BENHA UNIVERSITY
FACULTY OF ENGINEERING AT SHOUBRA

ECE-508

Sensor Networks

Lecture #1
Course Introduction & Motivation and Applications

Instructor:

Dr. Ahmad El-Banna

SPRING 2015

Agenda

- Course Objectives
- Course Information
- Motivation
- Applications

Course Objectives

- ***Understand the basics of Wireless Sensor Networks (WSNs) and their applications.***
- ***Learn the architecture of WSNs and its programming.***
- ***Study the Localization and positioning of the WSNs.***
- ***Deal with the power efficient design issues of the WSNs.***
- ***Case study.***

Course Information

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Lectures:	Saturday: 12:30 -15:30
Office Hours:	Tuesday (12:00~15:30) & Wednesday (14:00~16:30) & Thursday(11:00~14:30)
Texts/Notes:	• Lectures slides, available by each lecture, and found online at http://bu.edu.eg/staff/ahmad.elbanna-courses/12189 • H. Karl and A. Willig, **Protocols and Architectures for Wireless Sensor Networks**, Wiley 2005. • G. Pottie and W. Kaiser, **Principles of Embedded Networked Systems Design**, 2005.
Grading:	▪ **210 Marks** • Final Exam (Closed-Book) ▪ **50 Marks** • Quizzes and Assignments ▪ **40 Marks** • Case Study Project

Ad hoc and Sensor Networks
Chapter 1: Motivation & Applications

By: Holger Karl

Goals of this chapter

- Give an understanding what ad hoc & sensor networks are good for, what their intended application areas are.
- Commonalities and differences .
- Limitations of these concepts.

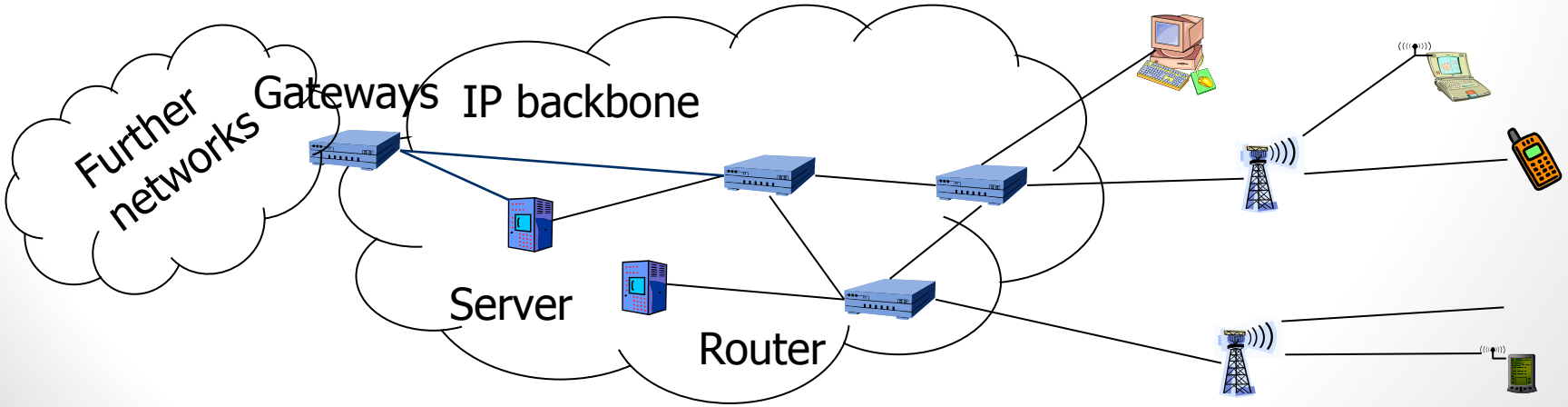
Headlines:

- Infrastructure for wireless
- (Mobile) ad hoc networks
- Wireless sensor networks
- Comparison

INFRASTRUCTURE FOR WIRELESS

Infrastructure-based wireless networks

- Typical wireless network: Based on infrastructure
  - E.g., GSM, UMTS, …
  - Base stations connected to a wired backbone network
  - Mobile entities communicate wirelessly to these base stations
  - Traffic between different mobile entities is relayed by base stations and wired backbone
  - Mobility is supported by switching from one base station to another
  - Backbone infrastructure required for administrative tasks

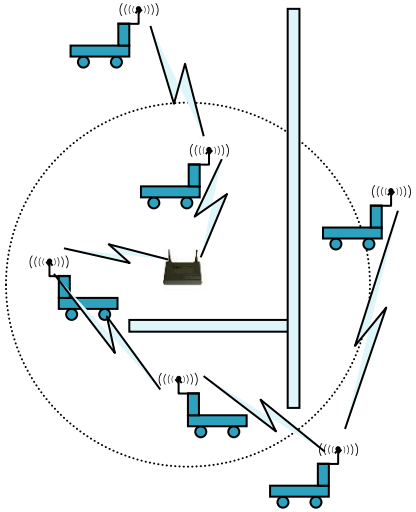


Infrastructure-based wireless networks – Limits?

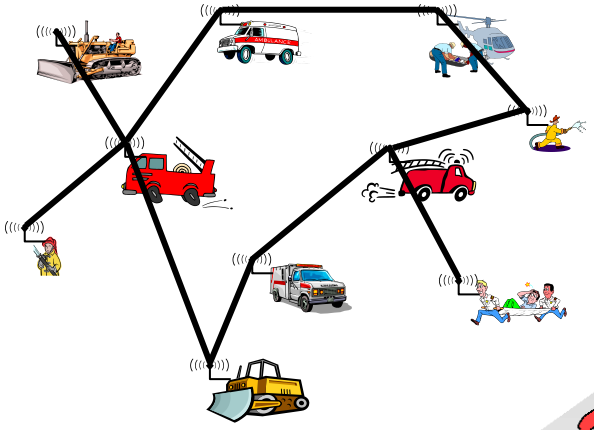
- What if …
  - No infrastructure is available? – E.g., in disaster areas
  - It is too expensive/inconvenient to set up? – E.g., in remote, large construction sites
  - There is no time to set it up? – E.g., in military operations

Possible applications for infrastructure-free networks

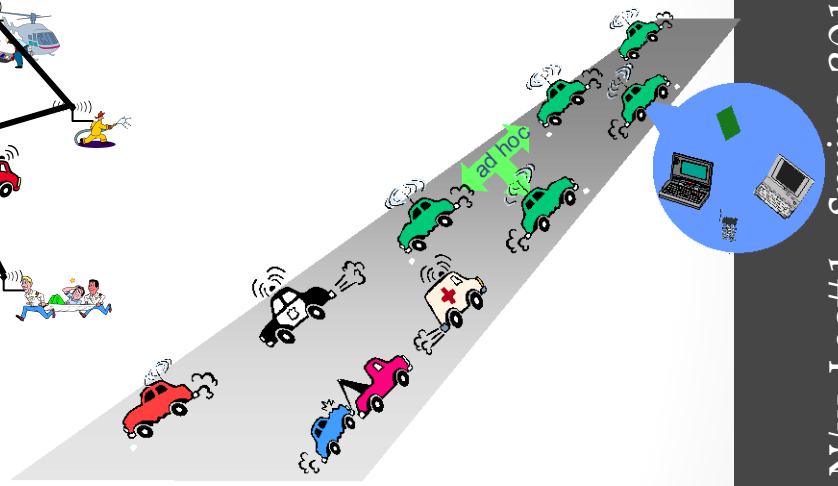
- Factory floor automation



- Disaster recovery



- Car-to-car communication

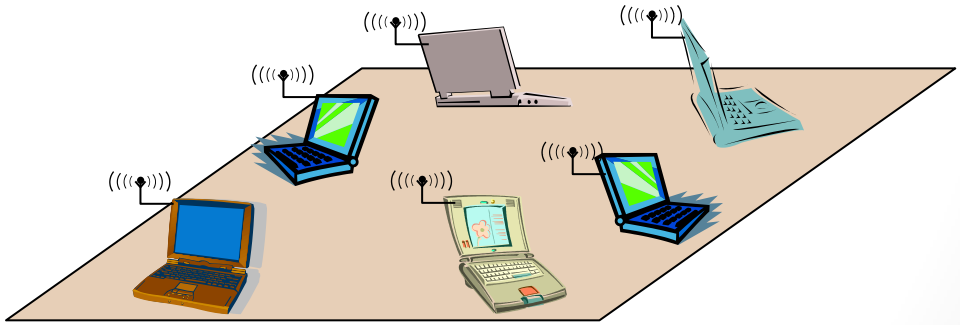


- Military networking: Tanks, soldiers, …
- Finding out empty parking lots in a city, without asking a server
- Personal area networking (watch, glasses, PDA, medical appliance, …)
- …

(MOBILE) AD HOC NETWORKS

Solution: (Wireless) ad hoc networks

- Try to construct a network without infrastructure, using networking abilities of the participants
  - This is an ***ad hoc network*** – a network constructed "for a special purpose"
- Simplest example: Laptops in a conference room – a ***single-hop ad hoc network***



→ A *wireless ad hoc network* (WANET) is a decentralized type of wireless network that does not rely on a pre existing infrastructure.

Problems/challenges for ad hoc networks

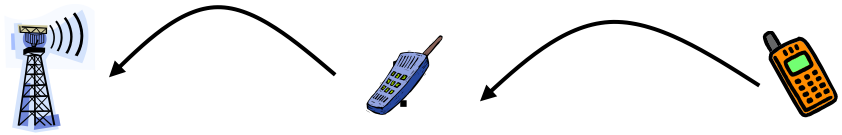
- Without a central infrastructure, things become much more difficult
- Problems are due to
  - Lack of central entity for organization available
  - Limited range of wireless communication
  - Mobility of participants
  - Battery-operated entities

No central entity ! self-organization

- Without a central entity (like a base station), participants must organize themselves into a network (***self-organization***)
- Pertains to (among others):
  - Medium access control – no base station can assign transmission resources, must be decided in a distributed fashion
  - Finding a route from one participant to another

Limited range ! multi-hopping

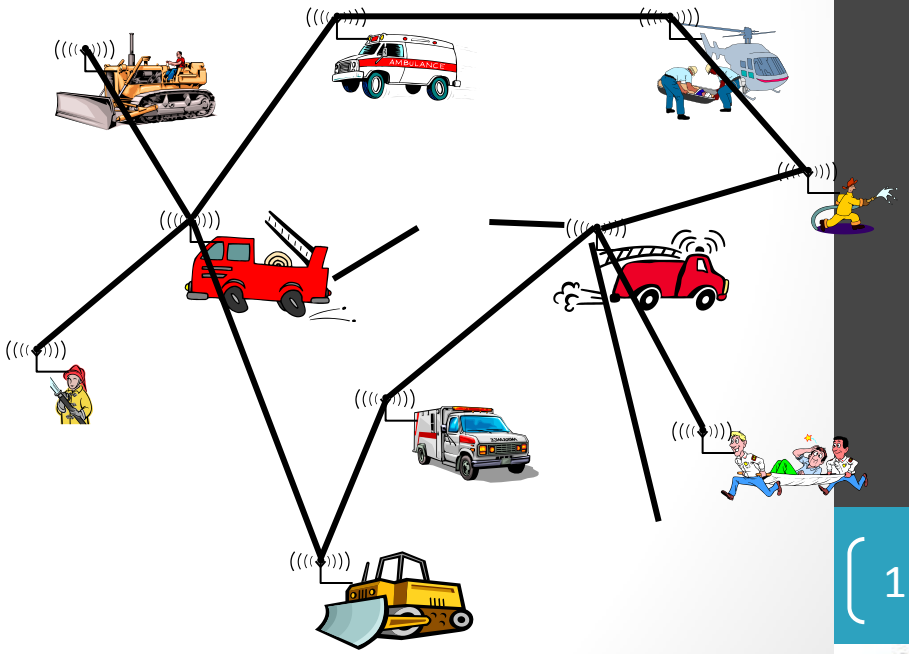
- For many scenarios, communication with peers outside immediate communication range is required
  - Direct communication limited because of distance, obstacles, …
  - Solution: ***multi-hop network***



Mobility ! Suitable, adaptive protocols

- In many (not all!) ad hoc network applications, participants move around
  - In cellular network: simply hand over to another base station

- In ***mobile ad hoc networks (MANET)***:
  - Mobility changes neighborhood relationship
  - Must be compensated for
  - E.g., routes in the network have to be changed



- Complicated by scale
  - Large number of such nodes difficult to support

Battery-operated devices ! energy-efficient operation

- Often (not always!), participants in an ad hoc network draw energy from batteries
- Desirable: long run time for
  - Individual devices
  - Network as a whole

! Energy-efficient networking protocols

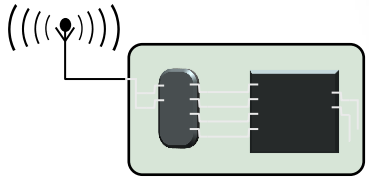
- E.g., use multi-hop routes with low energy consumption (energy/bit)
- E.g., take available battery capacity of devices into account
- How to resolve conflicts between different optimizations?

Applications

WIRELESS SENSOR NETWORKS

Wireless sensor networks

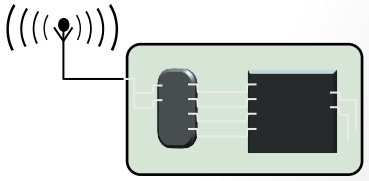
- Participants in the previous examples were devices close to a human user, interacting with humans



- Alternative concept:

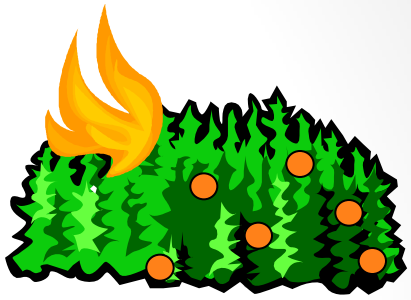
  Instead of focusing interaction on humans, focus on interacting with ***environment***
  - Network is ***embedded*** in environment
  - Nodes in the network are equipped with ***sensing*** and ***actuation*** to measure/influence environment
  - Nodes process information and communicate it wirelessly

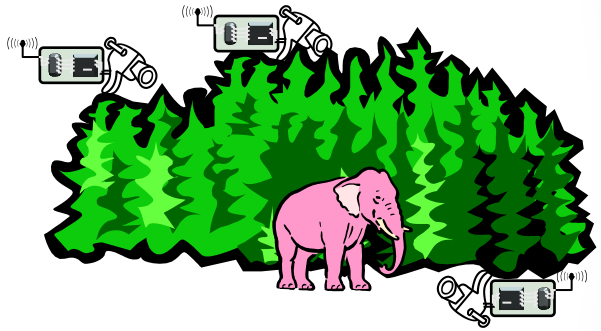
! ***Wireless sensor networks*** (WSN)
  - Or: ***Wireless sensor & actuator networks*** (WSAN)



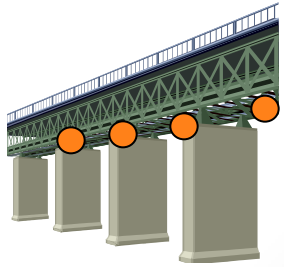
WSN application examples

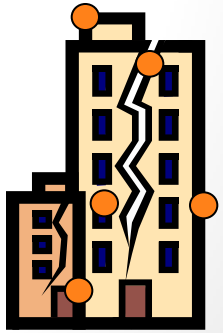
- Disaster relief operations
  - Drop sensor nodes from an aircraft over a wildfire
  - Each node measures temperature
  - Derive a “temperature map”
- Biodiversity mapping
  - Use sensor nodes to observe wildlife





- 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





WSN application scenarios

- 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 with a sensor node
  - Track their places – ***total asset management***
  - Note: passive readout might suffice – compare RF IDs
- Telematics
  - Provide better traffic control by obtaining finer-grained information about traffic conditions
  - ***Intelligent roadside***
  - Cars as the sensor nodes

Homework: Compare RF IDs with WSN !

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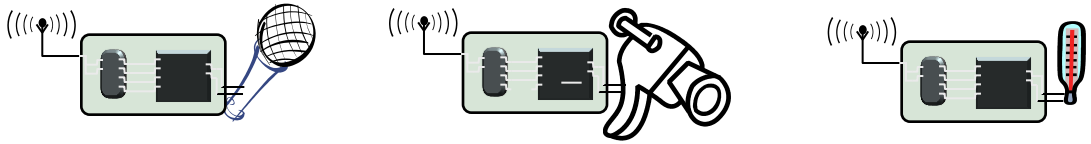
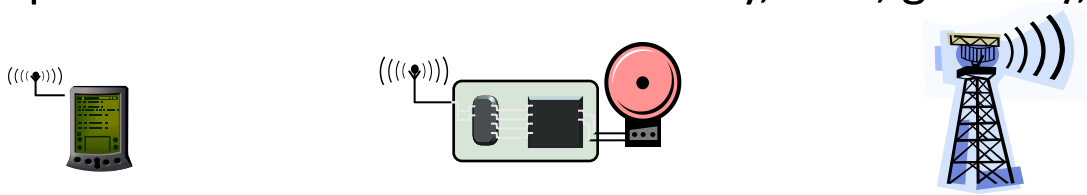
Roles of participants in WSN

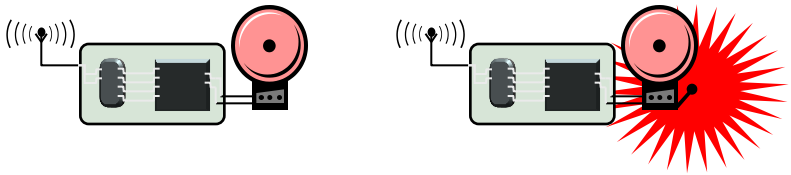
- ***Sources*** of data: Measure data, report them "somewhere"
  - Typically equip with different kinds of actual sensors



- ***Sinks*** of data: Interested in receiving data from WSN
  - May be part of the WSN or external entity, PDA, gateway, …



- ***Actuators***: Control some device based on data, usually also a sink



Structuring WSN application types

- ***Interaction patterns*** between sources and sinks classify application types
  - ***Event detection***: Nodes locally detect events (maybe jointly with nearby neighbors), report these events to interested sinks
    - ***Event classification*** additional option
  - ***Periodic measurement***
  - ***Function approximation:*** Use sensor network to approximate a function of space and/or time (e.g., temperature map)
  - ***Edge detection:*** Find edges (or other structures) in such a function (e.g., where is the zero degree border line?)
  - ***Tracking***: Report (or at least, know) position of an observed intruder ("pink elephant")

Deployment options for WSN

- How are sensor nodes deployed in their environment?
  - Dropped from aircraft ! ***Random deployment***
    - Usually uniform random distribution for nodes over finite area is assumed
    - Is that a likely proposition?
  - Well planned, fixed ! ***Regular deployment***
    - E.g., in preventive maintenance or similar
    - Not necessarily geometric structure, but that is often a convenient assumption
  - ***Mobile*** sensor nodes
    - Can move to compensate for deployment shortcomings
    - Can be passively moved around by some external force (wind, water)
    - Can actively seek out “interesting” areas

Maintenance options

- Feasible and/or practical to maintain sensor nodes?
  - E.g., to replace batteries?
  - Impossible but not relevant? Mission lifetime might be very small
- Energy supply?
  - Limited from point of deployment?
  - Some form of recharging, energy scavenging from environment?
    - E.g., solar cells

Requirements & mechanisms

WIRELESS SENSOR NETWORKS

Characteristic requirements for WSNs

- Type of service of WSN
  - Not simply moving bits like another network
  - Rather: provide ***answers*** (not just numbers)
  - Issues like geographic scoping are natural requirements, absent from other networks
- 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
  - The ***network*** should fulfill its task as long as possible – definition depends on application
  - Lifetime of individual nodes relatively unimportant
  - But often treated equivalently

Homework: Definition of network 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

Required mechanisms to meet requirements

- Multi-hop wireless communication
- Energy-efficient operation
  - Both for communication and computation, sensing, actuating
- Auto-configuration
  - Manual configuration just not an option
- Collaboration & in-network processing
  - Nodes in the network collaborate towards a joint goal
  - Pre-processing data in network (as opposed to at the edge) can greatly improve efficiency

Required mechanisms to meet requirements

- Data centric networking
  - Focusing network design on ***data***, not on ***node identifies*** (id-centric networking)
  - To improve efficiency
- Locality
  - Do things locally (on node or among nearby neighbors) as far as possible
- Exploit tradeoffs
  - E.g., between invested energy and accuracy

COMPARISON

MANET vs. WSN

- Many commonalities: Self-organization, energy efficiency, (often) wireless multi-hop
- Many differences
  - ***Applications, equipment***: MANETs more powerful (expensive) equipment assumed, often "human in the loop"-type applications, higher data rates, more resources
  - ***Application-specific***: WSNs depend much stronger on application specifics; MANETs comparably uniform
  - ***Environment interaction***: core of WSN, absent in MANET
  - ***Scale***: WSN might be much larger (although contestable)
  - ***Energy***: WSN tighter requirements, maintenance issues
  - ***Dependability/QoS***: in WSN, individual node may be dispensable (network matters), QoS different because of different applications
  - ***Data centric*** vs. id-centric networking
  - ***Mobility***: different mobility patterns like (in WSN, sinks might be mobile, usual nodes static)

Wireless fieldbuses and WSNs

- Fieldbus:
  - Network type invented for real-time communication, e.g., for factory-floor automation
  - Inherent idea of sensing/measuring and controlling
  - Wireless fieldbus: Real-time communication over wireless

! Big similarities

- Differences
  - Scale – WSN often intended for larger scale
  - Real-time – WSN usually not intended to provide (hard) real-time guarantees as attempted by fieldbuses

Enabling technologies for WSN

- Cost reduction
  - For wireless communication, simple microcontroller, sensing, batteries
- Miniaturization
  - Some applications demand small size
  - “Smart dust” as the most extreme vision
- Energy scavenging
  - Recharge batteries from ambient energy (light, vibration, …)

Conclusion

- MANETs and WSNs are challenging and promising system concepts
- Many similarities, many differences
- Both require new types of architectures & protocols compared to “traditional” wired/wireless networks
- In particular, application-specificness is a new issue

- For more details, refer to:
  - Chapter 1, H. Karl and A. Willig, **Protocols and Architectures for Wireless Sensor Networks**, Wiley 2005.
- The lecture is available online at:
  - http://bu.edu.eg/staff/ahmad.elbanna-courses/12189
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