Wireless Sensor Networks

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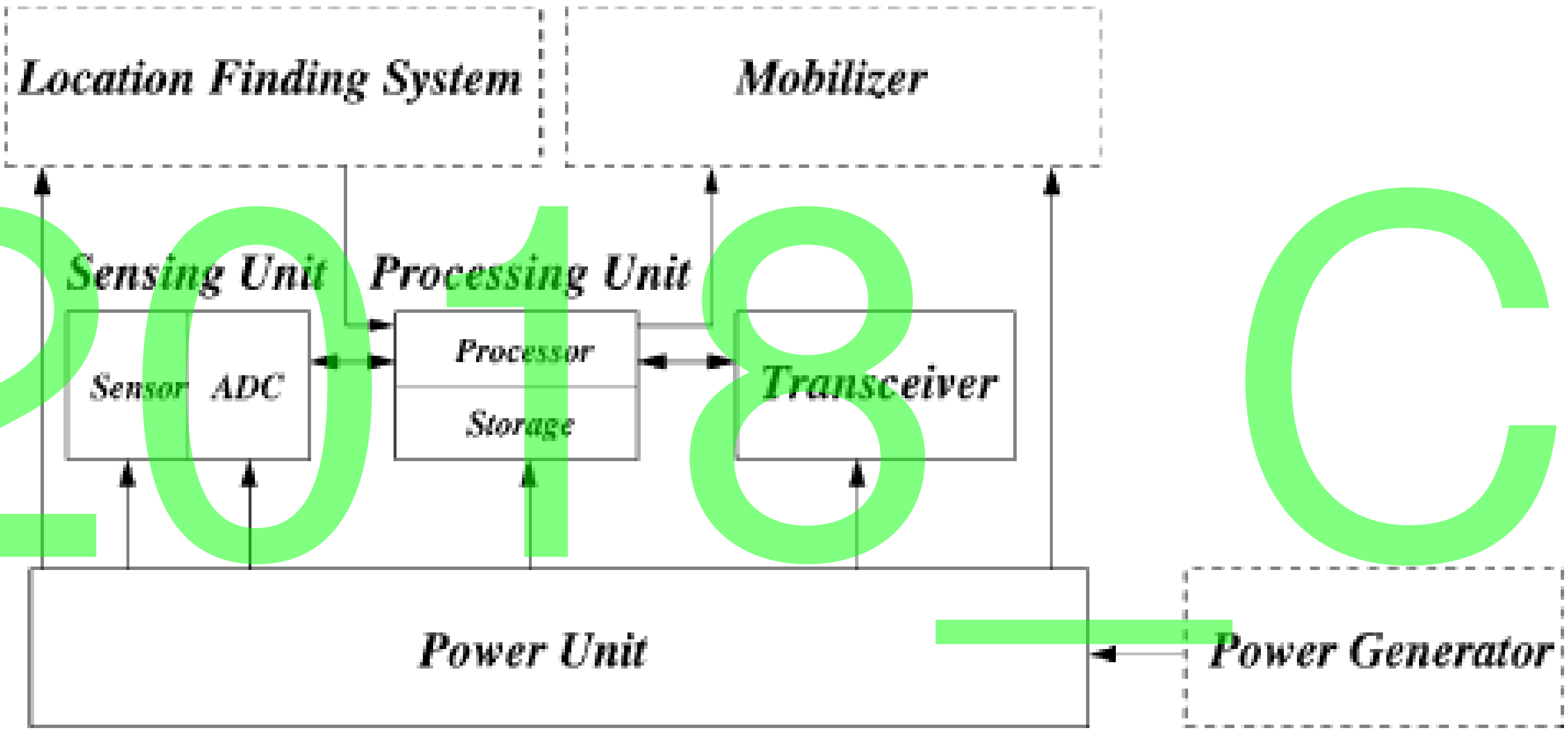
Note: Some of the slides are directly copied from other sources.

Introduction

- sensor
  - A transducer
  - converts physical phenomenon e.g. heat, light, motion, vibration, and sound into electrical signals
- sensor node
  - basic unit in sensor network
  - contains on-board sensors, processor, memory, transceiver, and power supply
- sensor network
  - consists of a large number of sensor nodes
  - nodes deployed either inside or very close to the sensed phenomenon

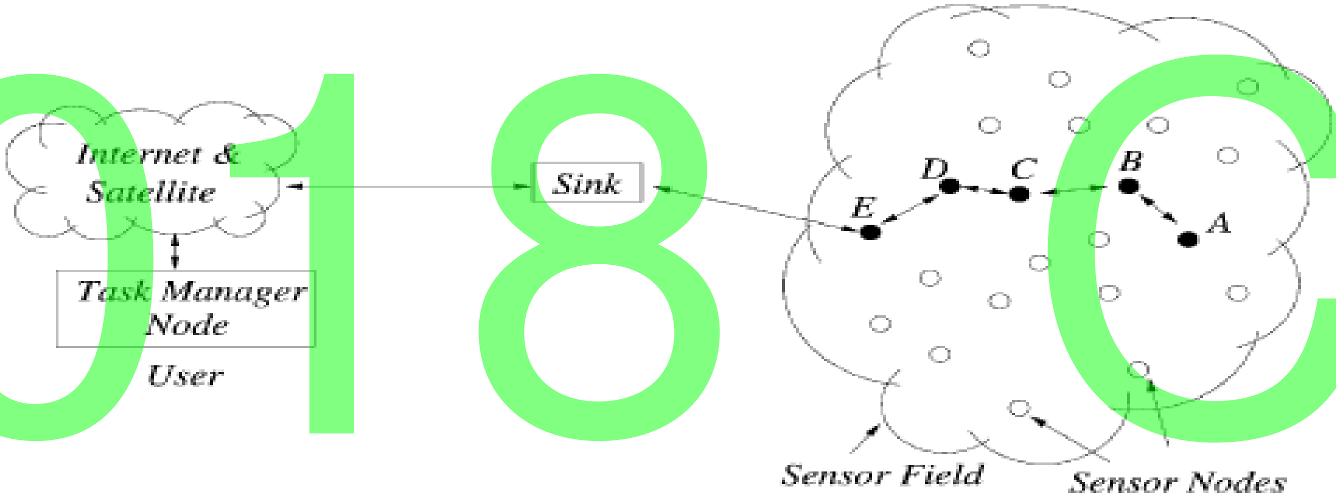
Sensor node components



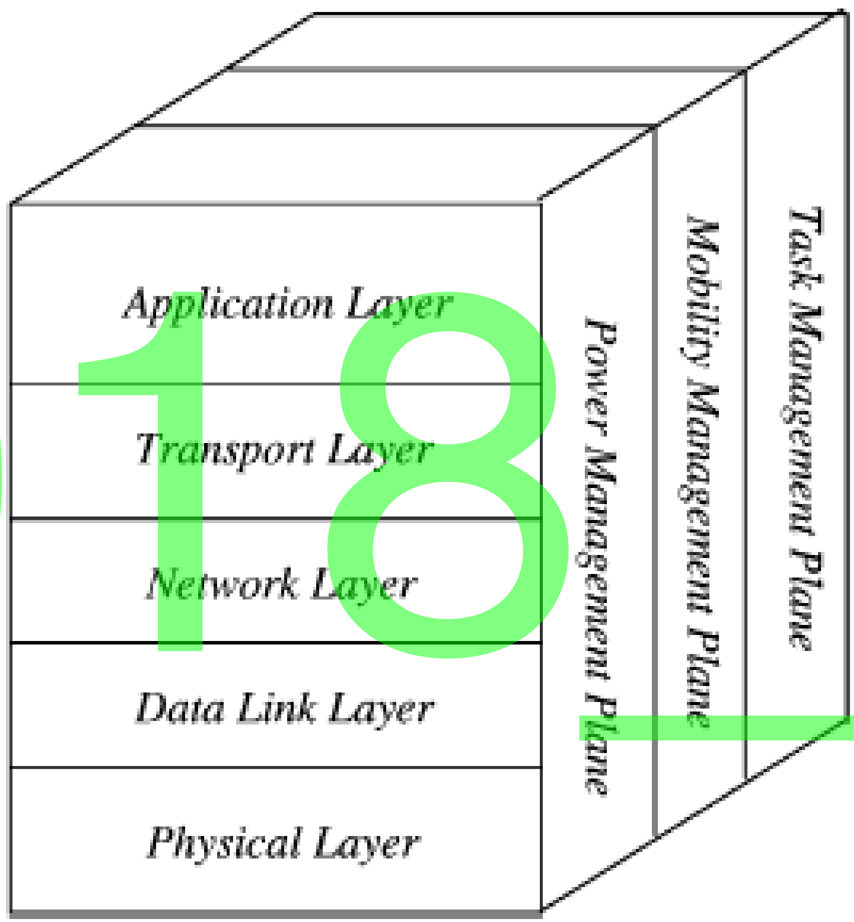
Sensor node components

- Sensing Unit
- Processing Unit
- Transceiver Unit
- Power Unit
- Location Finding System (optional)
- Power Generator (optional)
- Mobilizer (optional)

WSN Communication Architecture



WSN protocol stack



WSN operating systems

- TinyOS
- Contiki
- MANTIS
- BTnut
- SOS
- Nano-RK

TinyOS and nesC

- TinyOS
  - Most widely used operating system for sensor networks
  - Developed at UC, Berkeley
- nesC
  - Programming language for sensor networks
  - Developed at UC, Berkeley and Intel Research

Why TinyOS

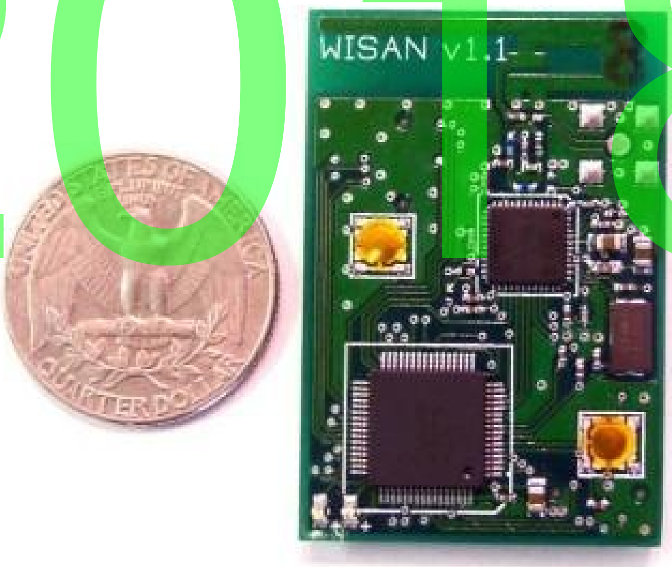
- Traditional OS are not suitable for networked sensors
- Characteristics of networked sensors
  - Small physical size & low power consumption
    - Software must make efficient use of processor & memory, enable low power communication
  - Concurrency intensive
    - Simultaneous sensor readings, incoming data from other nodes
    - Many low-level events, interleaved high-level processing
  - Limited physical parallelism (few controllers, limited capability)
  - Diversity in design & usage
    - Software modularity – application specific

TinyOS solution

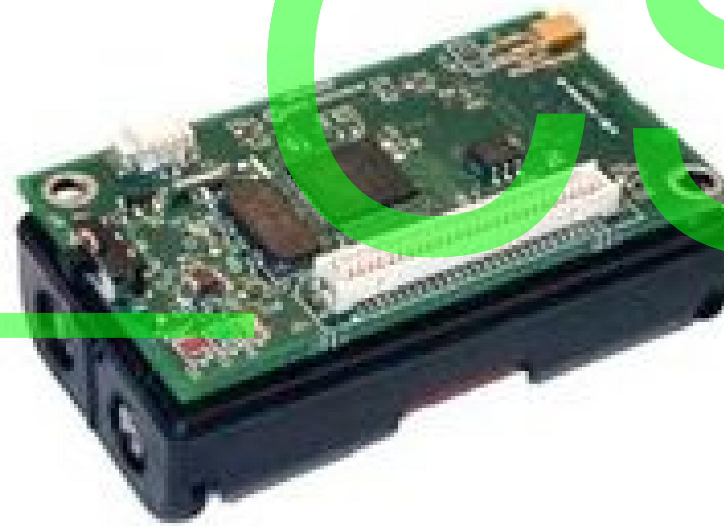
- Support concurrency
  - event-driven architecture
- Software modularity
  - application = scheduler + graph of components
  - A component contains commands, event handlers, internal storage, tasks
- Efficiency: get done quickly and then sleep
- Static memory allocation

Sensor nodes

Worldsens Inc. Sensor Node



Crossbow Sensor Node



What are motes?

Motes mainly consist of three parts:-

- Mote basically consists of a low cost and power computer.
- The computer monitors one or more sensors. Sensors may be for temperature, light, sound, position, acceleration, vibration, stress, weight, pressure, humidity, etc.
- The computer connects to the outside world with a radio link.

Mica 2 Motes

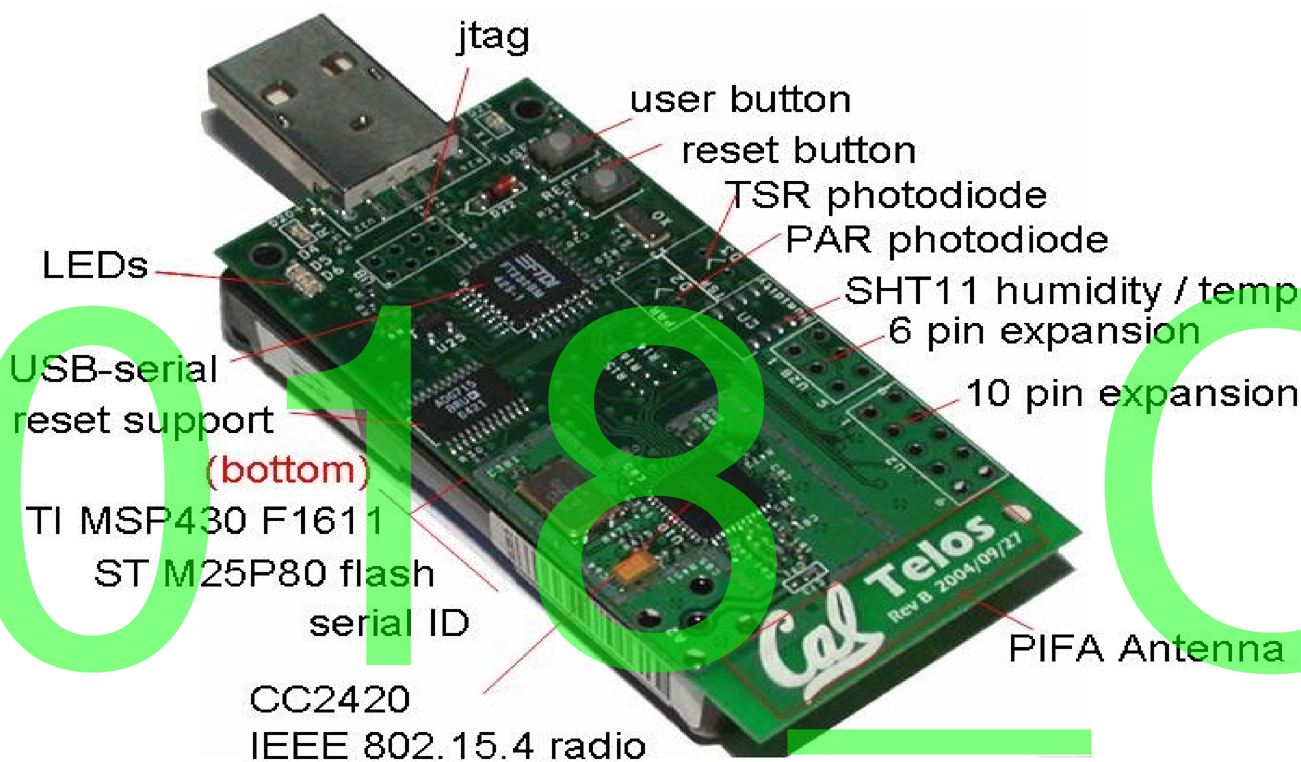
- These motes sold by Crossbow were originally developed at the University of California Berkeley.
- The MICA2 motes are based on the ATmega128L AVR microprocessor. The motes run using TinyOS as the operating system.
- Mica2 mote is one of the most popular and commercially available sensors which are marketed by CrossBow technologies.

Copied from http://www.xbow.com/Products/Product_pdf_files/Wireless_pdf/MICA2_Datasheet.pdf

Telosb Motes

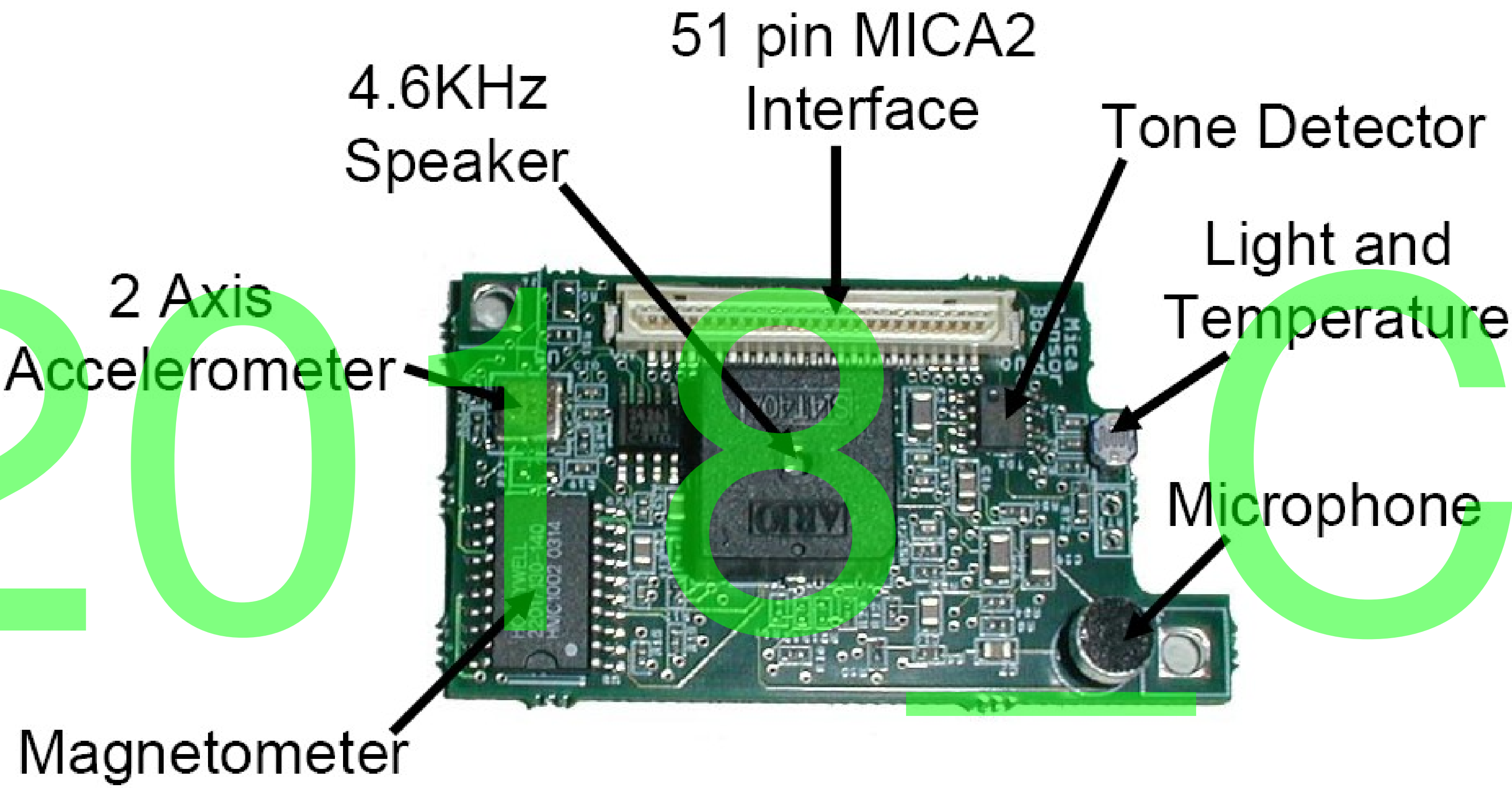
- Telosb motes have USB programming capability
- An IEEE 802.15.4 compliant, high data rate radio with integrated antenna, a low-power MCU
- There are also equipped with extended memory and an optional sensor suite

TELOSB MOTE



Ref:http://www.eecs.berkeley.edu/~culler/eecs194/labs/lab1/telosb.JPG

One Example Sensor Board - MTS310

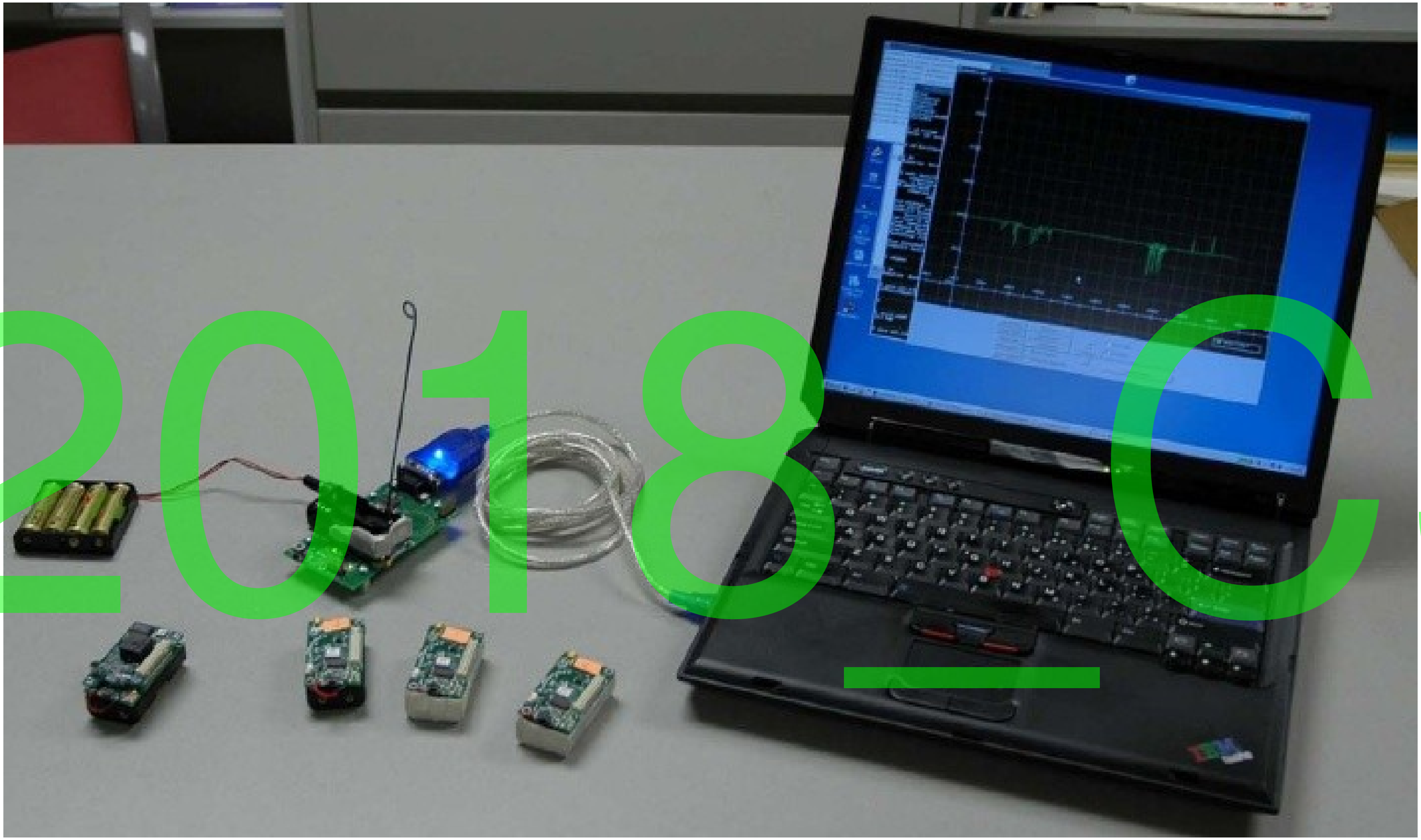


One More Example of Sensor Board - MTS400/420

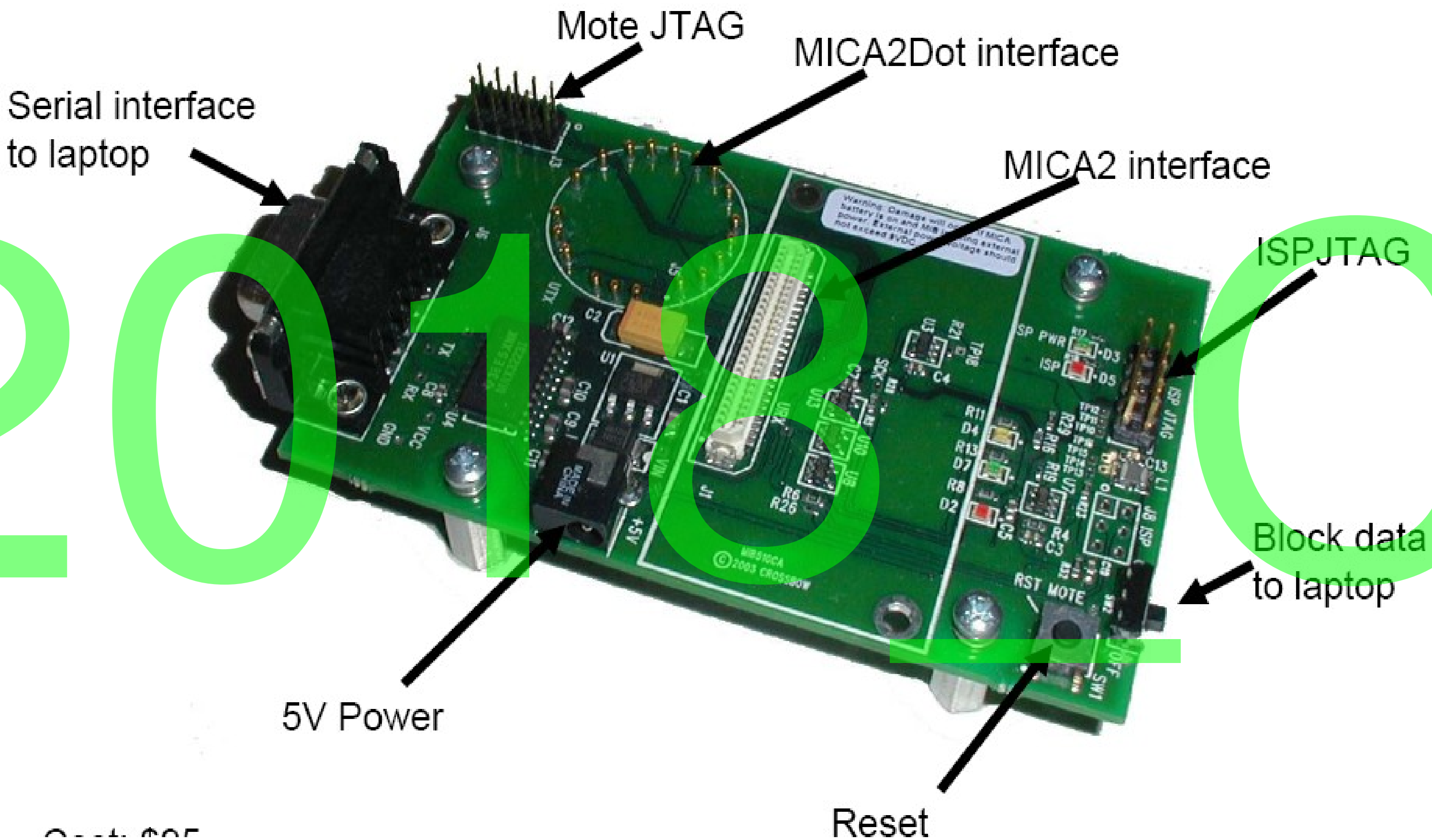
- Besides the functions of MTS 300, it mainly adds GPS functionality

- Further Reading
  - http://firebug.sourceforge.net/gps_tests.htm

Hardware Setup Overview



Programming Board (MIB520)



Architecture to Build WSN Applications

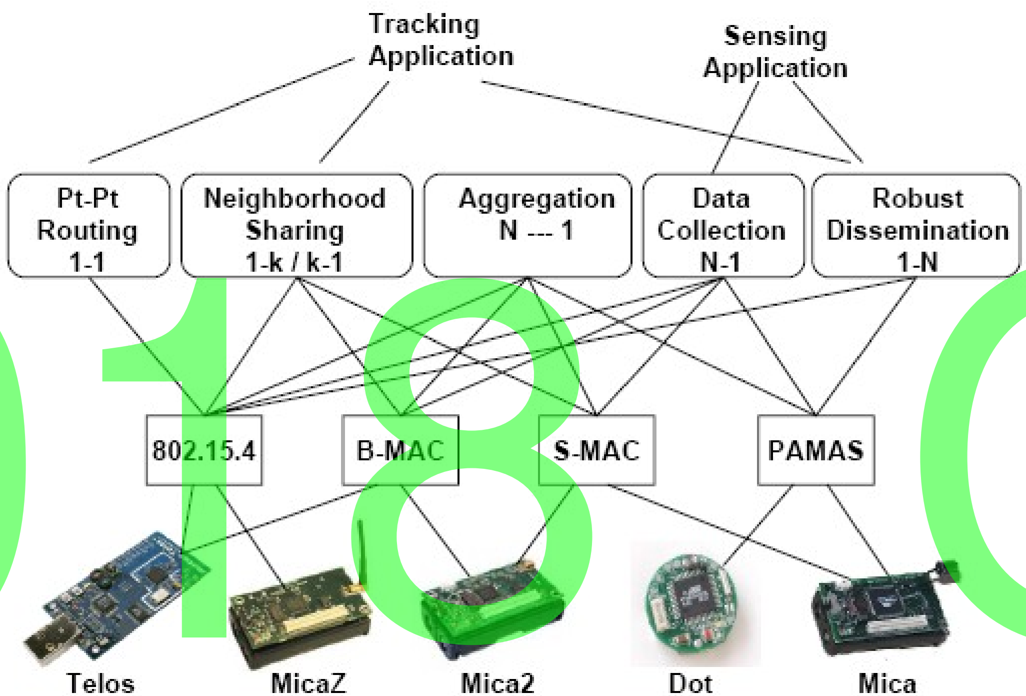


Figure 2.1: Current architecture for building sensornet applications. An application may choose a subset of network services that it requires. Those network protocols specify a set of link protocols that they support, which constrains the platforms available for application developers.

Introduction to Wireless Sensor Networks

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- Ref: Fig. 2.1 of J. Polastre Dissertation

WSN Simulators

- NS-2/NS-3
- GloMoSim
- OPNET
- SensorSim
- J-Sim
- OMNeT++
- Sidh
- SENS

WSN Simulators

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Applications of Wireless Sensor networks

The applications can be divided in three categories:

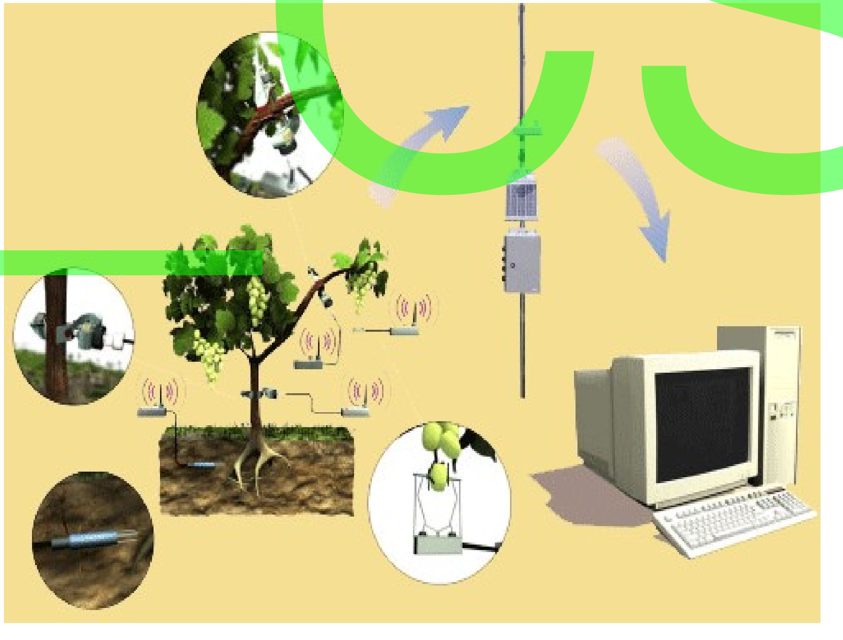
- Monitoring of objects.
- Monitoring of an area.
- Monitoring of both area and objects.

Monitoring Area

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

Example: Precision Agriculture

- Precision agriculture aims at making cultural operations more efficient, while reducing environmental impact.
- The information collected from sensors is used to evaluate optimum sowing density, estimate fertilizers and other inputs needs, and to more accurately predict crop yields.



Monitoring Objects

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

Example: Condition-based Maintenance

- Intel fabrication plants
  - Sensors collect vibration data, monitor wear and tear; report data in real-time
  - Reduces need for a team of engineers; cutting costs by several orders of magnitude

Monitoring Interactions between Objects and Space

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

Example: Habitat Monitoring

- The ZebraNet Project

  Collar-mounted sensors monitor zebra movement in Kenya

Source: Margaret Martonosi, Princeton University

Operational Challenges of Wireless Sensor Networks

- Energy Efficiency
- Limited storage and computation
- Low bandwidth and high error rates
- Errors are common
  - Wireless communication
  - Noisy measurements
  - Node failure are expected
- Scalability to a large number of sensor nodes
- Survivability in harsh environments
- Experiments are time- and space-intensive

Low bandwidth

Bandwidth is the capacity or amount of data that can transmit over an electronic channel during a specific period of time.

- Low bandwidth is a type of bandwidth classified by bit rate, or bits per second.
- Low bandwidth services, such as dial-up Internet, typically are limited to a bit rate of less than 56 kbit/s, or kilobits per second, and may require a dedicated phone line for connection.
- Dial-up Internet access is a form of Internet access that uses the facilities of the public switched telephone network (PSTN) to establish a connection to an Internet service provider (ISP) by dialing a telephone number on a conventional telephone line.
- A kilobit is equal to 1,000 bits.
- High bandwidth or broadband Internet can transmit over multiple channels that have frequency capacities measured in megahertz

Communication architecture of sensor networks

Network layer:

- Power efficiency is always an important consideration.
- Sensor networks are mostly data centric.
- Data aggregation is useful only when it does not hinder the collaborative effort of the sensor nodes.
- An ideal sensor network has attribute-based addressing and location awareness.

Several Network Layer Schemes for Sensor Networks

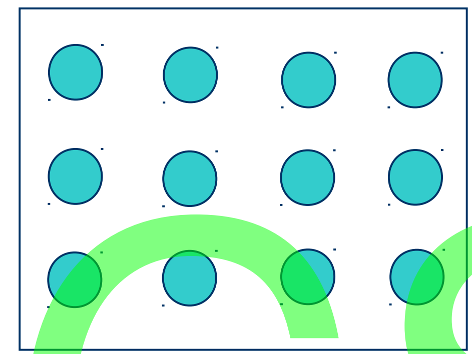
Network layer scheme	Description
SMECN [18]	Creates a subgraph of the sensor network that contains the minimum energy path
Flooding	Broadcasts data to all neighbor nodes regardless if they receive it before or not
Gossiping [19]	Sends data to one randomly selected neighbor
SPIN [15]	Sends data to sensor nodes only if they are interested; has three types of messages (i.e., ADV, REQ, and DATA)
SAR [13]	Creates multiple trees where the root of each tree is one hop neighbor from the sink; selects a tree for data to be routed back to the sink according to the energy resources and additive QoS metric
LEACH [16]	Forms clusters to minimize energy dissipation
Directed diffusion [5]	Sets up gradients for data to flow from source to sink during interest dissemination

Issues in sensor networks

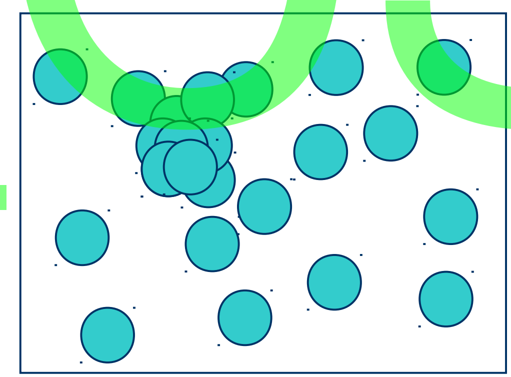
- Deployment
- Coverage
- Location discovery
- Tracking

Sensor Deployment

- How to deploy sensors over a field?
  - Deterministic, planned deployment
  - Random deployment

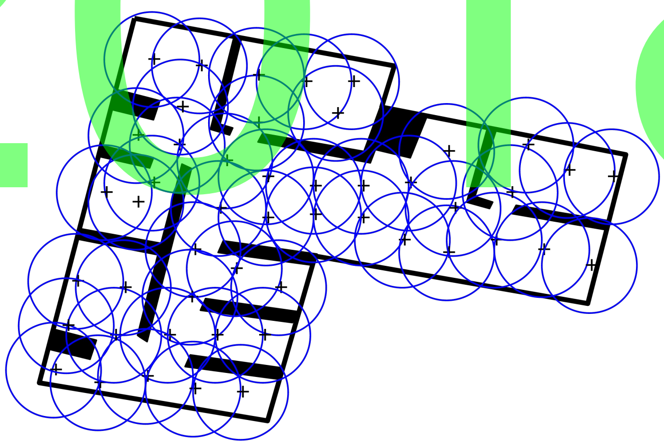


- Desired properties of deployments?
  - Depends on applications
  - Connectivity
  - Coverage

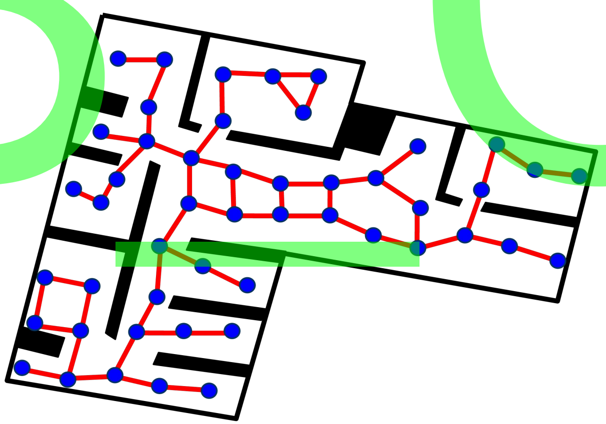


Sensor Deployment

- Sensor deployment is a critical issue because it affects the *cost* and *detection capability* of a wireless sensor network
- A good sensor deployment should consider both *coverage* and *connectivity*



Coverage



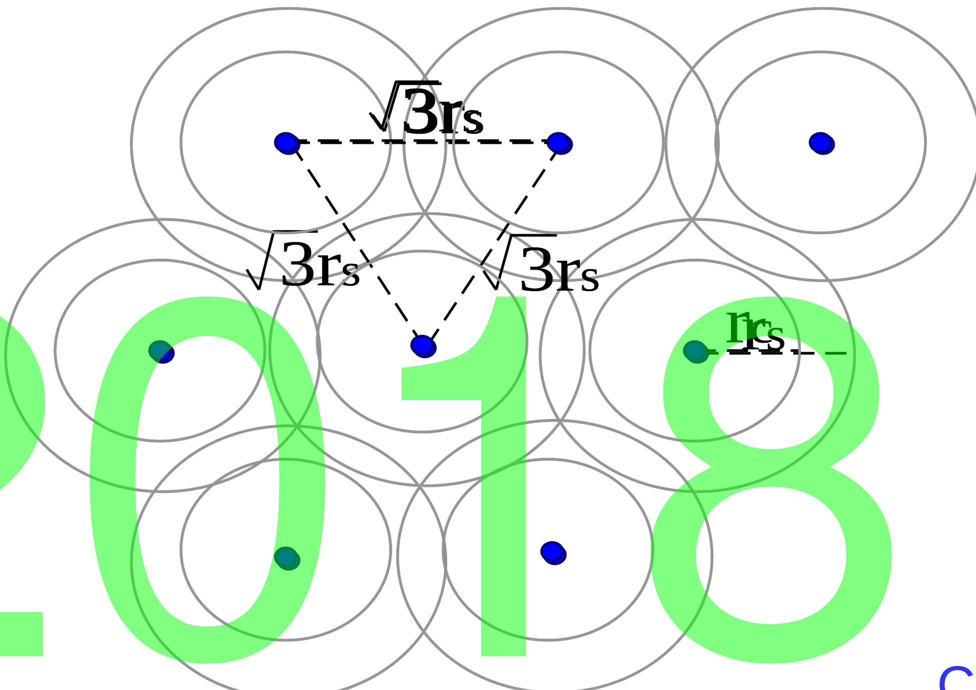
Connectivity

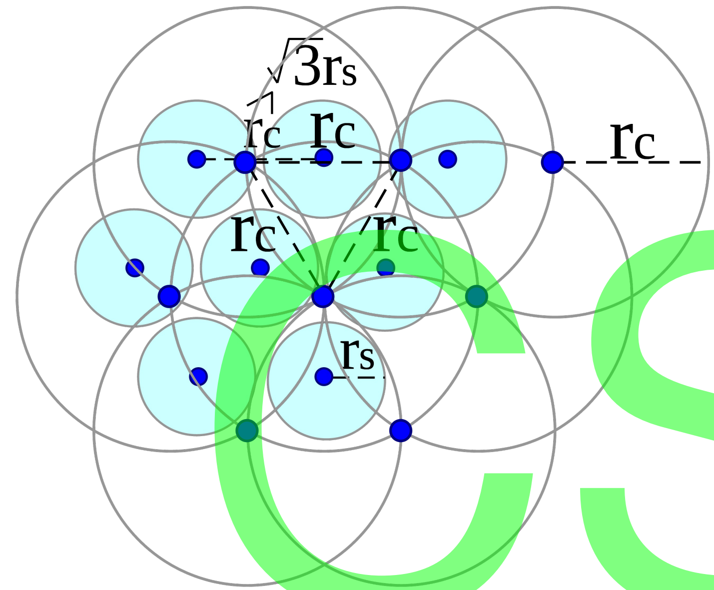
Coverage in WSN

Coverage: Measure of Quality of Service

- How well a region is covered?
- What is the probability that an object will be detected?
- K-coverage

Coverage and connectivity





Consider coverage first

Need to add extra sensors to maintain *connectivity* when

$$r_c < \sqrt{3} r_s$$

Consider connectivity first

Need to add extra sensors to maintain *coverage* when

$$r_c > \sqrt{3} r_s$$

Read

- Coverage and Connectivity Issues in Wireless Sensor Networks, by AMITABHA GHOSH and SAJAL K. DAS
- Coverage Problems in Sensor Networks: A Survey, by BANG WANG, Huazhong University of Science and Technology
- A Solution to Sensor Network Coverage Problem, by M. P. Singh and M. M. Gore

Problem

- We are given
  - A sensing field **A**
  - An area of interest **I** inside **A**
  - A set of mobile sensors **S** resident in **A**
- The sensor dispatch problem asks how to find a *subset* of sensors **S'** in **S** to be moved to **I** such that after the deployment, **I** satisfies *coverage* and *connectivity* requirements and the movement cost satisfies some *objective functions.*