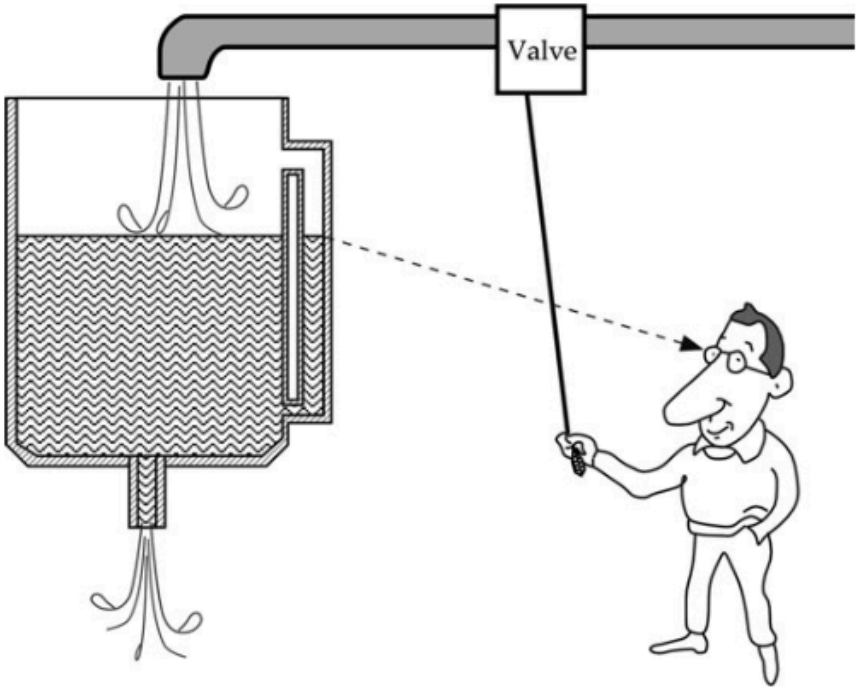
Laboratório de Pesquisa em Redes e Multimídia

Redes de Sensores e Internet das Coisas (IoT)

Introdução

Universidade Federal do Espírito Santo
Departamento de Informática

What is a Sensor?

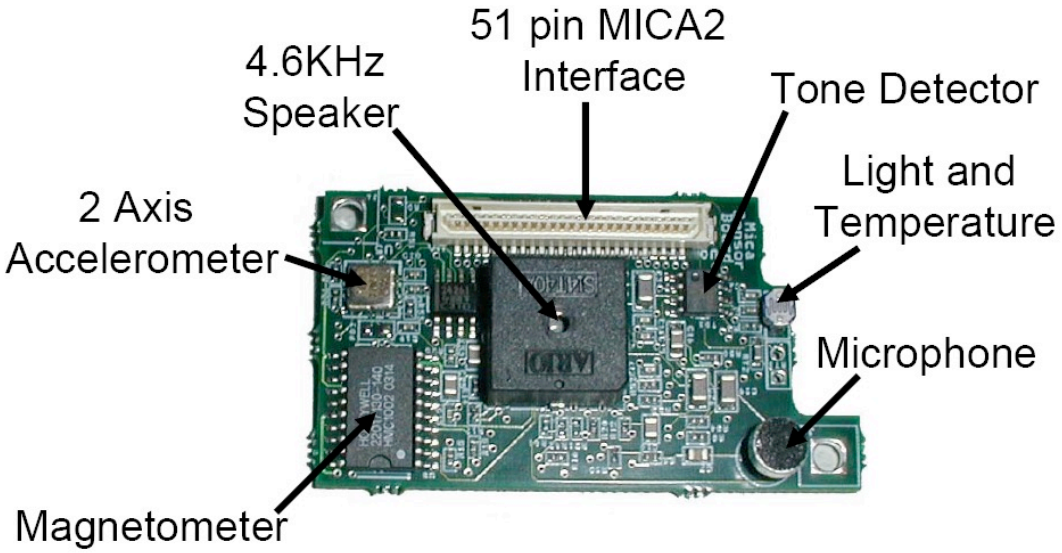


A sensor is often defined as a *"device that receives and responds to a signal or stimulus."* (too generic!!)

In this fluid control system, the operator adjusts the level of fluid in the tank by manipulating its valve. Variations in the inlet flow rate, temperature changes (these would alter the fluid's viscosity and consequently the flow rate through the valve), and similar disturbances must be compensated for by the operator. Without control, the tank is likely to flood, or run dry.

The sensor consists of two main parts: the sight tube on the tank and the operator's eye, which produces an electric response in the optic nerve. The sight tube by itself is not a sensor, and in this particular control system, the eye is not a sensor either. Only the combination of these two components makes a narrow-purpose sensor (detector), which is selectively sensitive to the fluid level.

A More Narrow Definition of a Sensor



*A sensor is a device that receives a stimulus and responds with an **electrical signal**. The stimulus is the quantity, property, or condition that is received and converted into an electrical signal.*

We may say that a sensor is a translator of a generally nonelectrical value into an electrical value. When we say "electrical," we mean a signal, which can be channeled, amplified, and modified by electronic devices.

After all, the purpose of a sensor is to respond to some kind of an input physical property (stimulus) and to convert it into an electrical signal that is compatible with electronic circuits.

Types of Stimulus

Stimulus	
Acoustic	Wave amplitude, phase, polarization
	Spectrum
	Wave velocity
	Other
Biological	Biomass (types, concentration, states)
	Other
Chemical	Components (identities, concentration, states)
	Other
Electric	Charge, current
	Potential, voltage
	Electric field (amplitude, phase, polarization, spectrum)
	Conductivity
	Permittivity
	Other
Magnetic	Magnetic field (amplitude, phase, polarization, spectrum)
	Magnetic flux
	Permeability
	Other
Optical	Wave amplitude, phase, polarization, spectrum
	Wave velocity
	Refractive index
	Emissivity, reflectivity, absorption
	Other
Mechanical	Position (linear, angular)
	Acceleration
	Force
	Stress, pressure
	Strain
	Mass, density
	Moment, torque
	Speed of flow, rate of mass transport
	Shape, roughness, orientation
	Stiffness, compliance
	Viscosity
	Crystallinity, structural integrity
	Other
Radiation	Type
	Energy
	Intensity
	Other
Thermal	Temperature
	Flux
	Specific heat
	Thermal conductivity
	Other

Objeto Inteligente ("smart object")

- *Pequeno dispositivo eletrônico equipado com um elemento sensor ou atuador, um pequeno microprocessador, uma memória de baixa capacidade, um componente de comunicação de baixo alcance e uma fonte de alimentação que garante a energia elétrica necessária para que o dispositivo possa realizar o seu trabalho*.

(Vasseus, 2010)

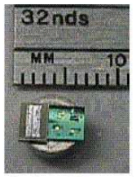
- Exemplos: nós de RSSF, coisas do mundo real ("*things*")

UC Berkeley: **COTS Dust**

UCLA: **WINS**

UC Berkeley: **COTS Dust**

Rockwell: **WINS**



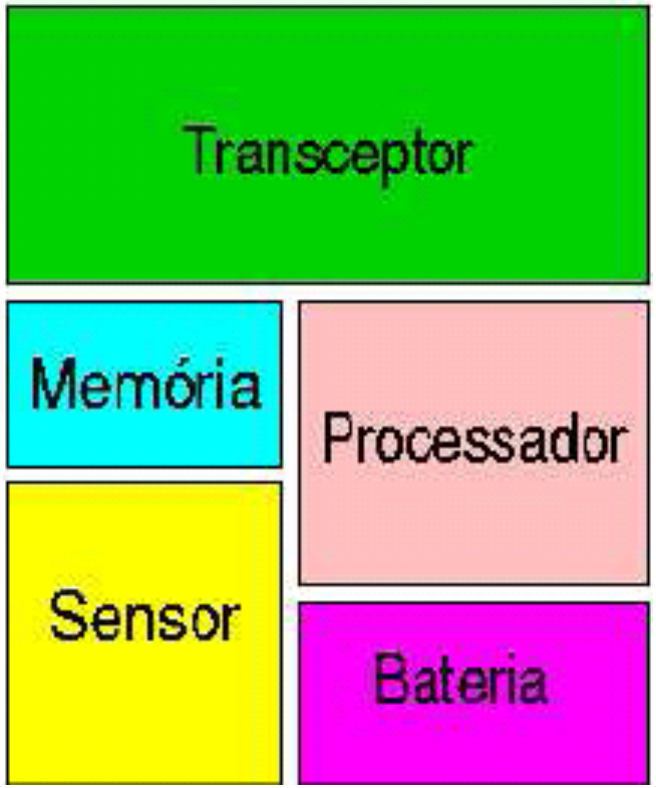
UC Berkeley: **Smart Dust**

JPL: **Sensor Webs**

Objeto Inteligente (cont.)

- O *sensor ou atuador* provê ao objeto a capacidade de interagir com o mundo físico
  - A informação do mundo físico é obtida através dos sensores e o mesmo mundo físico é afetado pelos atuadores.
- O *microprocessador* permite ao objeto realizar transformações sobre os dados capturados, embora a uma velocidade e complexidade limitadas.
  - Exemplos: fusão de dados, cálculo de médias, roteamento
- O *componente de comunicação*, por sua vez, expõe as leituras dos sensores para o mundo exterior e recebe informações enviadas por outros objetos inteligentes.

Componentes do Nó Sensor ("Mote", Sensor Node")



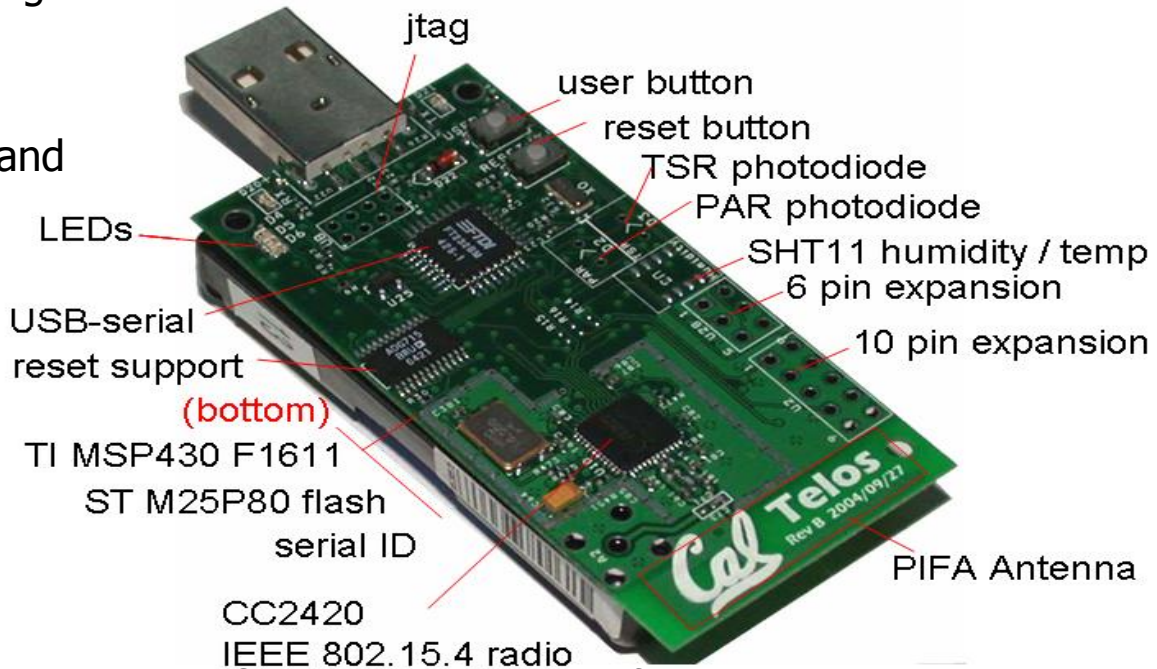
Exemplo: MicaZ

- Processador MPR2400, baseado no Atmel ATmega 128L
- 4Kbytes de EEPROM
- Conector de expansão para sensor de luminosidade, temperatura, umidade relativa, pressão barométrica, aceleração/sísmico, acústico, magnético e outras placas de sensoriamento da MEMSIC
- 2 baterias AA

Ref - http://www.memsic.com/userfiles/files/Datasheets/WSN/micaz_datasheet-t.pdf

Exemplo: TelosB

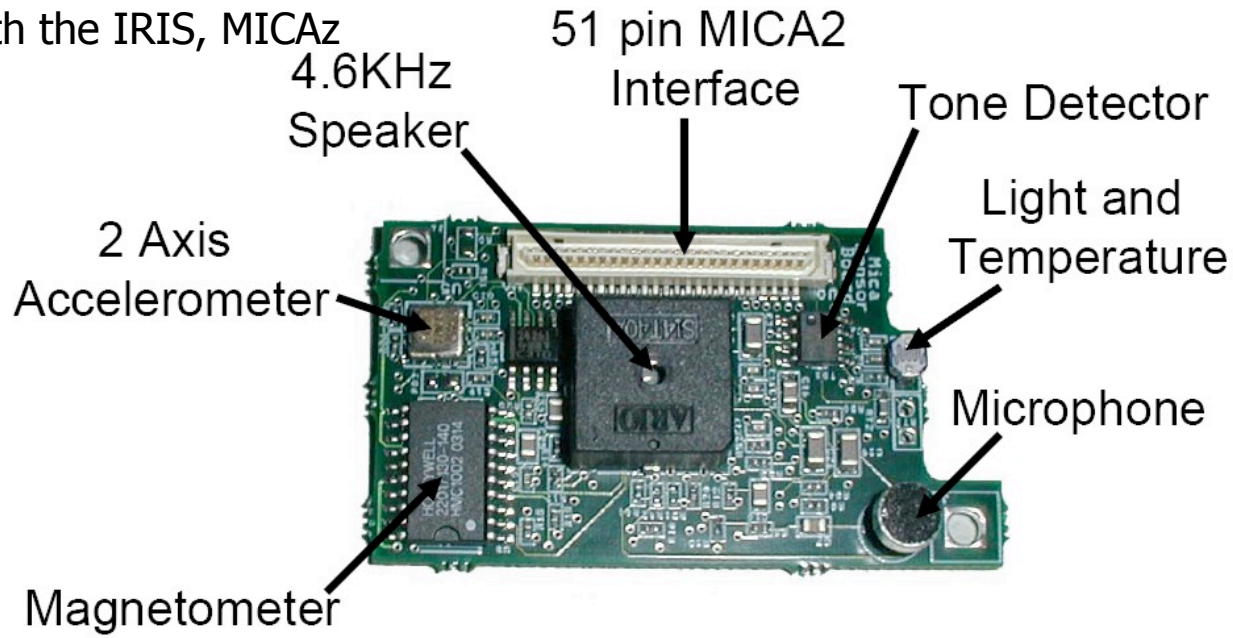
- 250 kbps, High Data Rate Radio
- TI MSP430 Microcontroller with 10kB RAM
- Integrated Onboard Antenna
- Data Collection and Programming via USB Interface
- Open-source Operating System
- Integrated Temperature, Light and Humidity Sensor



Ref - http://www.memsic.com/userfiles/files/Datasheets/WSN/telosb_datasheet.pdf

Exemplo: Sensor Board - MTS310

- The MTS310 is a flexible sensor board with a variety of sensing modalities. These modalities include a Dual-Axis Accelerometer, Dual-Axis Magnetometer, Light, Temperature, Acoustic and Sounder.
- The MTS310 is for use with the IRIS, MICAz and MICA2 Motes.



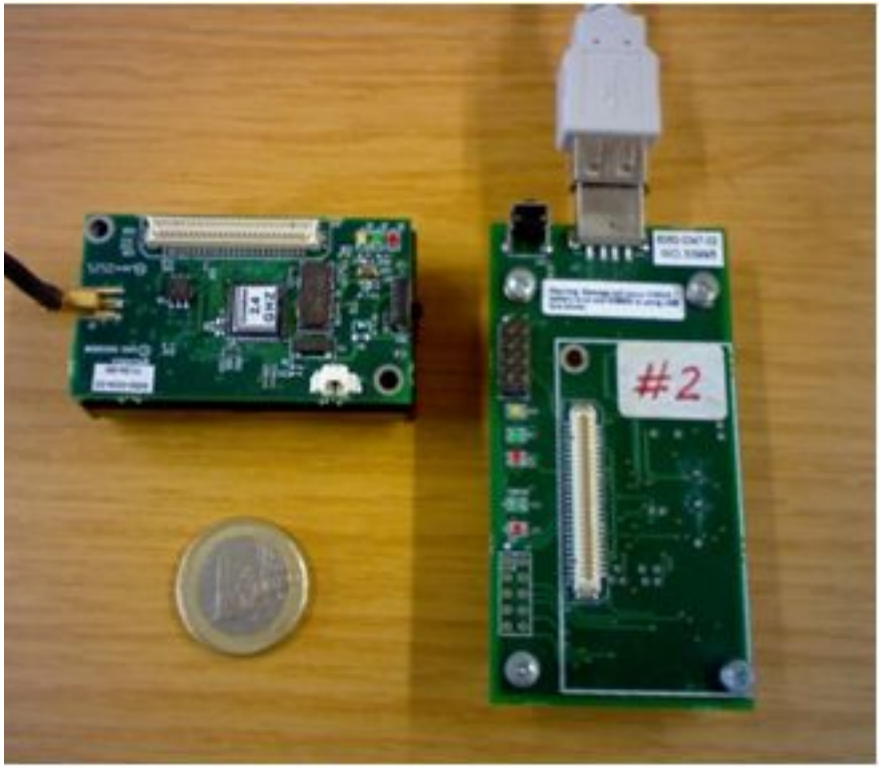
Ref - http://www.memsic.com/userfiles/files/Datasheets/WSN/mts_mda_datasheet.pdf

Exemplo: Sensor Board – MTS400/420

- Adiciona à família MTS 300 a funcionalidade de GPS

http://www.memsic.com/userfiles/files/Datasheets/WSN/mts400_420_datasheet-t.pdf

Programming Board (MIB520)

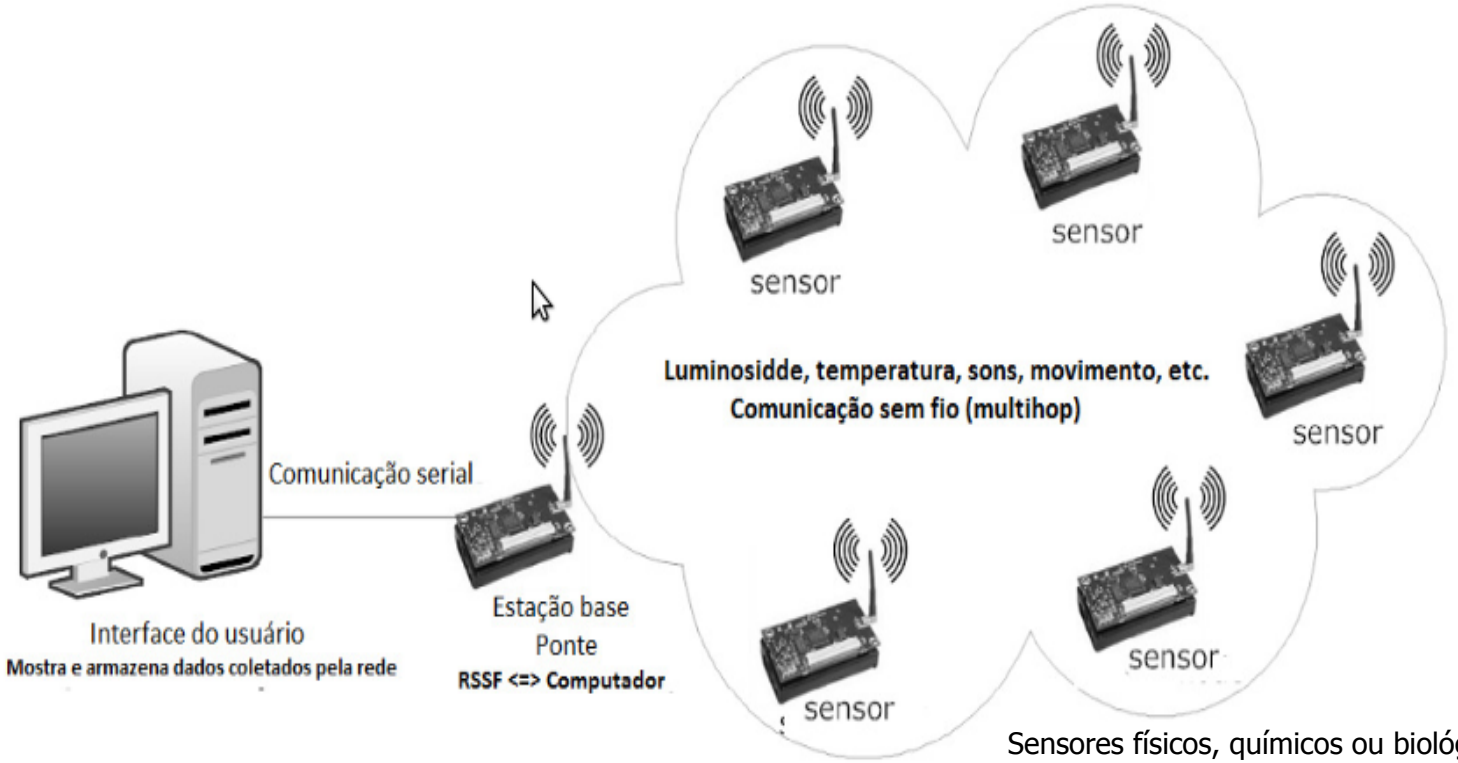


http://www.memsic.cn/userfiles/files/Datasheets/WSN/6020-0091-04_a_mib520cb-t.pdf

Wireless Sensor Networks (WSN)

- Wireless Sensor Networks are networks that consists of sensor nodes which are distributed in an ad hoc manner.
- The WSN gives the user the ability to instrument, observe, and react to events and phenomena in a specified environment, i.e., the sensor nodes work with each other to sense some physical phenomenon and then the information gathered is processed by backend systems to get relevant results.
- In addition to sensing, one is often also interested in control and activation.
- WSN consists of protocols and algorithms with self-organizing capabilities.

Redes de Sensores sem Fio (RSSF)



Sensores físicos, químicos ou biológicos

A função mais comum de um nó sensor é amostrar propriedades físicas de um ambiente, comunicar as leituras e, eventualmente, exercer alguma atuação baseada em uma ou mais entradas.

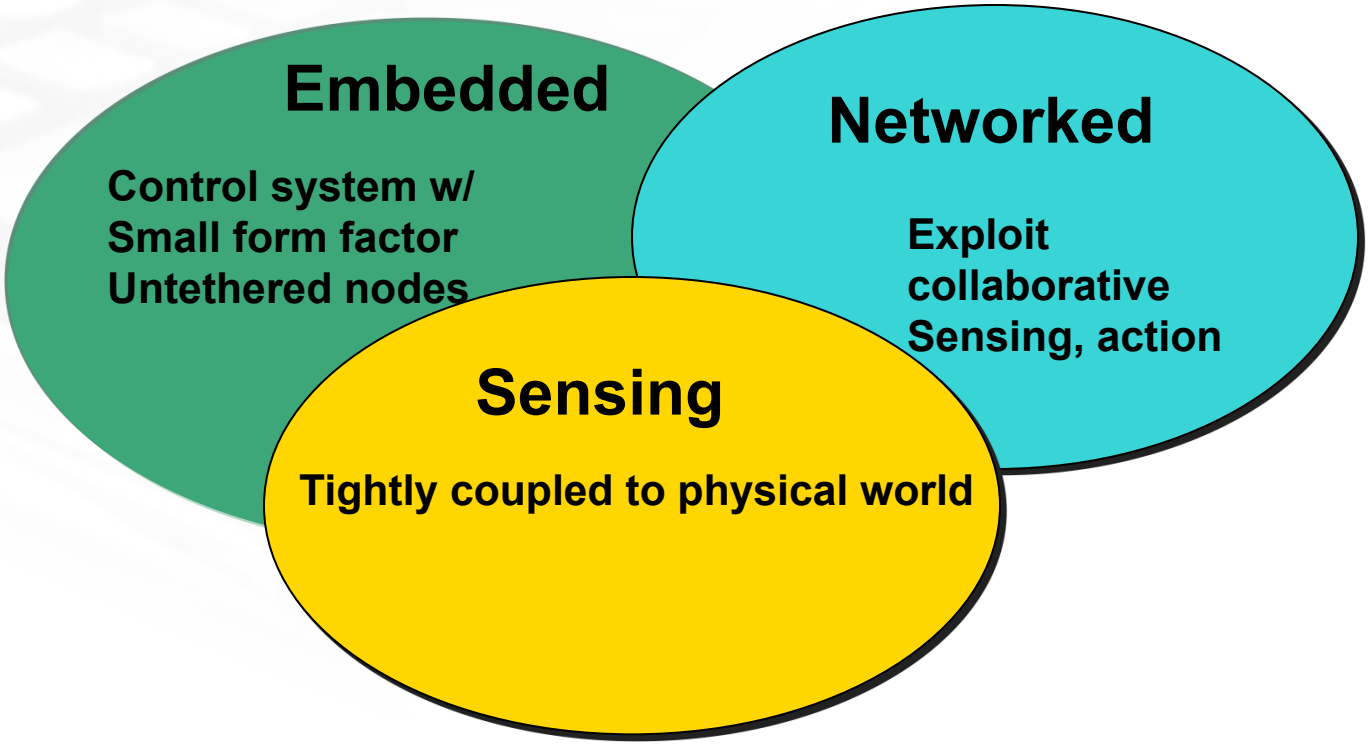
Resumindo…

- 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

Enabling Technologies

Embed numerous distributed devices to monitor and interact with physical world

Network devices to coordinate and perform higher-level tasks



Exploit spatially and temporally dense, in situ, sensing and actuation

Características Gerais das RSSF

- Alta granularidade
- Baixo custo
- Flexibilidade
- Facilidade de implantação
- Podem ser implantados em locais inóspitos, de difícil acesso e em condições ambientais extremas.
- O observador não necessariamente está ciente da infraestrutura da rede e dos sensores individualmente.
  - *Although deployed in an ad hoc manner they need to be **self organized** and **self healing** and can face constant reconfiguration.*

Operational Characteristics

- Self-management
  - *It is the nature of many sensor network applications that they must operate in remote areas and harsh environments, without infrastructure support or the possibility for maintenance and repair. Therefore, sensor nodes must be self-managing in that they configure themselves, operate and collaborate with other nodes, and adapt to failures, changes in the environment, and changes in the environmental stimuli without human intervention.*
- Limited storage and computation. Low cost & energy constraints implies low power CPU, radio with minimum bandwidth and range
- 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

Operational Characteristics

Lifetime

- Nodes are battery-powered
- Small size implies small battery
- Ad-hoc deployment implies no maintenance or battery replacement
- Nobody is going to change the batteries. So, each operation brings the node closer to death.

"**Lifetime is crucial!", so to save energy**:

- Sleep as much as possible.
- Acquire data only if indispensable.
- Use data fusion and compression.
- Transmit and receive only if necessary. Receiving is just as costly as sending.
- No raw data is transmitted

Operational Characteristics

Scalability and Reliability

WSNs should

- self-configure and be robust to topology changes (e.g., death of a node)
- maintain connectivity**:** can the Base Station reach all nodes?
- ensure coverage**:** are we able to observe all phenomena of interest?

Maintenance

- Reprogramming is the only practical kind of maintenance.
- It is highly desirable to reprogram wirelessly.

Operational Characteristics

Data Collection

- Centralized data collection puts extra burden on nodes close to the base station. Clever routing can alleviate that problem
- Clustering: data from groups of nodes are fused before being transmitted, so that fewer transmissions are needed
- Often getting measurements from a particular area is more important than getting data from each node
- Security and authenticity should be guaranteed. However, the CPUs on the sensing nodes cannot handle fancy encryption schemes.

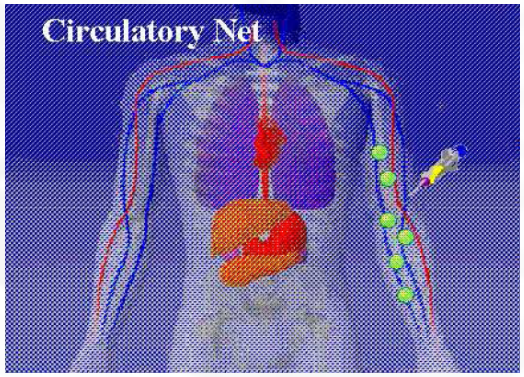
Comparation with Ad Hoc Networks

- Wireless sensor networks mainly use broadcast communication while ad hoc networks use point-to-point communication.
- Unlike ad hoc networks wireless sensor networks are limited by sensors limited power, energy and computational capability.
- Sensor nodes may not have global ID because of the large amount of overhead and large number of sensors.

Aplicações de Rede de Sensores sem Fio

- Monitoramento ambiental (poluição atmosférica)
- Agricultura (controle das condições do solo)
- Agropecuária (alimentação animal)
- Monitoramento de prédios, pontes e outras estruturas civis (fadiga, controle sísmico)
- Transporte urbano (redes veiculares)
- Logística (corredores sincromodais)
- Medicina e saúde (monitoramento de pacientes, armazenamento de medicamentos)
- Produção industrial (controle de vazão, pressão, nível e temperatura)
- Segurança e monitoramento de espaços públicos
- Monitoramento de áreas de risco (encostas)
- Gerenciamento de desastres (incêndios, enchentes de rios urbanos)

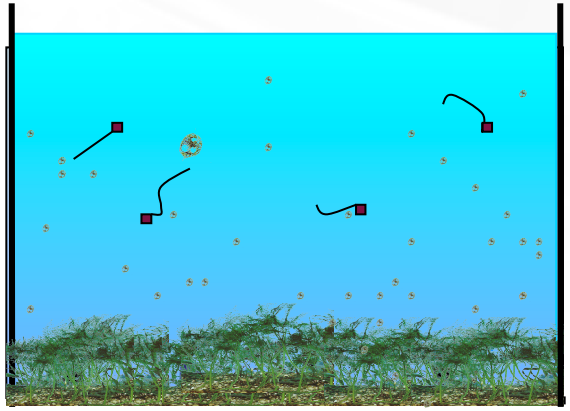
Exemplos de Aplicações



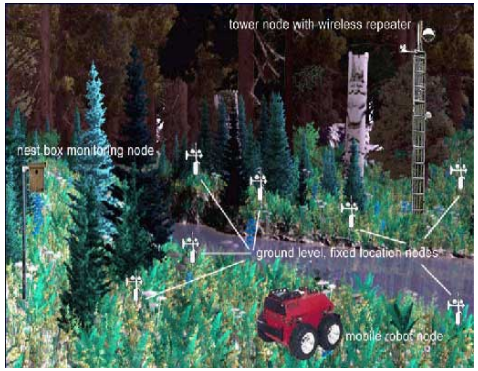
Monitoramento de sinais vitais

Controle de produção industrial (ex: vazamento e aquecimento)

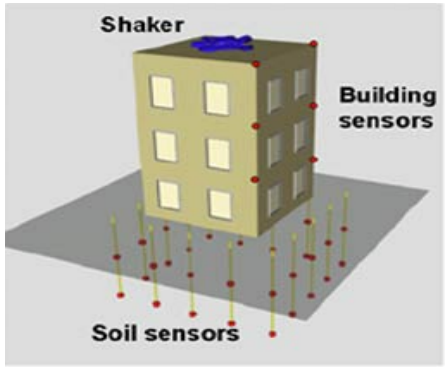
Extração do petróleo



Biologia marinha



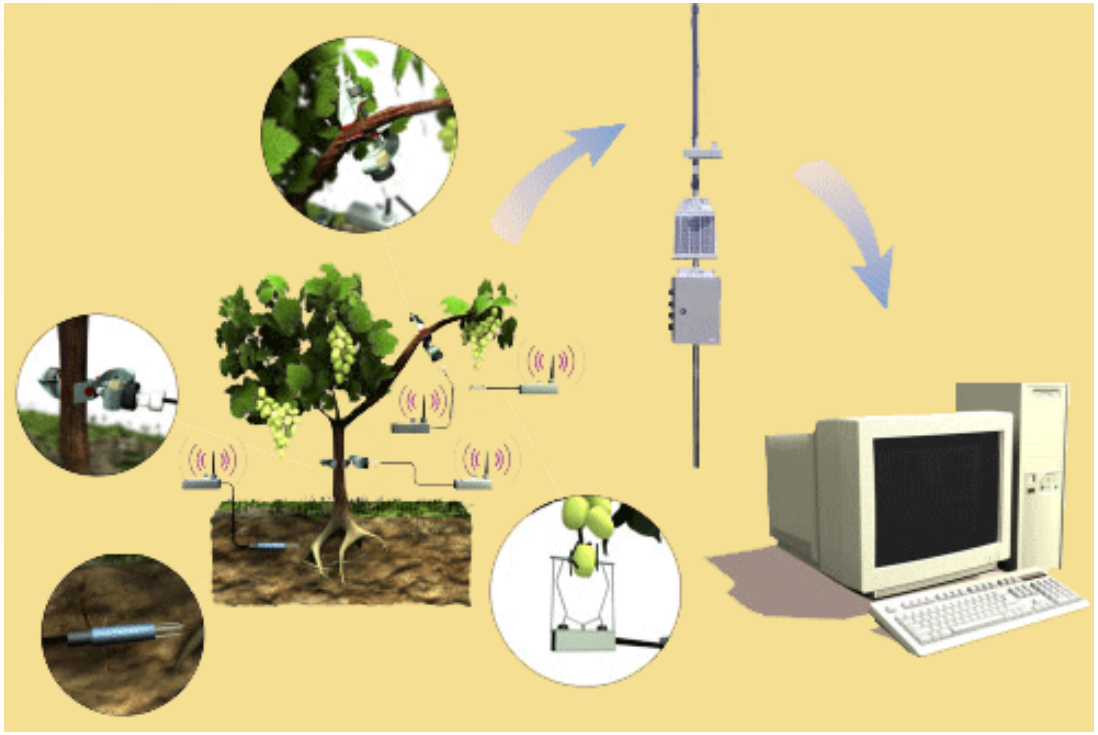
Monitoramento de florestas e rios



Monitoramento sísmico

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.



Example: Habitat Monitoring

- The ZebraNet Project

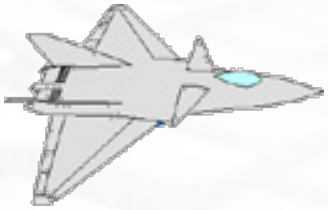
  Collar-mounted sensors monitor zebra movement in Kenya

Source: Margaret Martonosi, Princeton University

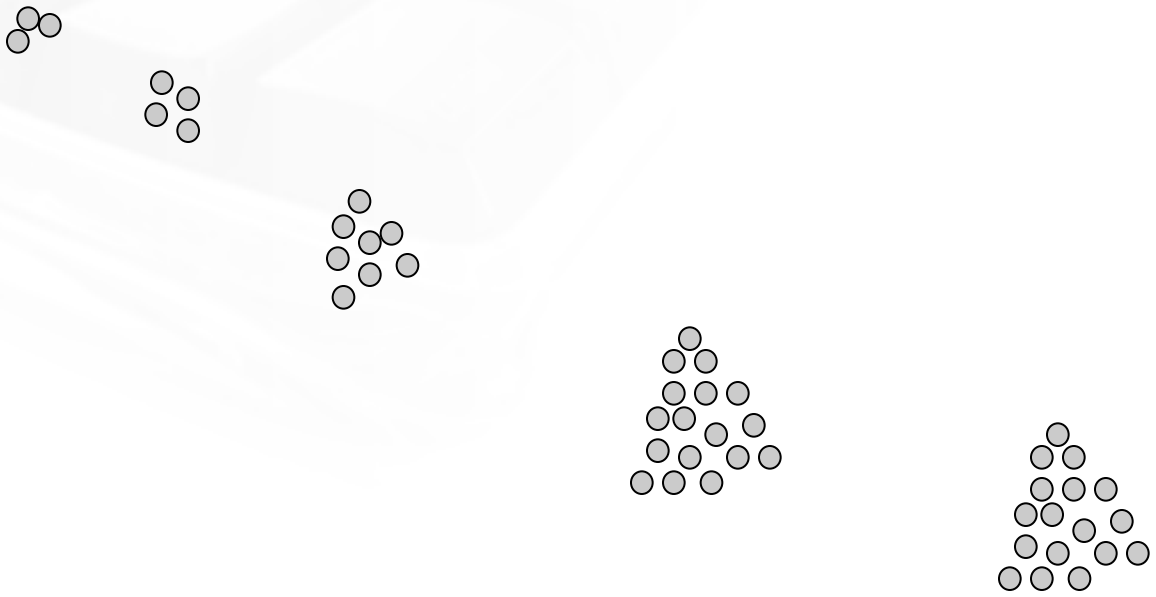
Example: Smart Home/Smart Office

- Sensors controlling appliances and electrical devices in the house.
- Better lighting and heating in office buildings.

Example: Military Applications



Remote deployment of sensors for tactical monitoring of enemy troop movements.

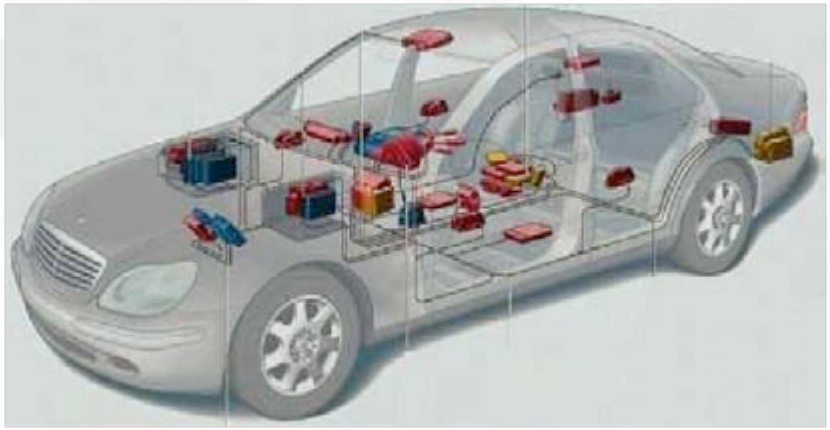


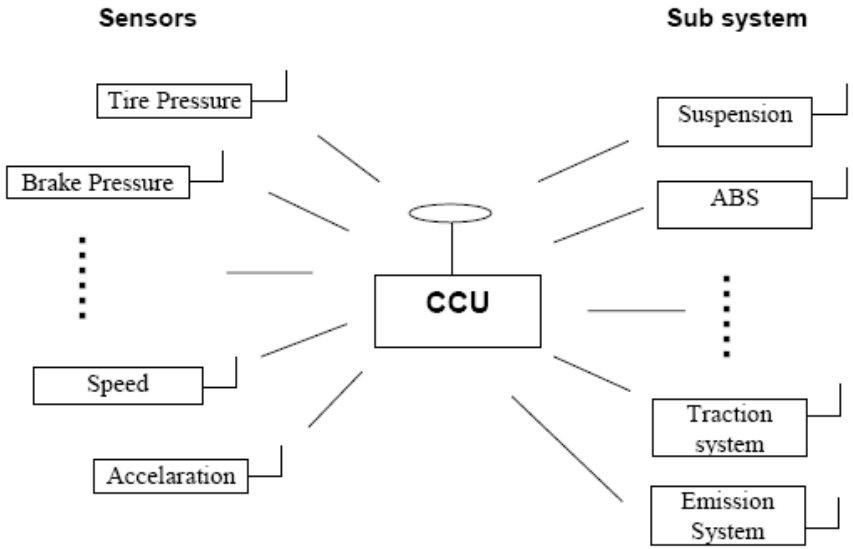
Example: Environment Monitoring

Great Duck Island

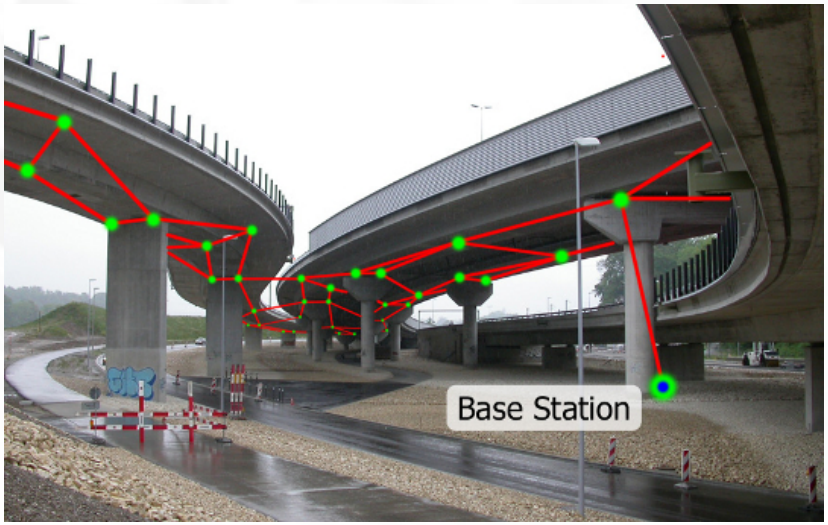
- 150 sensing nodes deployed throughout the island relay data temperature, pressure, and humidity to a central device.
- Data was made available on the Internet through a satellite link.

Example: Automotive Applications





Domínios das Aplicações



- RSSF geralmente são projetadas para atender a uma determinada aplicação em um domínio específico no qual ela está inserida.

Compartilhamento de Dados de RSSF

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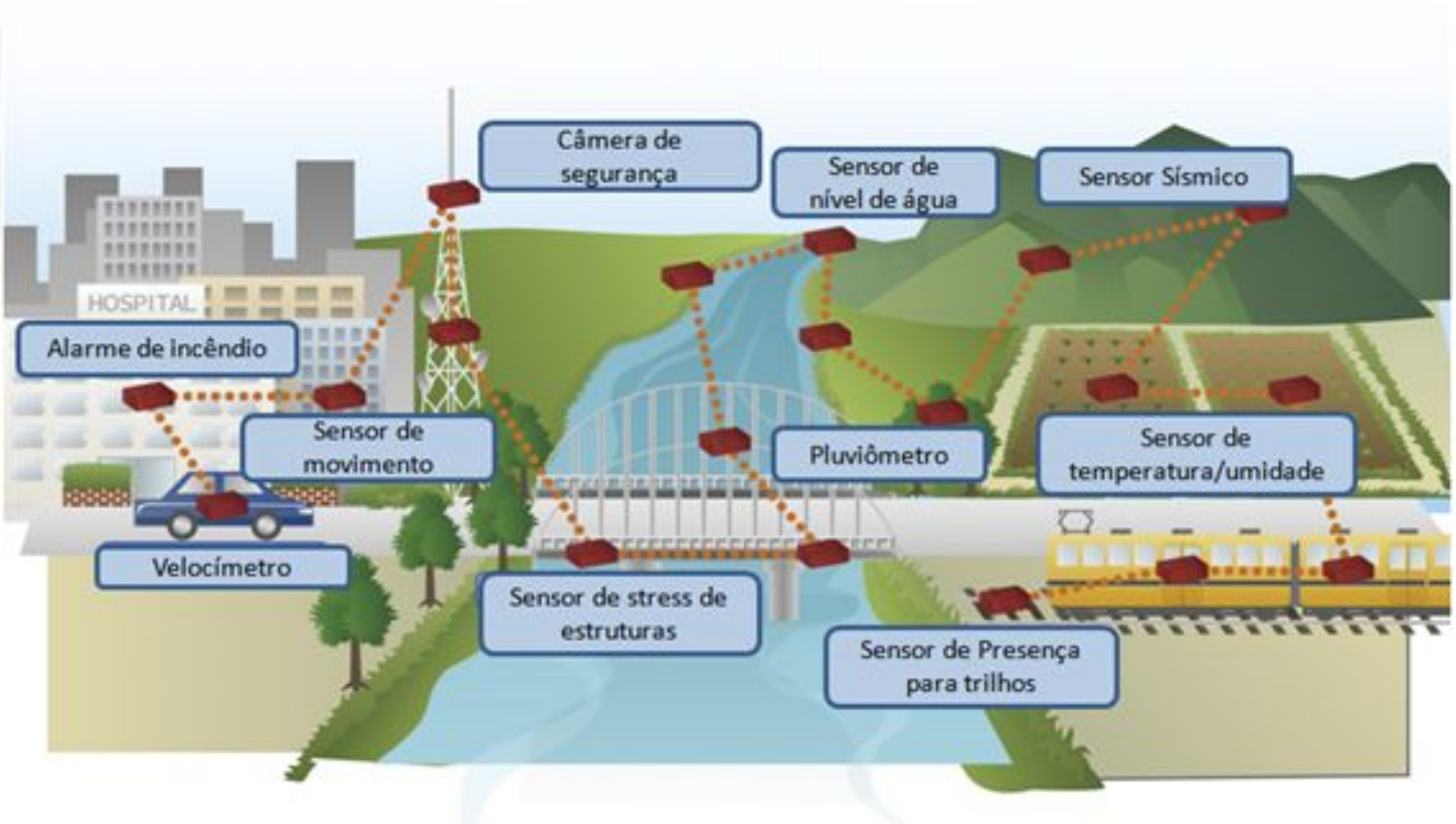
Biólogo

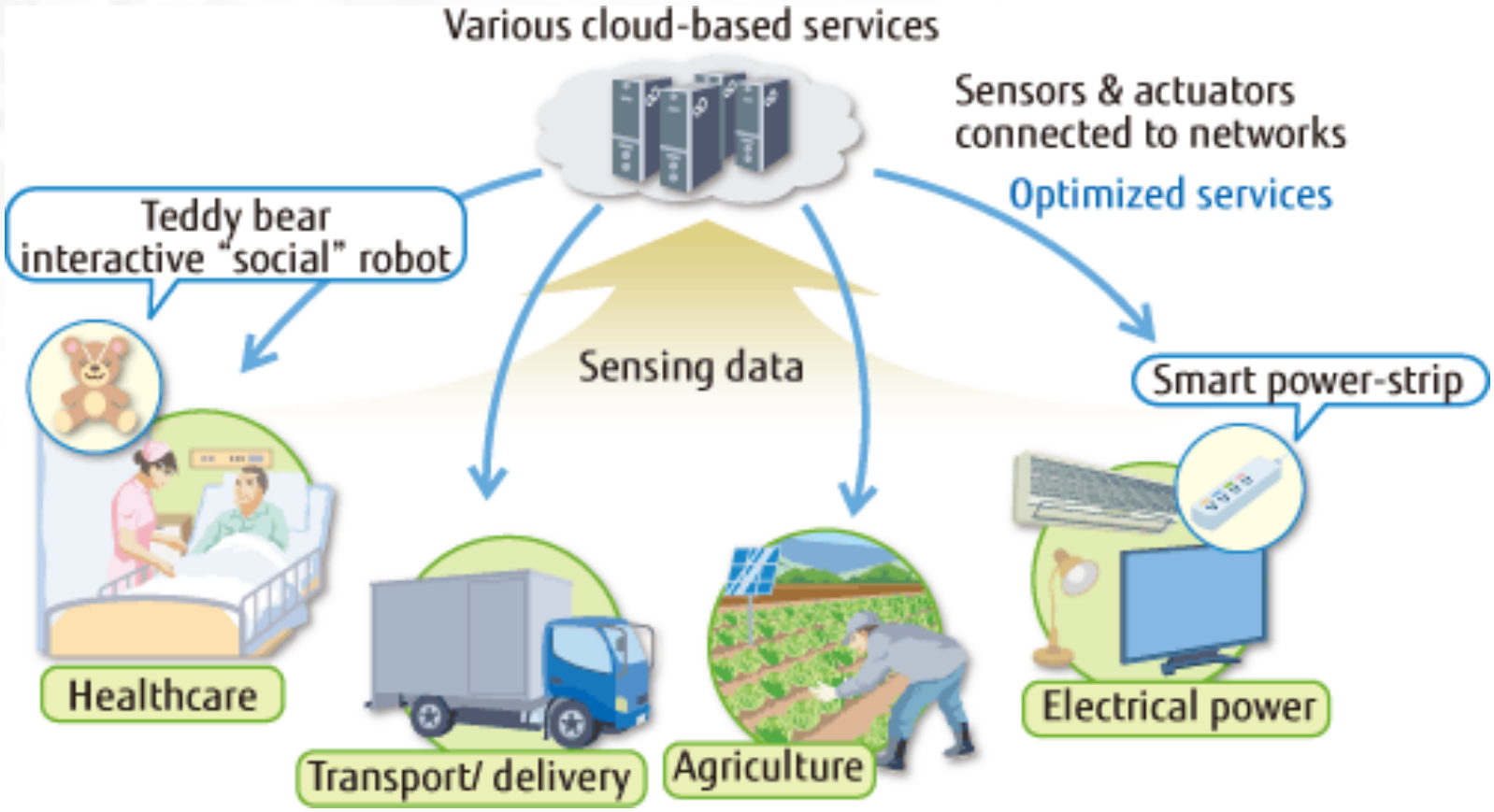
Biólogo

Indústria

Compartilhamento de Dados em Smart Cities



WSN, Big Data and Sensor Cloud



Programação de RSSF

- O desenvolvimento de aplicações para RSSF ainda é uma atividade desafiadora.
  - Programador tem que lidar com muitos aspectos de baixo nível.
  - Falta de flexibilidade

Building WSN Applications

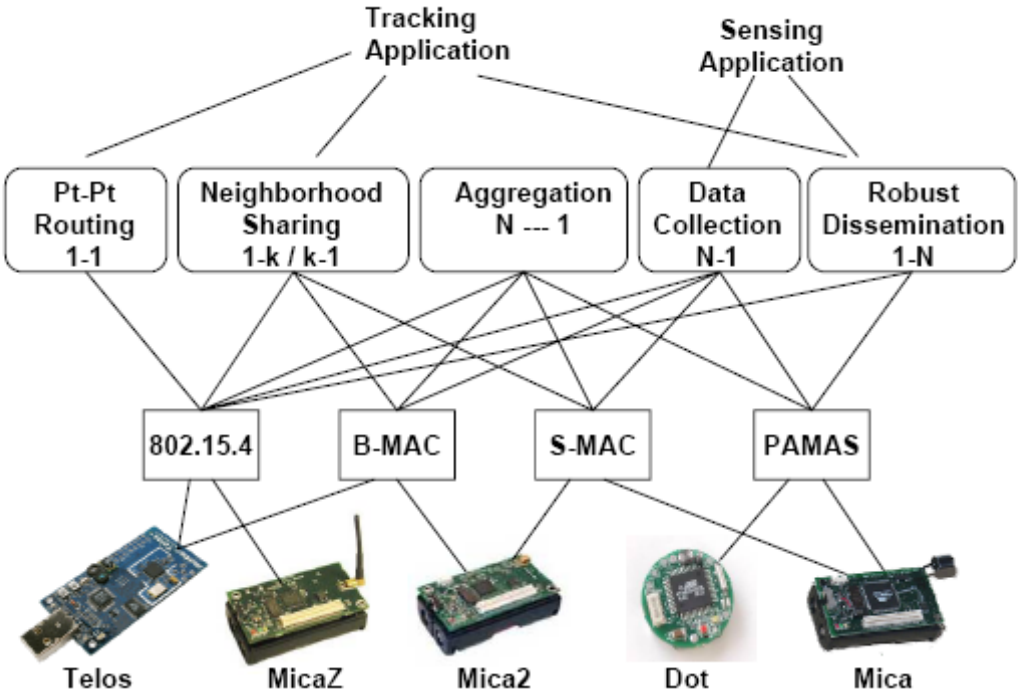
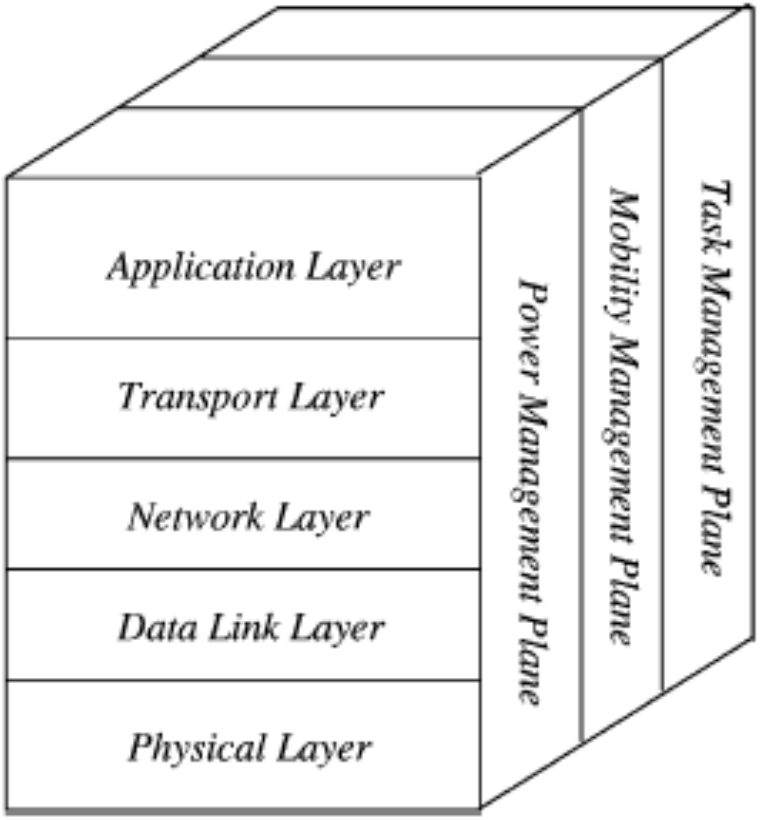


Figure 2.1: Current architecture for building sensornet applications. An application may choose a subset of network services that it requires. Those network protocols specify a set of link protocols that they support, which constrains the platforms available for application developers.

- Ref: Fig. 2.1 of J. Polastre PhD Thesis

WSN Protocol Stack



WSN Operating Systems

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

WSN Manufactors

- Memsic
- Libellium
  - Dust Networks
  - Sensoria Corporation
  - Ember Corporation
  - Worldsens

WSN Simulators/Emulators

- TOSSIM
- AVRORA
- CooJA
- OPNET
- NS-2
- SensorSim
- GloMoSim
- J-Sim
- OMNeT++
- SENS
- ATEMU

References (under construction …)

1. http://computer.howstuffworks.com/mote1.htm