EE5726
Embedded Sensor Networks

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MichiganTech

General Information (EE 5726)

- Meeting time: 3:35 pm – 4:50 pm, TR
- Location: EERC 214
- Office hours: 12:00 – 1:00 pm, MW or by appointment
- Office: EERC 506
- Phone: (906) 487-2054
- Email: zhaohuiw@mtu.edu
  - EE 5726 in the subject

Today's Agenda

- Today
  - Course Overview
- Next Time: Introduction to WSNs

Prerequisites

- Computer networks:
  - *CS 4461 or EE 5722*
- Digital and statistic signal processing:
  - *EE 4252: Digital Signal Processing and its Applications*
  - *EE 5500: Probability and Stochastic Process*
  - *EE 5521: Detection and Estimation Theory*
- Wireless communications:
  - *EE 5527: Digital Communications*
  - *EE 5525: Wireless Communications*
- Hardware design:
  - *EE 3170: Microcontroller Applications*
  - *EE 3173: Hardware/Software System Integration*
  - *EE 4272: VLSI Design*
- Medium level programming:
  - *CS 1129: Introduction to Computer Science II in C++*
  - *CS 2141: Software Development Using C/C++*

Textbooks and References

- Main textbooks
  - *"Protocols and Architectures for Wireless Sensor Networks",* Holger Karl and Andreas Willig, Wiley, Chichester, 2005, http://www.wiley.com//legacy/wileychi/wsn/
  - *"Fundamentals of Wireless Sensor Networks: Theory and Practice",* Waltenegus Dargie and Christian Poellabauer, Wiley, John & Sons, Incorporated, 2010 (available online)
- Supplemental references
  - *"Networking Wireless Sensors",* Bhaskar Krishnamachari, Cambridge Press, 2005
  - *"Intelligent Sensor Networks: The Integration of Sensor Networks, Signal Processing and Machine Learning",* edited by Fei Hu and Qi Hao, CRC Press, 2012 (digital version available in library)
  - *"Wireless Sensor Networks: Signal Processing and Communications",* edited by Ananthram Swami, Qing Zhao, Yao-Win Hong, and Lang Tong, Wiley, 2007

Textbooks and References

- Supplemental references (cont.)
  - "*Security and Cooperation in Wireless Networks*", L. Buttyan and J-P. Hubaux, Cambridge University Press, 2007, http://secowinet.epfl.ch/
  - "*Fundamentals of Wireless Communication*", D. Tse and P. Viswanath, Cambridge University Press, 2005, http://www.eecs.berkeley.edu/~dtse/book.html

Most of the books are available online!

Course Description

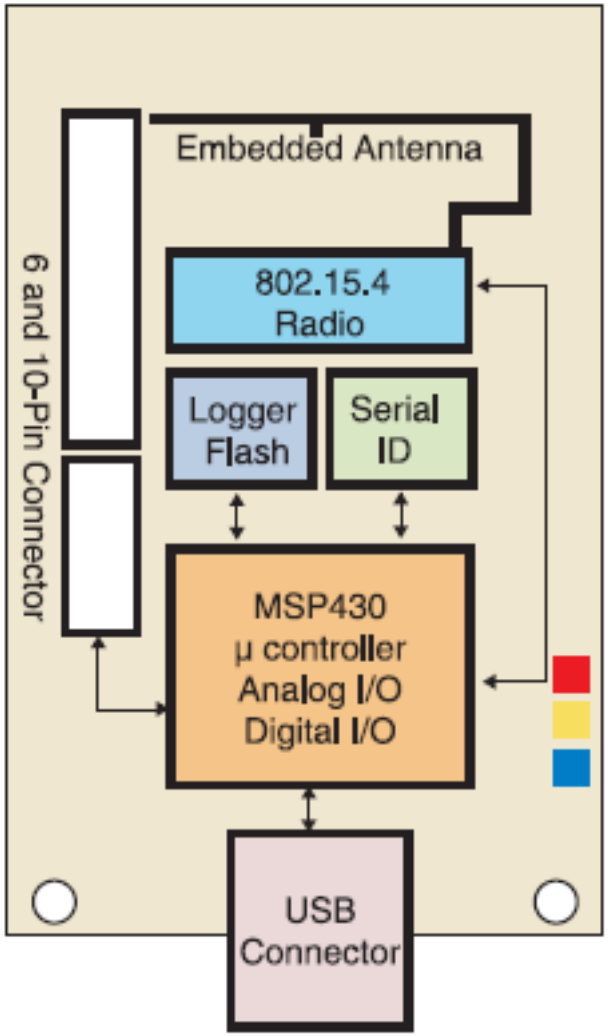
- Embedded sensor networks, largely *a.k.a* wireless sensor networks
- What is your definition of “Wireless Sensor Networks”?
  - Wiki Definition:
  - A **Wireless Sensor Network (WSN)** consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. and to cooperatively pass their data through the network to a main location…The WSN is built of "nodes" – from a few to several hundreds or even thousands, where each node is connected to one or sometimes several sensors.
    - *Network nodes*
    - *Sensing tasks*
    - *Wireless data transfer*

Wireless Sensor Node

- What components a sensor node is supposed to have?

TelosB Mote

- IEEE 802.15.4 compliant
- 250 kbps, high data rate radio
- Integrated onboard antenna
- TI MSP430 microcontroller with 10kB RAM
- Open-source operating system
- Data collection and programming via USB interface
- Integrated temperature, light and humidity sensor



TPR2400CA Block Diagram

Sensors

- Sensor (transducer):
  - gather information about physical objects or areas
  - converts one form of energy in the physical world into electrical energy
  - e.g., cameras as vision sensors, microphones as audio sensors, ultrasonic sensors, infrared sensors, temperature sensors, humidity sensors, force sensors, pressure sensors, vibration sensors, and conductivity sensors

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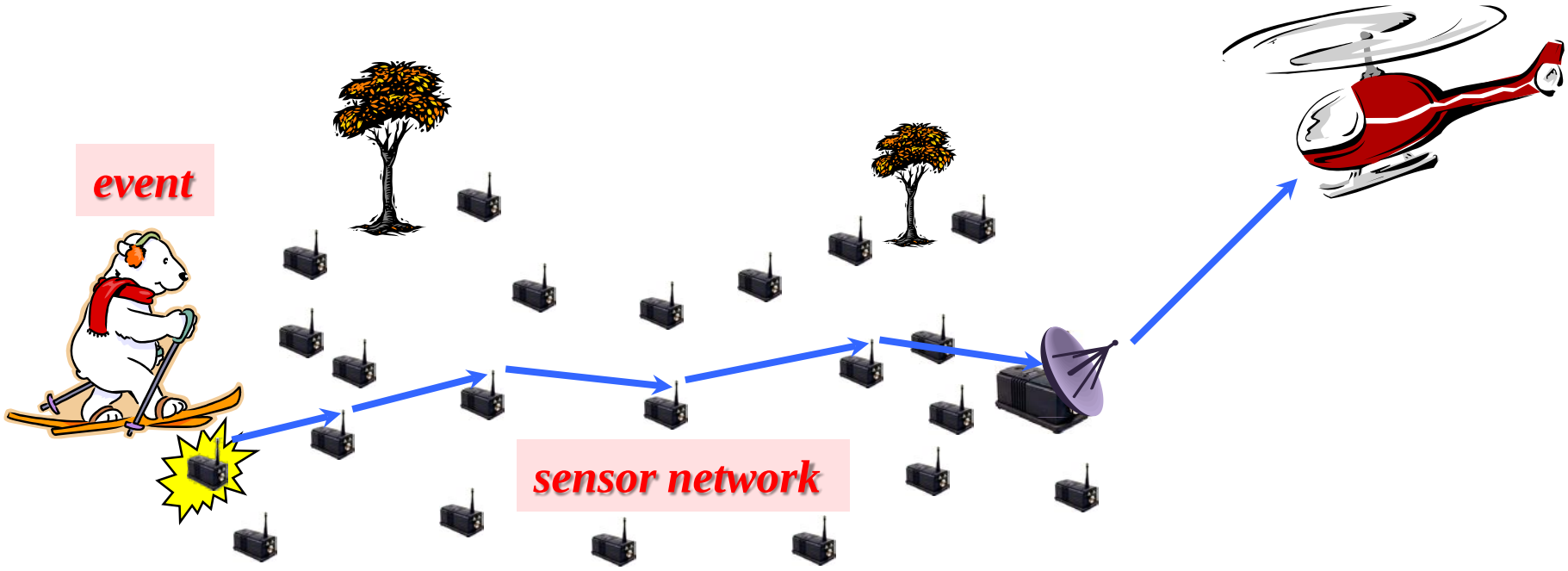
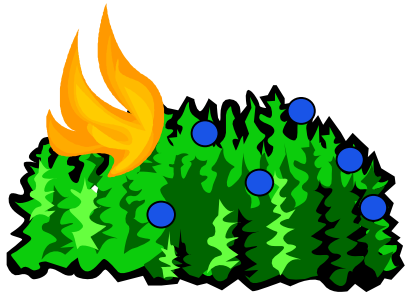
What applications of "Wireless Sensor Networks" can you think about?

Example: Event Detection

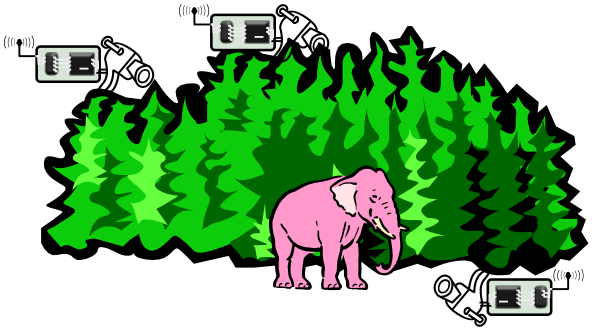
- Events: monitoring of wildlife, intruders, earthquakes, fire, contaminants, office environment, machine conditions, participants on reality shows, baby's diaper conditions, etc.



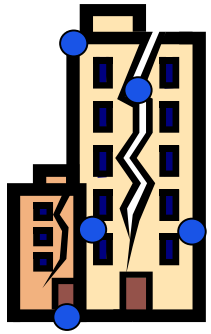
More Application Examples



- Disaster relief operations
  - Drop sensor nodes from an aircraft over a wildfire
  - Each node measures temperature
  - Derive a “temperature map”

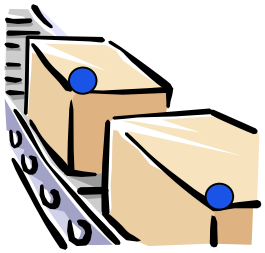


- Biodiversity mapping
  - Use sensor nodes to observe wildlife
- Intelligent buildings
  - Reduce energy wastage by proper humidity, ventilation, air conditioning (HVAC) control (smart home)
  - Structural health monitoring: e.g. buildings, bridges, stadiums, dams, aircrafts

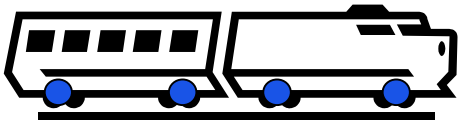


More Application Examples

- Facility management
  - Intrusion detection in industrial sites
  - Control of leakages in chemical plants
- Logistics
  - Equip goods (parcels, containers) with a sensor node
  - Track their whereabouts – total asset management



- 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

More Application Examples

- Medicine and health care
  - Post-operative or intensive care with sensors attached to patients
  - Long-term surveillance of chronically ill patients or the elderly
  - *Wireless health care networks*
- Telematics
  - *any integrated use of telecommunications and informatics*
    - e.g., for application in vehicles and with control of vehicles on the move
  - Cars as the sensor nodes
  - provide better traffic control by obtaining finer-grained information about traffic conditions
  - *Vehicular ad hoc networks (VANET)*

Lots of videos about the application of WSNs on Youtube

Why are Wireless Sensor Networks Important?

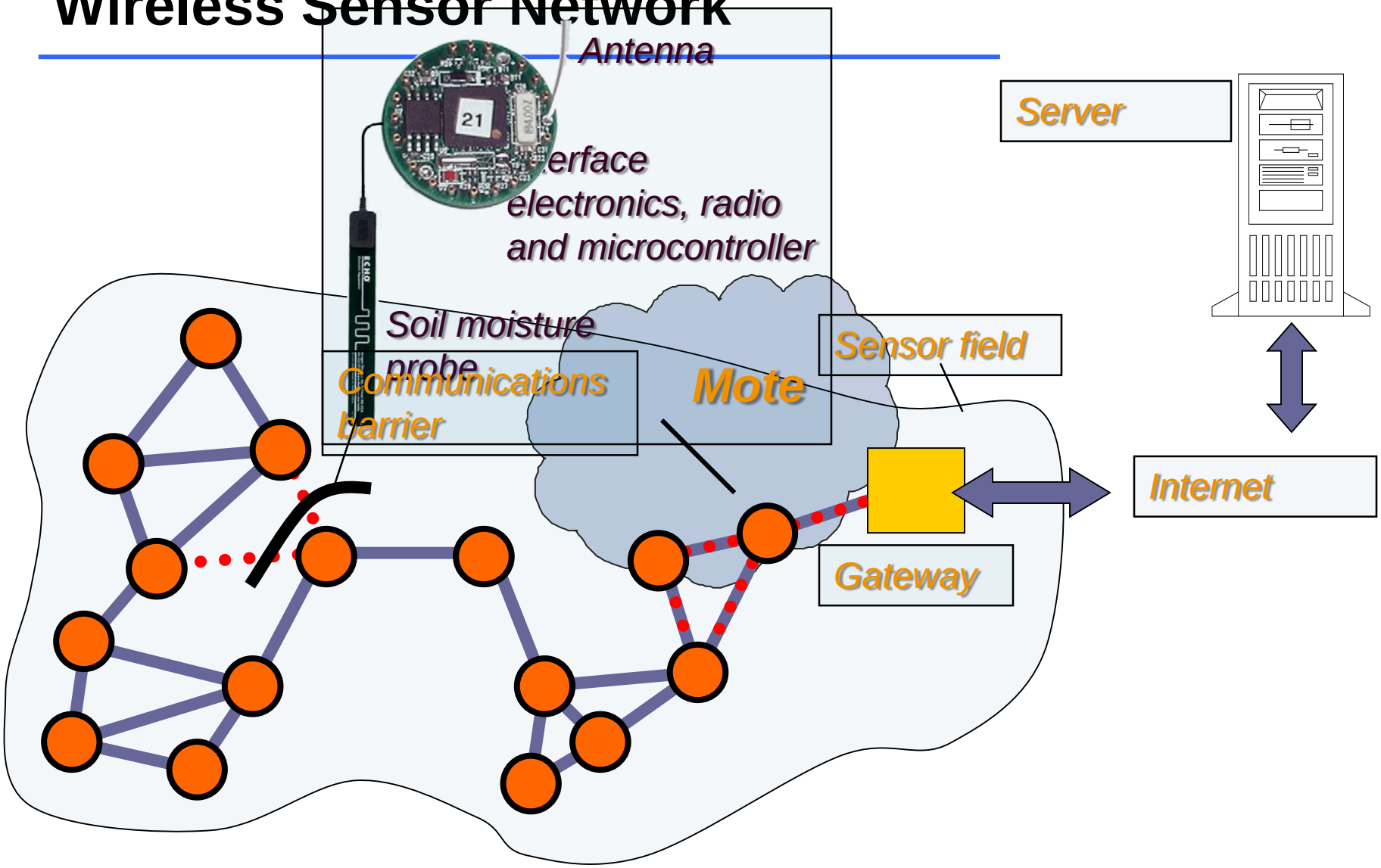
In the next century, planet earth will don an electronic skin. It will use the Internet as a scaffold to support and transmit its sensations. This skin is already being stitched together. It consists of millions of embedded electronic measuring devices: thermostats, pressure gauges, pollution detectors, cameras, microphones, glucose sensors, EKGs, electroencephalographs. These will probe and monitor cities and endangered species, the atmosphere, our ships, highways and fleets of trucks, our conversations, our bodies--even our dreams.

Business Week, 8/30, 1999.

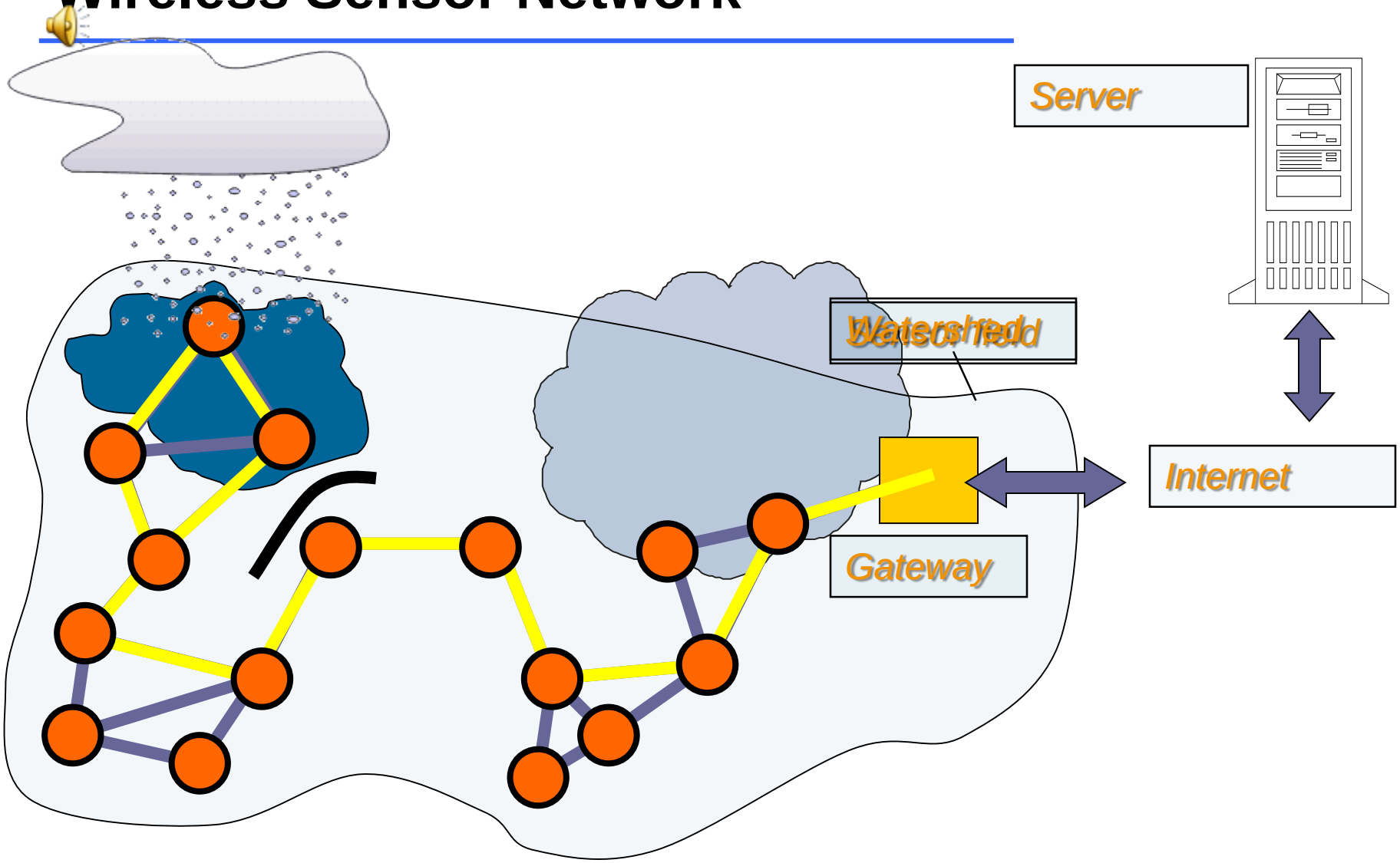
Internet of Things
Internet of Everything

http://www.businessweek.com/1999/99_35/b3644024.htm/
http://www.geoplace.com/gw/2003/0309/0309swb.asp

Wireless Sensor Network



Wireless Sensor Network



Challenges in WSNs

- Network node design
  - *sensor technology*
  - *wireless communication technology*
  - *power supply/management*
- Network node deployment
- Network node coordination: medium access control, data routing, in-network processing, etc.
- Data storage and query
- Network node clock synchronization and localization
- Fault tolerant and network security
- Mobile networks, e.g., vehicular ad hoc networks
- ...

- *John A. Stankovic, Tarek Abdelzaher, Chenyang Lu, Lui Sha, Jennifer Hou, Real-Time Communication and Coordination in Embedded Sensor Networks, Proceedings of the IEEE, 91(7): 1002-1022, July 2003*

Comparison between Traditional Networks and WSNs

Traditional networks	Wireless sensor networks
General-purpose design; serving many applications	Single-purpose design; serving one specific application
Typical primary design concerns are network performance and latencies; energy is not a primary concern	Energy is the main constraint in the design of all node and network components
Networks are designed and engineered according to plans	Deployment, network structure, and resource use are often ad hoc (without planning)
Devices and networks operate in controlled and mild environments	Sensor networks often operate in environments with harsh conditions
Maintenance and repair are common and networks are typically easy to access	Physical access to sensor nodes is often difficult or even impossible
Component failure is addressed through maintenance and repair	Component failure is expected and addressed in the design of the network
Obtaining global network knowledge is typically feasible and centralized management is possible	Most decisions are made localized without the support of a central manager

Course Objectives

- Understand the fundamental concepts in WSN
  - Wireless sensor network architecture
  - Important physical-layer algorithms and network protocols
- Preparation for graduate-level research on WSN
  - Physical-layer communication algorithms
  - Network protocol design
  - Distributed and collaborative information processing techniques for WSNs
  - Particular challenges in practical applications

Grading Systems

- Homework (20%):
  - Due in class every Thursday
  - Late assignments accepted with 20% reduction each day
- Mid-term exam (25%): middle of October
- Course project (40%):
  - Includes proposal, mid-term report and presentation, final report and presentation
  - The instructor shall schedule meetings with students on project matters
- In-class quizzes (10%): random
- Class participation (5%)
  - Attend all the classes
  - Ask/answer questions, contribute to class discussions

Course Project

- Goal: enhance understanding of course material through a *well-defined and well-motivated* research problem
- Team of no more than four students; formed in the 3rd week
- Project topics
  - The instructor will provide a list of project topics in the 2nd week
  - Identify the topic based on your own background and interests
- Proposal (one-page, due in the 5th week)
- Midterm report (five-page, due in the10th week)
- Final report/presentation (report of 10-15 pages in conference format, due at the end of semester)
  - Clear description of the problem
  - Good methodology/solution
  - Solid evaluation/validation
  - *Your role in the project*
  - Good projects could be turned into conference or journal papers

Course Outline (Tentative)

- First half of the semester
  - Wireless sensor network architecture
  - Physical-layer design
  - Network protocols
- Second half of the semester
  - Network services
    - Sensor clock synchronization
    - Sensor node localization
  - Advanced topics
  - Application examples

Course Schedule

- Syllabus

Getting to Know Your Peers

- Self introduction
  - Your name
  - Your background
  - Your research interest
  - Why take this course or what you expect to take away from this course

Homework 1

- Please briefly describe three applications of WSNs, one short paragraph for each application
  - Applications you've already known
  - Learn from
    - Textbooks
    - Reading papers
    - Watching videos
    - …
  - Due by next Thursday in class
  - More information about this assignment will be posted on Canvas

Summary

- Today
  - Course Overview
  - Any questions?
- Next time: Introduction to WSNs (Chapter 1 of Karl's book)

Questions?