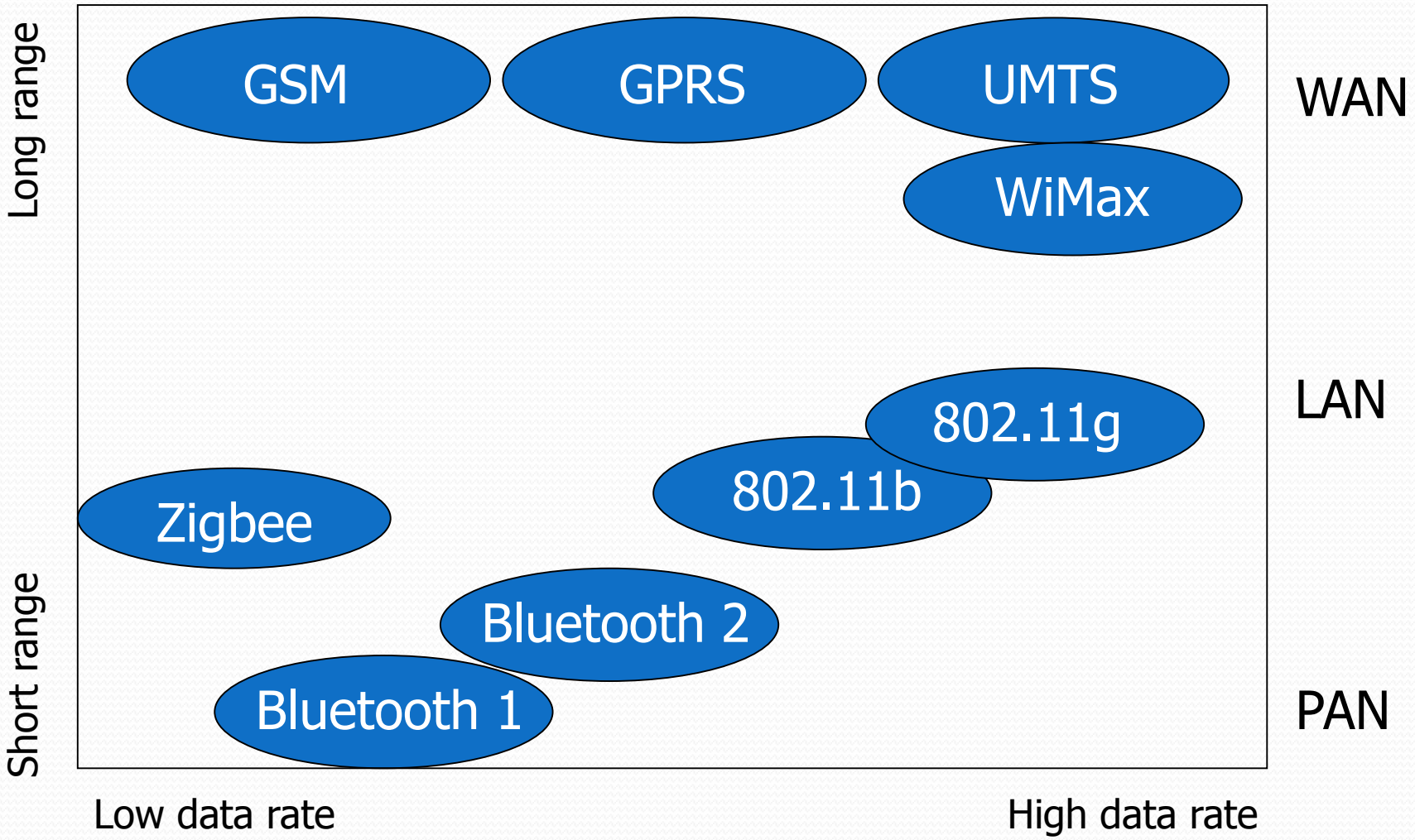
- Localization:
  - Locate a person or a device in an environment
- With barcode:
  - A code denotes an area
  - The user (equipped with a barcode reader) reads the code
  - The reader determines the position of the user
  - Used in some pilot project in museums etc..
- With RFID
  - A RFID reader denotes an area
  - The user brings an RFID tag
  - As the user approaches the area the reader detects the user's tag
- With a WSN
  - A WSN is deployed in a building
  - A user brings a sensor
  - The WSN detects the presence and position of the user's sensor in the building

Wireless Standards

Main standards for ad hoc & sensor networking

- IEEE 802.11 (Wi-Fi)
  - General purpose wireless access
- IEEE 802.15.1 & Bluetooth
  - Cable replacement
- IEEE 802.15.4 & ZigBee
  - Sensor and actuator networks
- IEEE 802.16 (WiMax)
  - Metropolitan wireless access networks

Wireless technologies



IEEE 802.11 standard & extensions

- A family of standards:
  - IEEE 802.11
    - Frequency: 2.4 Ghz
    - Bit rate: 1, 2 Mbps
    - Transmission range: ~ 100 meters (2Mbps)-130 meters (1Mbps)
  - IEEE 802.11a
    - Frequency: 5 Ghz
    - Bit rate: up to 54 Mbps
    - Transmission range: ~ 10 meters (54 Mbps)
  - IEEE 802.11b
    - Frequency: 2.4 Ghz
    - Bit rate: up to 11 Mbps
    - Transmission range: ~ 30 meters

IEEE 802.11 standard & extensions

- IEEE 802.11g
  - Frequency: 2.4 GHz
  - Bit rate: up to 54 Mbps
- IEEE 802.11h
  - Extension of 802.11a to lower interferences with satellites and radar systems
- IEEE 802.11e
  - QoS support
  - Priority management
- IEEE 802.11n
  - Directional antennas (antenna arrays)
- IEEE 802.11f
  - Protocol to allow roaming of mobile hosts between different access points

IEEE 802.15.4 and Zigbee

- The IEEE 802.15.4 defines both physical and MAC layers
- Zigbee is an industrial consortium promoting the development of low power sensor networks
  - Defines also higher network layers and application interfaces
- Designed for low power sensor network
  - Low throughput (up to 115 Kbps)
  - Low duty cycle (around 1 percent)
- Defines either a star or a peer to peer network

IEEE 802.15.4 and Zigbee vs Bluetooth

- No real overlapping
- Bluetooth:
  - Higher data rate
  - Thought for personal and multimedia communication
    - Audio
    - Video (low quality)
  - Bluetooth 2 increases the throughput up to 10 Mbps
  - Small networks
    - Up to 8 active nodes
      - Can be extended with piconets)
    - Star topology
  - Basically master-slave communications

IEEE 802.15.4 and Zigbee vs Bluetooth

- ZigBee:
  - Low data rate
  - Thought for communication and control of sensors and actuators
  - Can manage large networks
    - Up to thousands of nodes
    - Manages nodes' mobility
    - Different network topologies (tree and mesh)
  - Communications
    - Master-slave
    - Peer to peer

IEEE 802.15.4, Bluetooth, WiFi

Name	**ZigBee**	**WiFi**	**Bluetooth**
Standard	802.15.4	802.11 a,b,g	802.15.1
Applications	Monitoring and control	Web, e-mail, video	Cable replacement
System resources	50 to 60 Kbytes	>1 Mbytes	>250 Kbytes
Battery life (days)	100 to > 1000	1 to 5	1 to 7
Network size	65.536	32	7
Bandwidth (Kbps)	20 to 250	11K to 100k	720
Maximum transmission range	100+	100	10
Success metrics	Reliability, power, cost	Speed, flexibility	Cost, convenience

ZigBee

- ZigBee is distributed by hardware vendors
  - The vendors provide development kits with binary code
  - The source code is generally not distributed
  - The distribution is often free
- ZigBee is a complex protocol stack
  - Low-end sensors may not support it
  - It is the result of several compromises
    - Almost “general purpose”
    - Takes into account the requirements of several different industrial companies
  - In some applications it may result too heavy

ZigBee

- Thought for
  - Applications where dynamic network management is important
  - Interoperability among products of different vendors
- Service oriented architecture
- Expected applicative areas:
  - Personal networks
    - Individuals monitoring (elders, patients, disabled)
  - Home networks
    - House monitoring
    - Support to elders, disabled
    - Support to context-aware systems for multimedia systems
    - …

ZigBee alternatives

- Some HW vendors also offer lighter protocol stacks
  - For example the SimpliciTi stack of Texas Instruments
- There is an effort of standardization of an IPV6 stack for WSN
  - Stack 6LowPan
  - The main difficulty is in the compression of IPV6 headers
- Some vendors develop directly in C or even in assembler
- In the academy there are several alternatives
  - TinyOS
  - SOS
  - Contiki
  - …