APPLICATIONS OF WIRELESS SENSOR NETWORKS

Antoine Bagula, UCT

Outline

- Why Use WSNs
- Classification
- Sensor Usage
- WSN Applications
- Future

I. Why Use WSNs ?

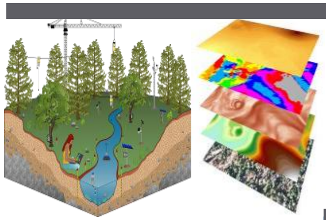
Predictive Maintenance

Energy Saving Smart Grid

High-Confidence Transport and Asset Tracking

Improve Productivity

Intelligent Buildings



Enable New Knowledge

Enhanced Safety & Security

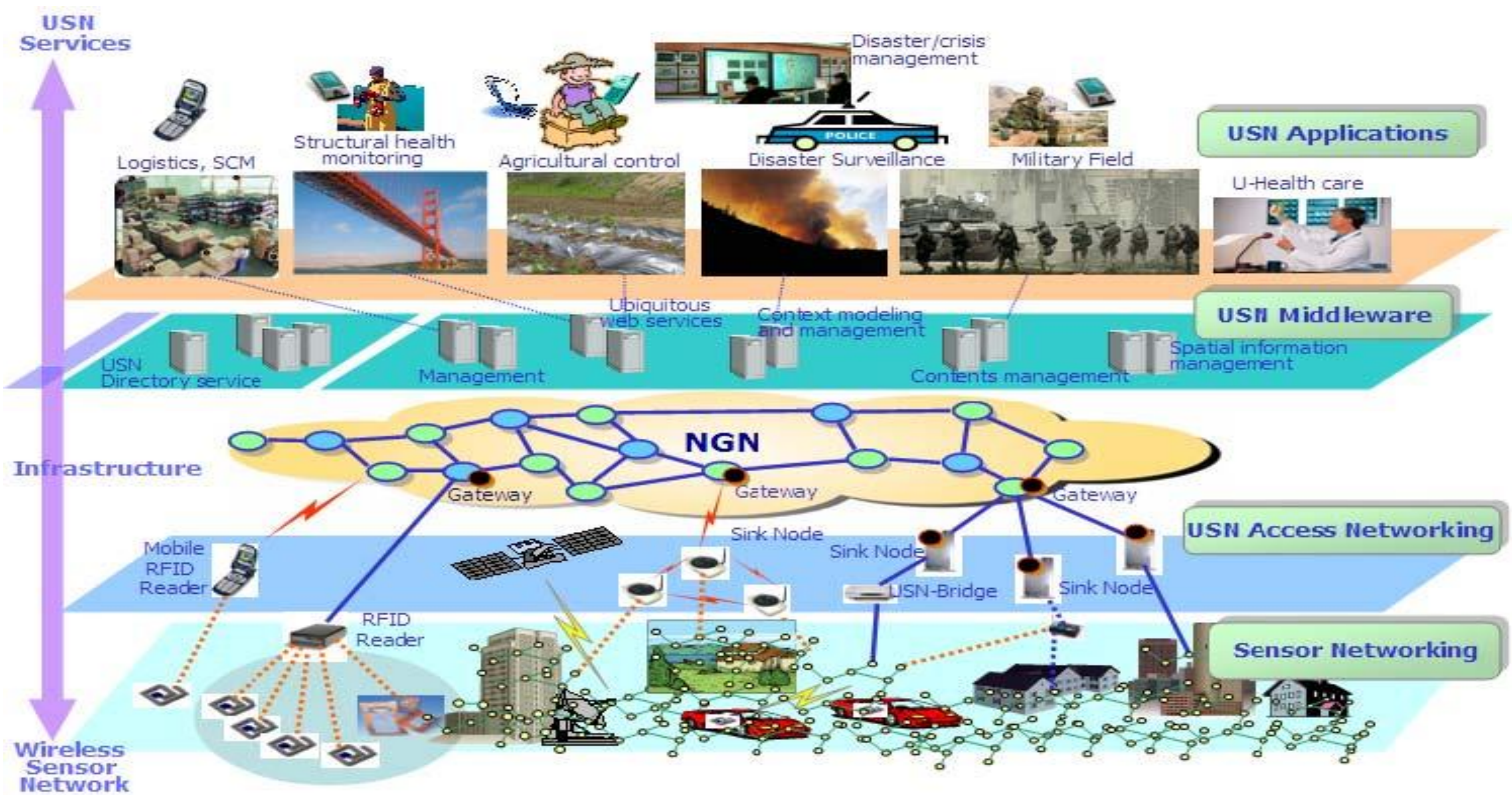
Improve Food and H_2O

Healthcare

Smart Home

✓ **Interesting Applications**

Why Use WSNs ?



✓ Translate Sensing and Identification activities into Services

Why Use WSNs ?

✓ Embed, Network and Disseminate to provide Services to different Clients

II. Sensors Classification

- Readiness for field deployment: measures maturity for field deployment in terms of economic and engineering efficiency.
- Scalability: a sensor's *scalability* to distributed environmental monitoring tasks require that the sensors be small and inexpensive enough to scale up to many distributed systems.
- Cost: Sensors are deployed in thousands. It is expected that cost will drop but current generation sensors are still expensive to allow wide deployment.

- For water quality monitoring, physical sensors are generally more field-ready and scalable than chemical sensors, which are, in turn, substantially more field-ready and scalable than biological sensors

Sensors Classification

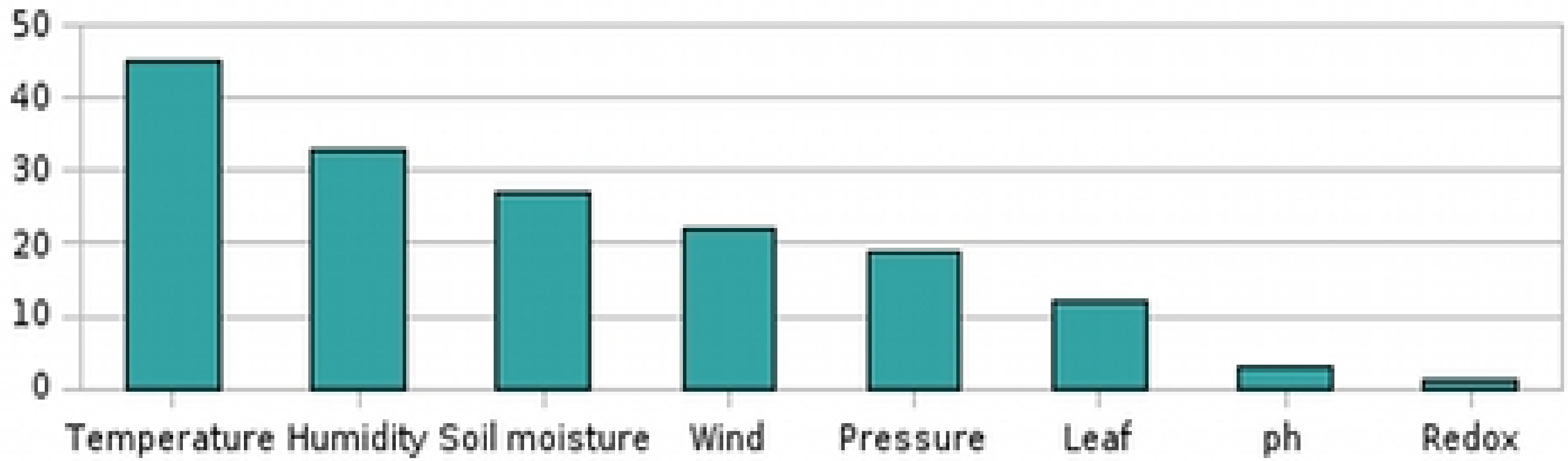
Sensor Category	Parameter	Field-Readiness	Scalability
Physical	Temperature	High	High
	Moisture Content	High	High
	Flow rate, Flow velocity	High	Med-High
	Pressure	High	High
	Light Transmission (Turb)	High	High
Chemical	Dissolved Oxygen	High	High
	Electrical Conductivity	High	High
	pH	High	High
	Oxydation Reduction Potential	Medium	High
	Major Ionic Species (Cl-, Na+)	Low–Medium	High
	Nutrientsa (Nitrate, Ammonium)	Low–Medium	Low–High
	Heavy metals	Low	Low
	Small Organic Compounds	Low	Low
	Large Organic Compounds	Low	Low
Biological	Microorganisms	Low	Low
	Biologically active contaminants	Low	Low

III. Sensors Usage

- Libelium study involving a total of **283** interested users in terms of sensors preferences. The users include researchers and practioners (developers).
- The results are classified in the next 5 main fields:
  - environmental,
  - gas,
  - physical,
  - optical and
  - biometric.

Use of environmental sensors

- **Sensors:** Temperature, Humidity (soil,leaf,ambient), Soil moisture, Wind (speed and direction), Pressure, Leaf, Ph, Redox.
- **Application:**
  - Precision agricultural applications are one of the most required in the terms of temperature, humidity (soil, leaf, ambient) and wind (speed and direction).
  - **Ph** and **Redox** sensors being demanded for water quality

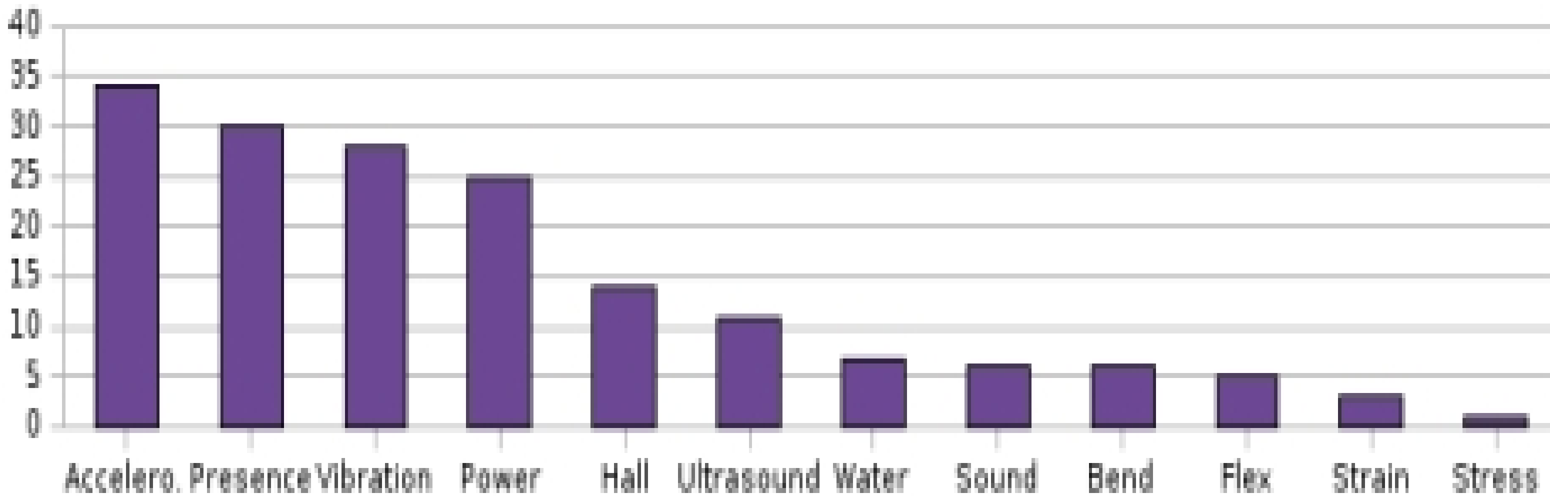


Use of physical sensors

• ***Sensors**:* accelerometer, presence, vibration, power, hall, ultrasound, water, sound, bend, flex, strain, stress.

• ***Application***:

- Motion of any kind using accelerometers, vibration, and presence sensors .
- security applications are waiting to be deployed.
- world of objects: bend, flex, strain and stress sensors let know how each object is interacting with the world and monitorize its state.

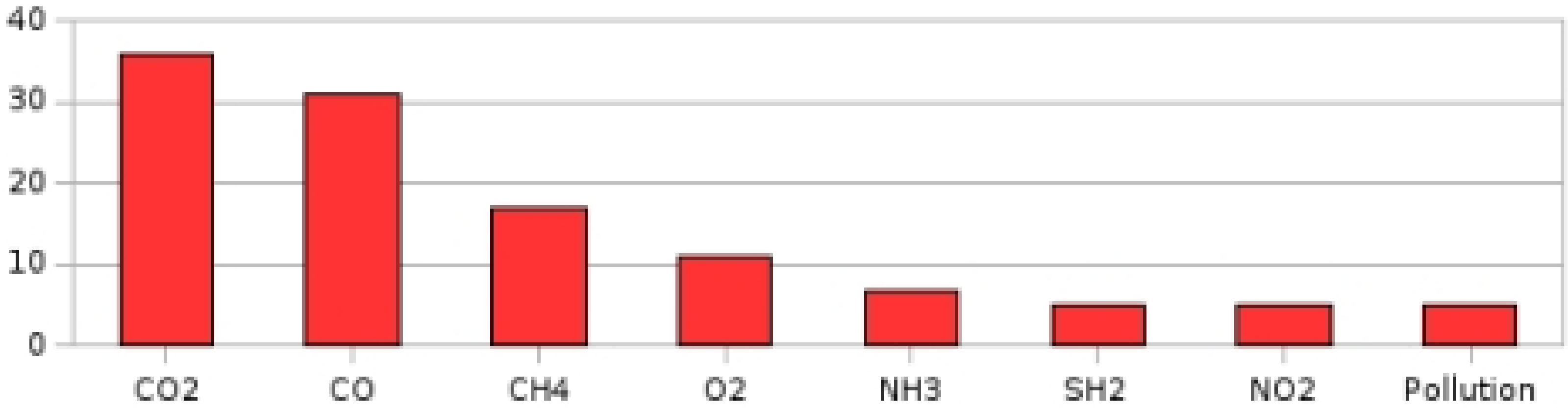


Use of gas sensors

• **Sensors**: Co2, Co, CH4, O2, NH3, SH2, NO2, Pollution.

. **Application**.

- Organic gases (carbone) derived from the "live systems" such as respiration in humans (CO2), animals (CH4) and combustion (CO) of vegetable elements (fire forest) are the most required sensors.
- Other toxic gases which can be found in animal farms (NH3, SH2) and the fabric and cars pollution gases (NO2) complete the list.

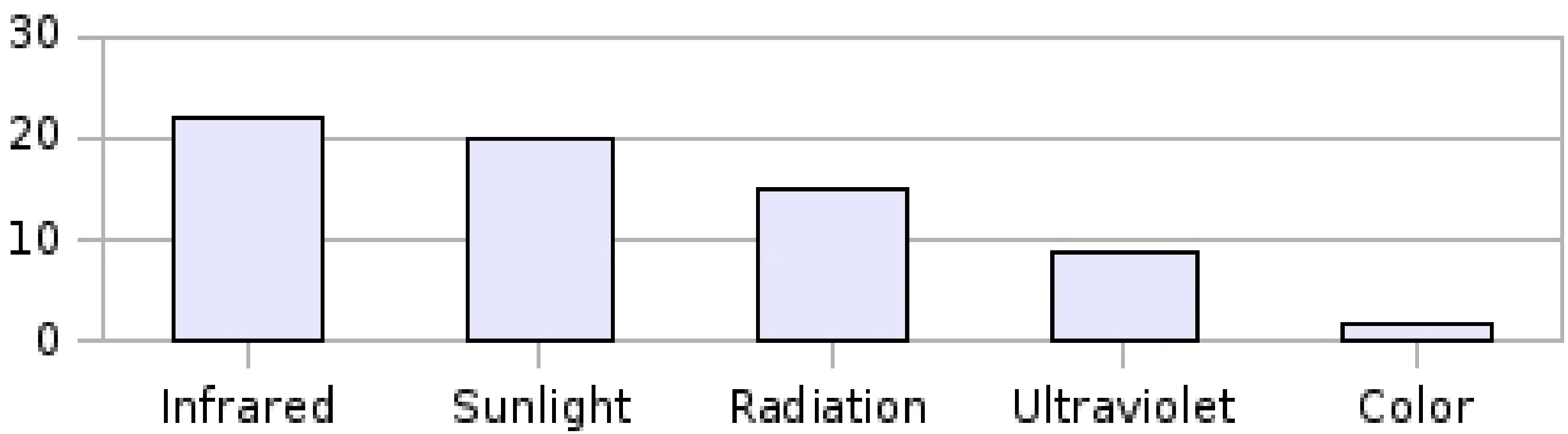


Use of optical sensors

Sensors: Infrared, Sunlight, Radiation, Ultraviolet, color

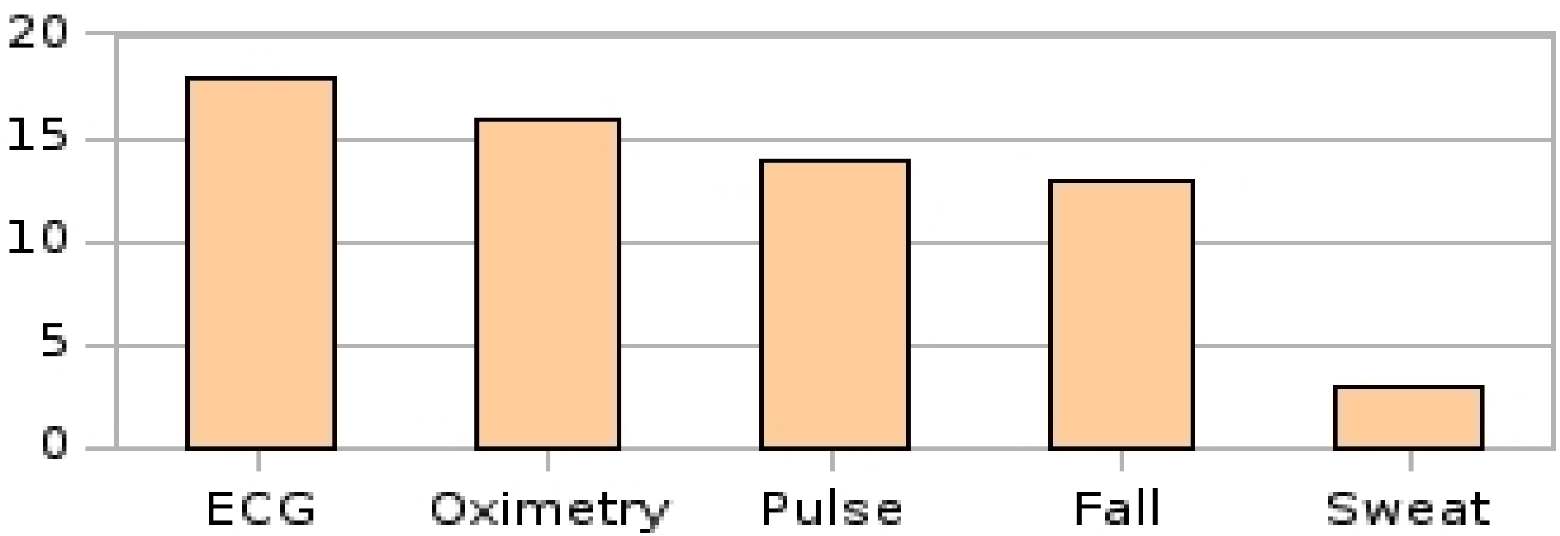
Application.

- Optical sensors to detect human presence through the IR spectrum are the most voted sensors in this area.
- Agriculture applications where the sun light, radiation and ultraviolet sensors are required in order to measure the total amount of energy and light which is absorbed by the plants.



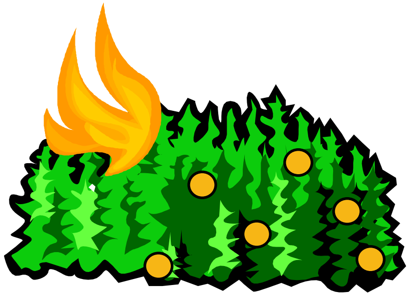
Use of biometric sensors

- **Sensor types:** Electrocardiogram ECG, Oximetry, Pulse, Fall, Sweat
- ***Application***:
  - Prevent a possible attack or the fall of a elderly person (using an accelerometer) by monitoring his heart pulse, rate and other heart activities. Used in combination of **SMS alarms** using the GSM/GPRS module
- ***Requirements***: a **real time and redundant alarm system** so that communication can always be established.

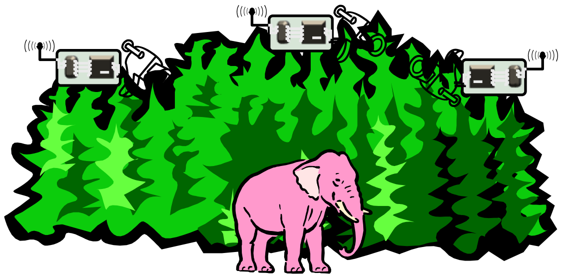


IV. WSN Application Examples

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

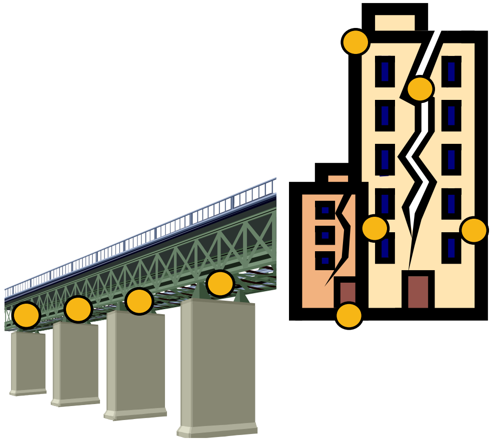


- Biodiversity mapping
  - Use sensor nodes to observe wildlife



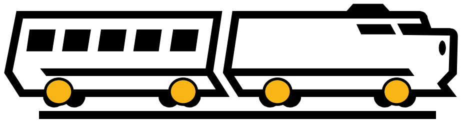
WSN application examples

- 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 examples

- 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 when and where needed
- Medicine and health care
  - Post-operative or intensive care
  - Long-term surveillance of chronically ill patients or the elderly

WSN application examples

[UCB, 2002]

Great Duck Island

- Reference: "Wireless Sensor Networks for Habitat Monitoring", A. Mainwaring, J. Polastre, R. Szewczyk, D. Culler, J. Anderson, WSNA (Wireless Sensor Networks and Applications), Sep 2002
- Monitoring seabird nesting environment (Leach's Storm Petrel)

Great Duck Island

Great Duck Island

- Impacts of human presence on plants and animals
  - Minimal disturbance is crucial while monitoring
  - Especially seabird colonies
  - 20% mortality of eggs due to a 15-min visit
  - Repeated disturbance ==> birds may abandon
- Leach's storm petrels desert nesting burrows if disturbed in first 2 weeks of incubation
- Natural answer: wireless sensor networks

Great Duck Island

- Motivation: Life Scientists' Perspective
- Usage pattern of nesting burrows over the 24-72 hour cycle when one or both members of a breeding pair alternate incubation and feeding at sea
- Changes in burrow and surface environmental parameters during the 7-month breeding season
- Differences in micro-environments with and without large numbers of nesting petrels

Great Duck Island

- Motivation: Sensor Networks Perspective
- Application-driven approach better than abstract problem statements
  - Separate actual problems from potential ones
  - Relevant versus irrelevant issues
- Develop an effective sensor network architecture
- Learn general solutions from specific ones

Great Duck Island

- Data Acquisition Rates
- Presence/absence data: using temperature differentials
  - Every 5-10 min
- General environmental parameters:
  - Every 2-4 hours
- Popular vs unpopular sites:
  - Every 1 hour, at the beginning of the breeding season

Great Duck Island

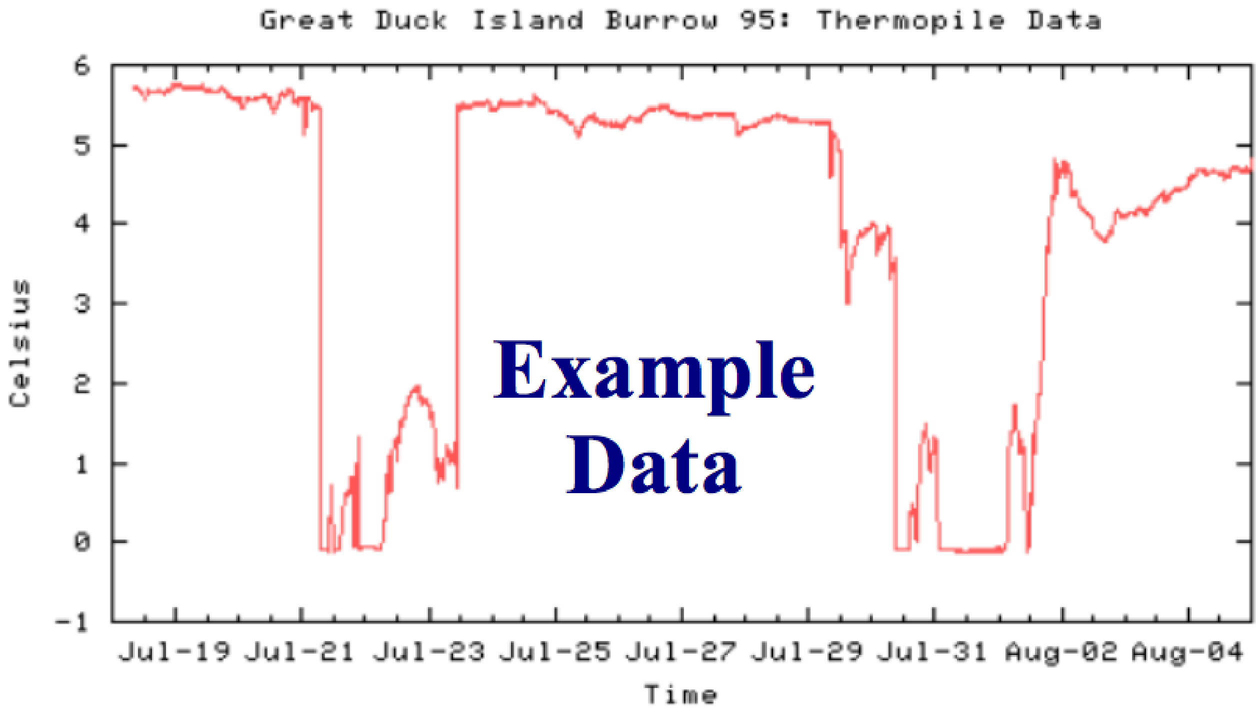
- Sensor network longevity: 9 months
  - Solar power where possible
  - Stable operation crucial
- Sensors: light, temperature, infrared, relative humidity, barometric pressure
- Remote data acquisition, management, and monitoring over the Internet
  - In-situ operations also

Great Duck Island

- Remarks on the Architecture
  - Hierarchical network
  - Solar panel at gateways and base-station
  - In-situ retasking possible
    - Example: collect temperature beyond a certain threshold, no need for all temperature readings
  - Base-station has satellite connectivity

Great Duck Island

Great Duck Island



Source: “Wireless Sensor Networks for Habitat Monitoring”, A. Mainwaring, J. Polastre, R. Szewczyk, D. Culler, J. Anderson, WSNA, Sep 2002

Figure 4: Thermopile data from a burrow mote on GDI during a 19-day period (July 18, 2002 to August 5, 2002).

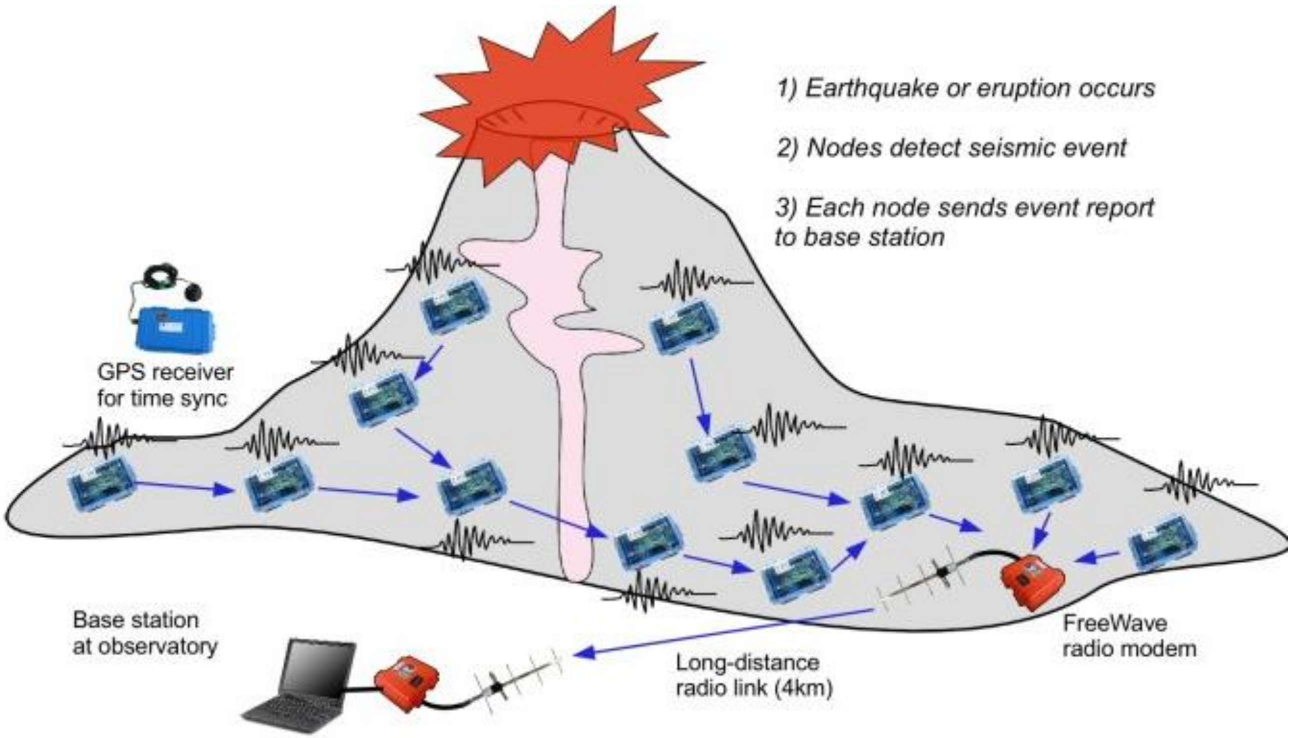
WSN application examples

[Princeton, 2004]

WSN application examples

- ZebraNet: an application to track zebras on the field
- The objective of the application is to gather dynamic data about zebra positions in order to understand their mobility patterns.
- What are the motivations for the zebras to move? water? food? weather?
- How do they interact?
- The sensors are deployed in collars that are carried by the animals.
- The users are the biologists.

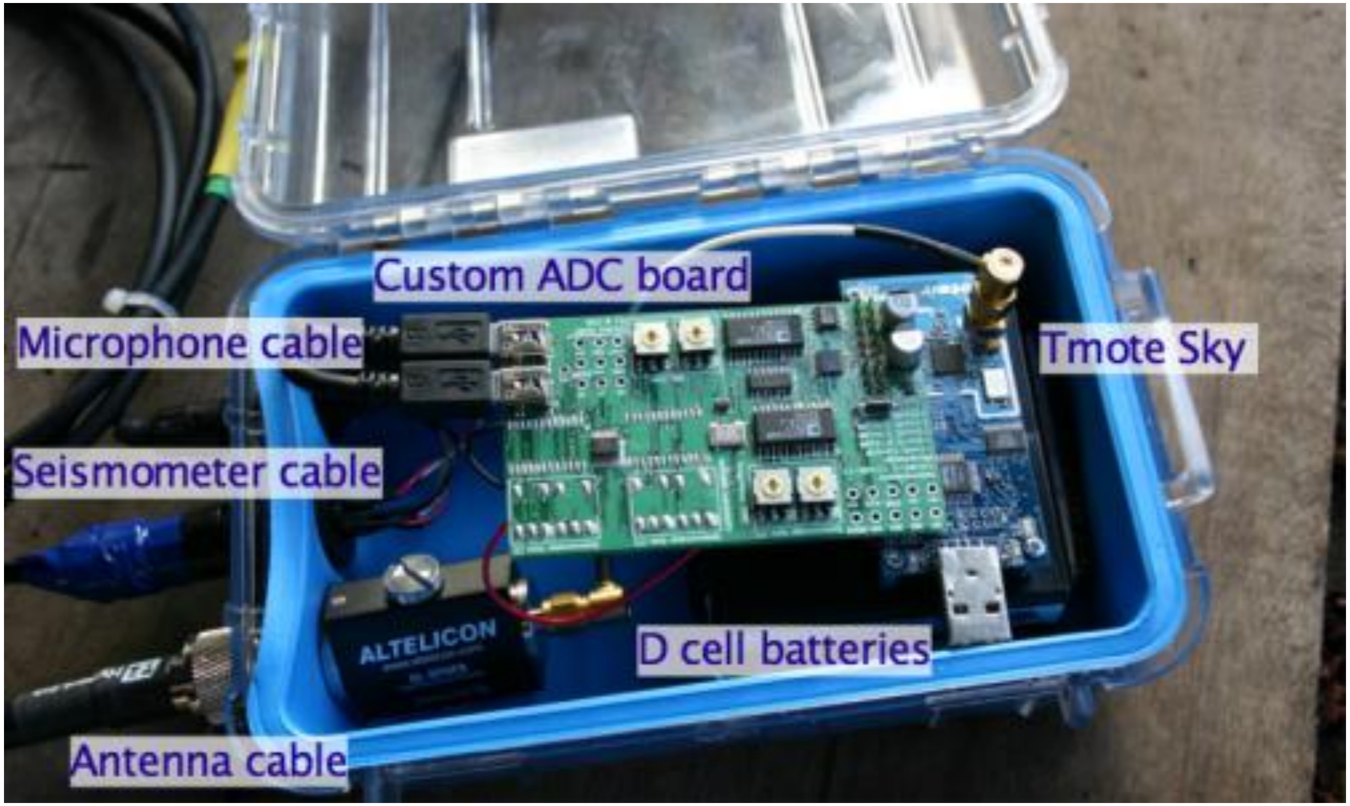
WSN application examples



WSN application examples

- Reference: "Deploying a Wireless Sensor Network on an Active Volcano", Geoffrey Werner-Allen, Konrad Lorincz, Matt Welsh, Omar Marcillo, Jeff Johnson, Mario Ruiz, Jonathan Lees, IEEE Internet Computing, Mar/Apr 2006
- Tungurahua, Ecuador

WSN application examples



WSN application examples

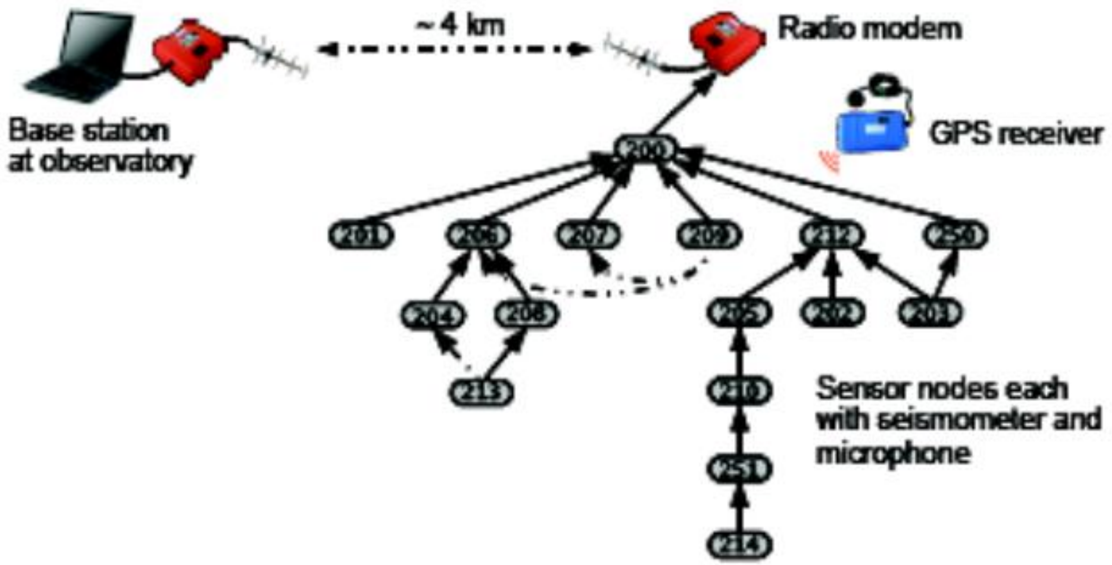


Figure 2: **Sensor network architecture.** *Nodes form a multihop routing topology, relaying data via a long-distance radio modem to the observatory. A GPS receiver is used to establish a global timebase. The network topology shown here was used during our deployment at Reventador.*

WSN application examples

- Challenges Encountered
  - Event detection: when to start collecting data?
  - High data rate sampling
  - Spatial separation between nodes
  - Data transfer performance: reliable transfer required
  - Time synchronization: data has to be time-aligned for analysis by seismologists

WSN application examples

- Bridge Monitoring
- Structural health monitoring (SHM) is a sensor-based preemptive approach
- In California, 13% of the 23,000 bridges have been deemed structurally deficient, while 12% of the nation's 600,000 bridges share the same rating.
- New York may be the first state with a 24/7 wireless bridge monitoring system.
- Another application in India: Bri-Mon

WSN application examples

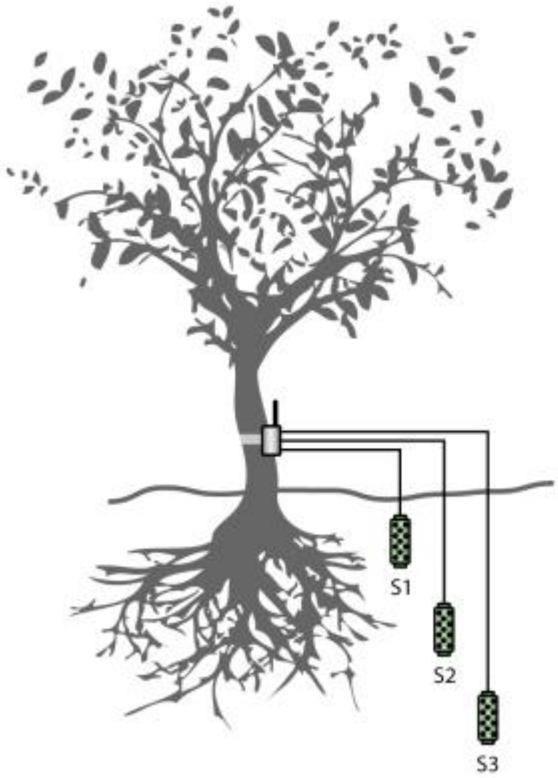
Agriculture

e.g., TU Delft Deployment

WSN application examples

Smart Agriculture

WSN application examples



Smart Agriculture

WSN application examples

- Objectives:
  - Using a combination of sensors such as humidity, temperature, and light, detect the risk of frost, possible plant diseases and find watering requirements based on soil humidity.
  - manage crop cultivation to know the exact condition in which plants are growing from the comfort of your own home.
  - control conditions in nurseries and closely monitor high performance of delicate crops, such as vines or tropical fruit, where the slightest change in climate can affect the final outcome
  - determine the optimum **conditions for each crop**, by comparing the figures obtained during the best harvests

WSN application examples

Animal Rearing

WSN application examples

- Objectives:
  - Instal a wireless sensor network near animals to help optimise their rearing conditions.
  - Monitor the temperature of litters to keep it at suitable levels;
  - Measure levels of gases produced by livestock such as methane (CH4), ammonia (NH3) and Hydrogen Sulphide (SH2);
  - Control animals' stress levels by monitoring flock restlessness with vibration and movement sensors.

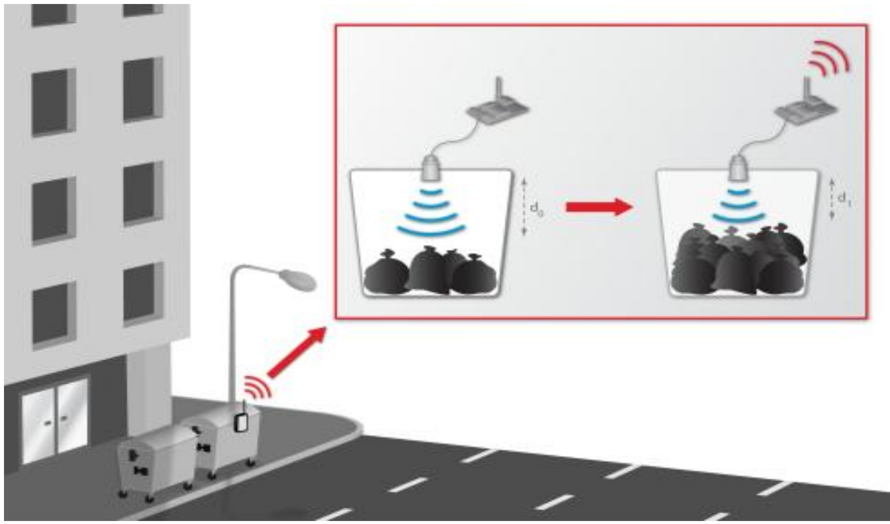
WSN application examples

Natural Environment Protection

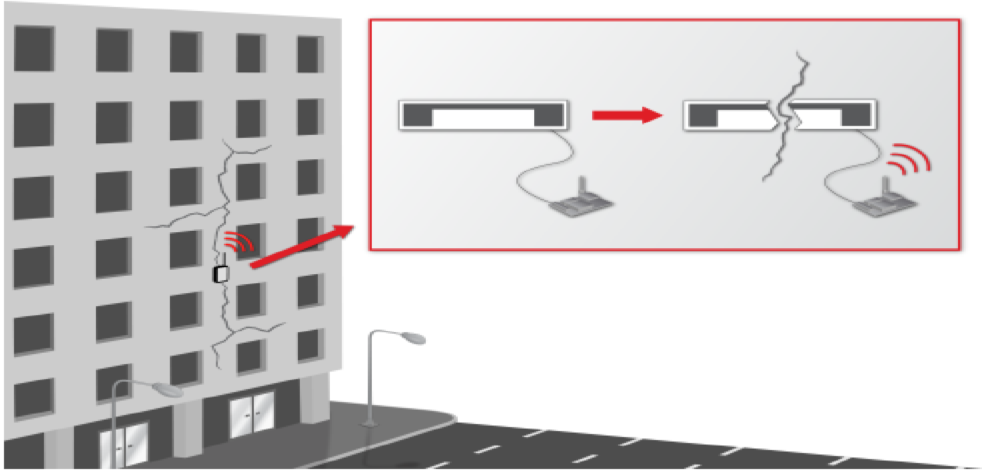
WSN application examples

- Objectives
  - **detect and prevent forest fires.** Detect flames, heat and gases that help to identify the molecules of chemical compounds generated during combustion (CO and CO2). With GPS, allow the exact geolocation of the nodes.
  - **Prevention.** After installing the WSN, the network can also acquire the daily values for temperature and relative humidity in order to determine the **likelihood of a fire** in each zone under surveillance.
  - **Alarm.** Send an **alarm** indicating the status of the fire or the probability level and the area.

WSN application examples



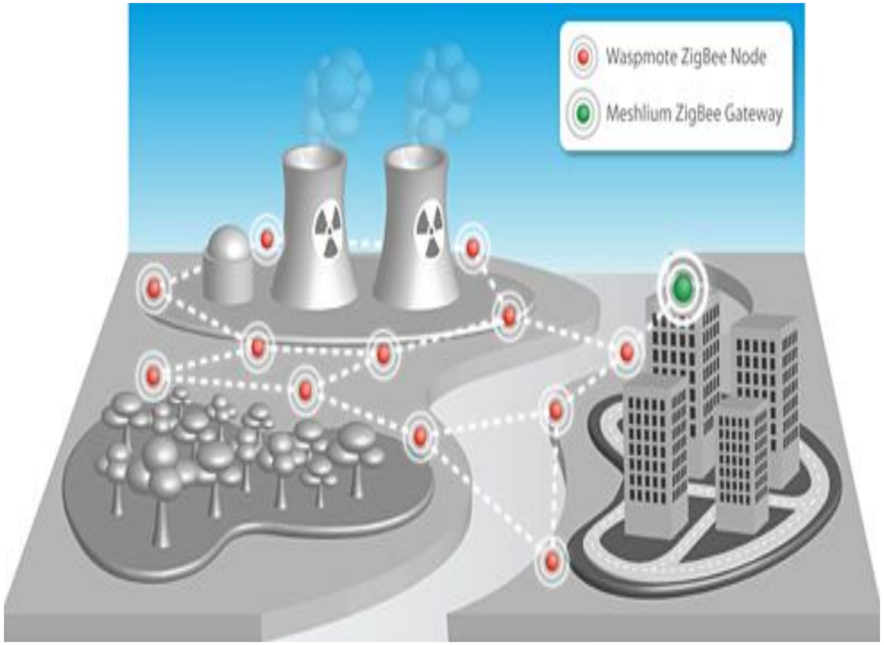
- **Smart Cities**



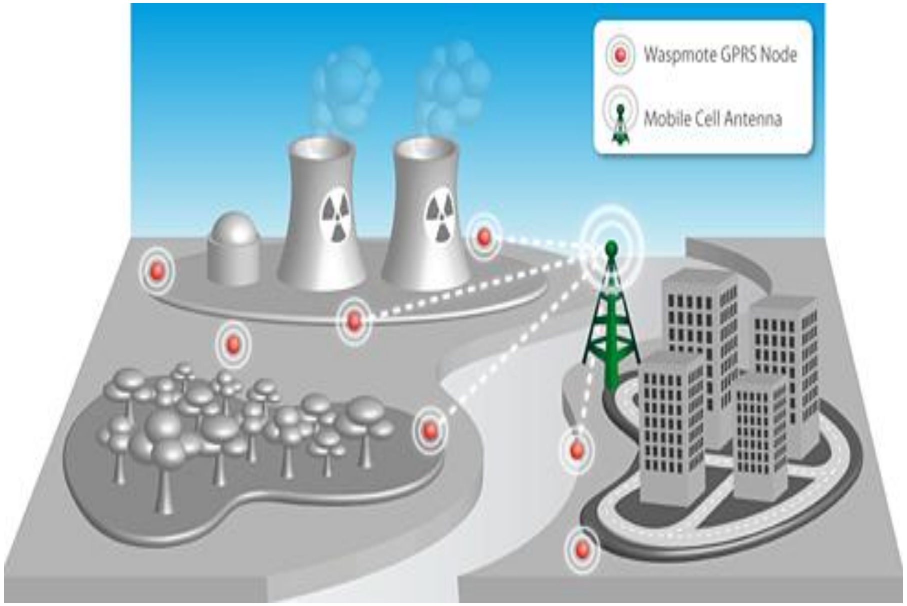
WSN application examples

- Objectives
  - **Noise pollution** to prevent common environmental problem affecting both the quality of life and health.
  - **Atmospheric pollution** in the form of gases such as CO2 and NO2 or dust – to prevent threats to the health of urban dwellers that cause respiratory diseases.
  - **Garbage levels** to promote public health by enabling timely garbage collection.
  - **structural health monitoring –** to enable public safety by ensuring that the largest structures found in cities including buildings, bridges and roads are sound.
  - **Traffic and parking management** - to minimize emissions and avoid unnecessary journeys.

WSN application examples



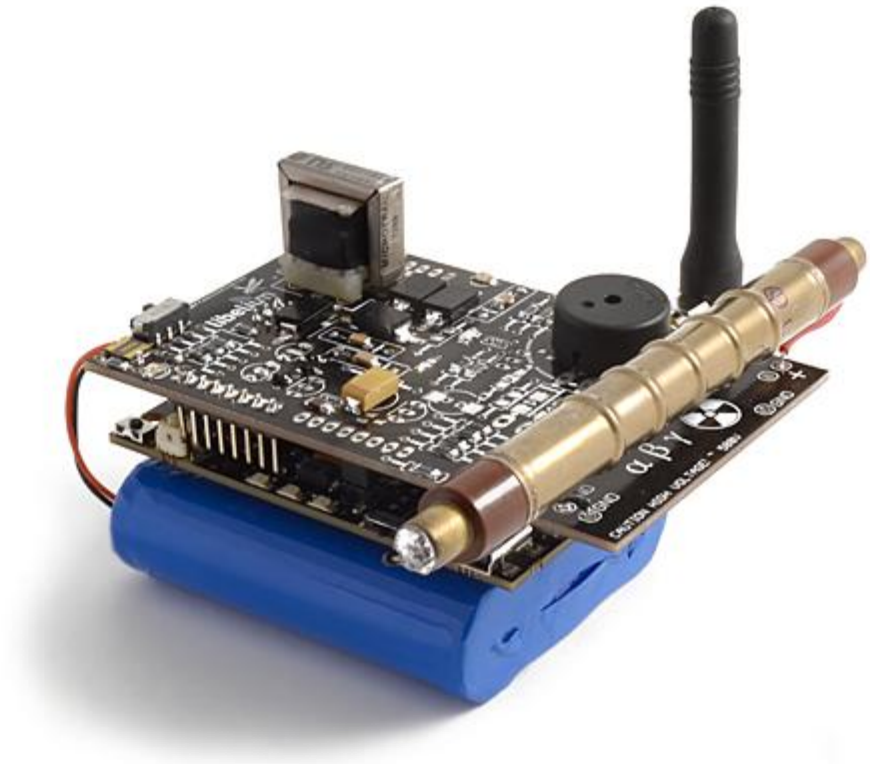
Radiation Sensor Network

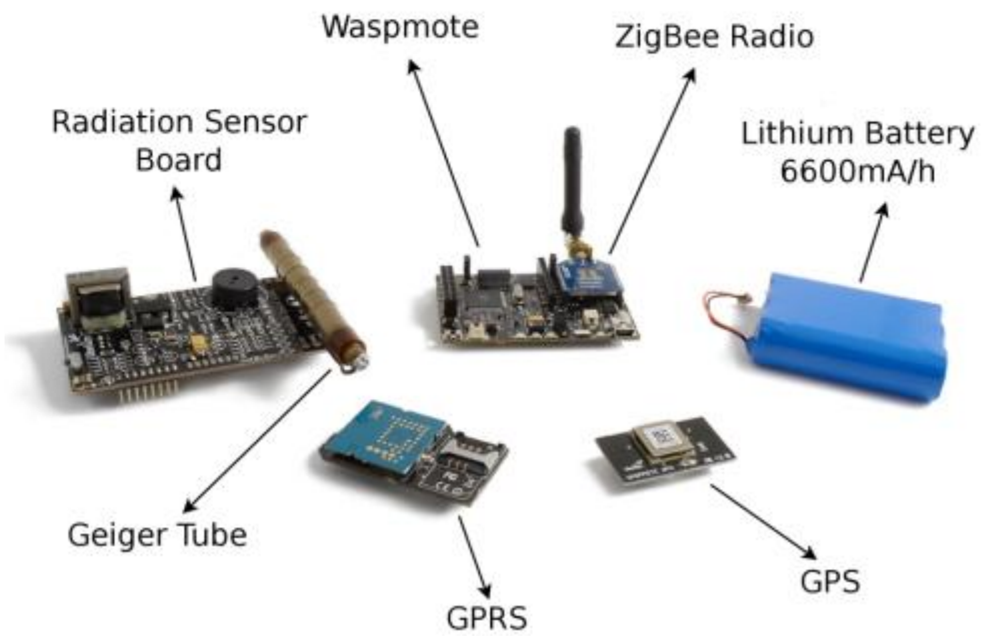


WSN application examples

- Objectives
  - **Radiation prevention** - help authorities and security forces to measure the levels of radiation of the affected zones without compromising the life of the workers.
  - **Geigger counting** - each node acts as an autonomous and wireless Geiger Counter which measures the number of counts per minute detected by the Geiger tube and send this value using ZigBee and GPRS protocols to the control point.

WSN application examples

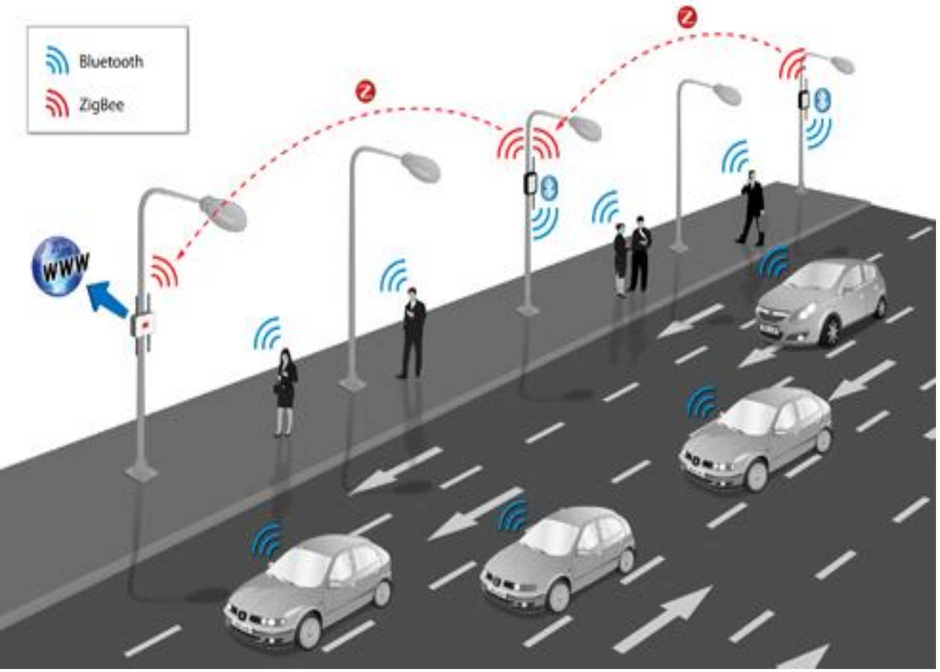


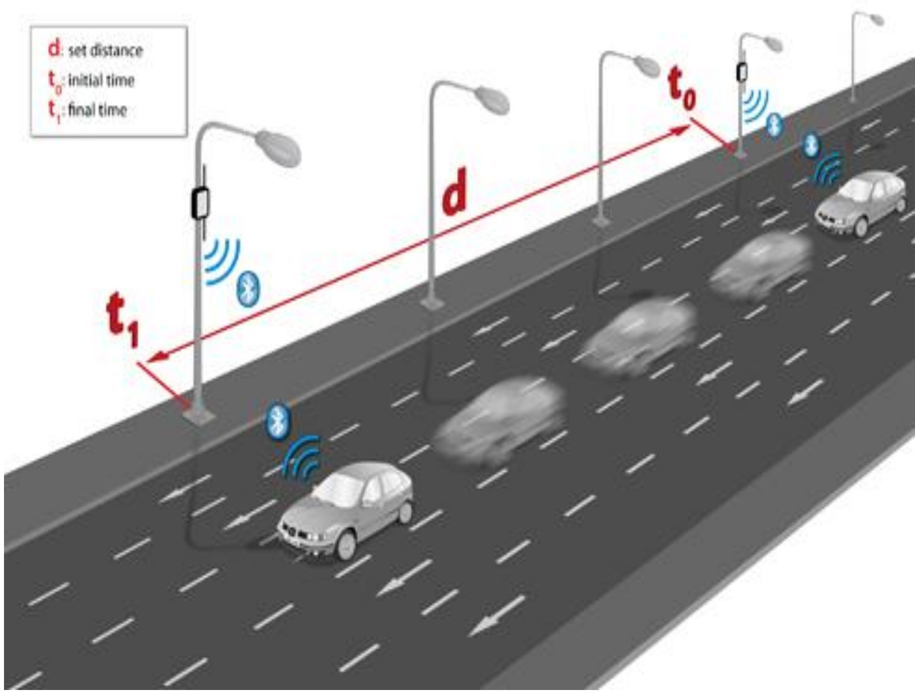


WSN application examples

- The **Prevention and Control Radiation Sensor Network.** It is formed by dozens of sensor devices deployed in the surroundings of the nuclear power plant and reaching the closest cities. Sensor nodes are installed in street lights and trees and take power from the internal battery which, at the same time is recharged using a small solar panel giving unlimited lifetime to the system. The nodes read the value of the Geiger tube during an specific time interval and calculate the number of counts per minute which are generated by the interaction of the radioactive particles.
- **Emergency radiation sensor network.** If a radiation leakage occurs in a place where there is not a previously installed radiation sensor network, an emergency deployment can be done in just a couple of hours. Security corps just need to spread the sensor nodes on the ground at certain places.

WSN application examples



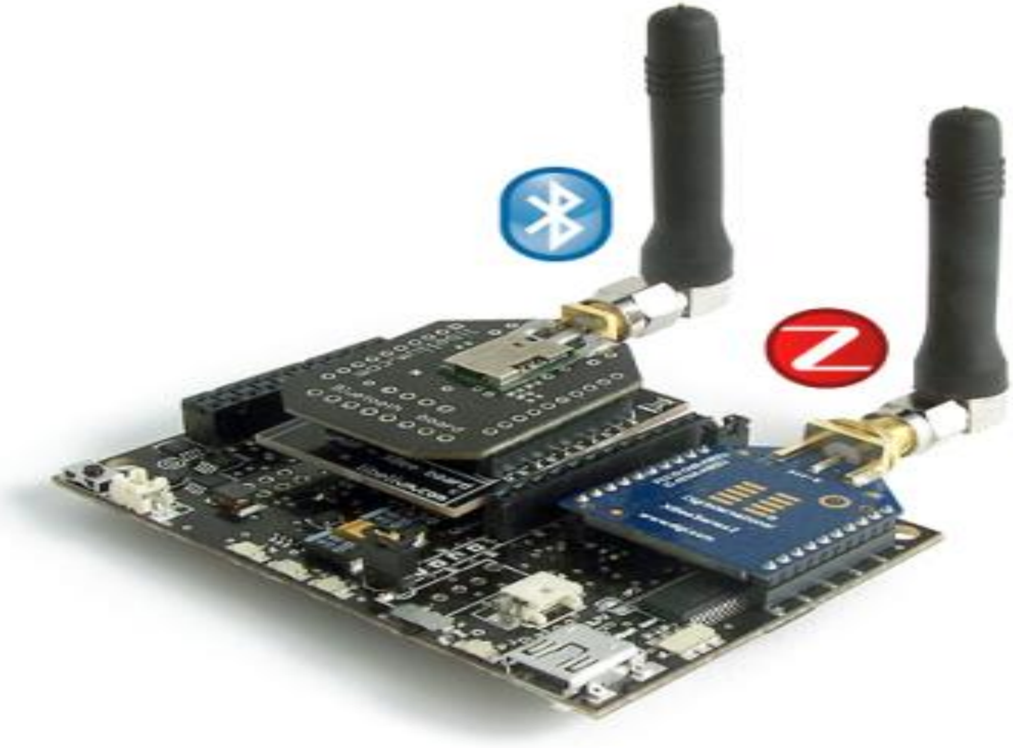


Smart Parking

WSN application examples

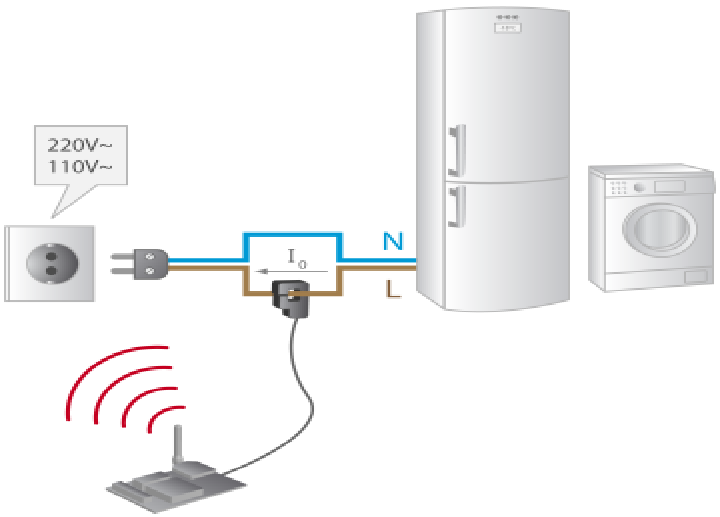
- Objectives
  - **Traffic monitoring** - to calculate the **average speed** of the vehicles which transit over a roadway by taking the time mark at two different points.
  - **Flow and congestion control.** – Understand the flow and congestion of vehicular traffic for efficient road systems in cities: reduce journey times, reduce emissions and save energy.

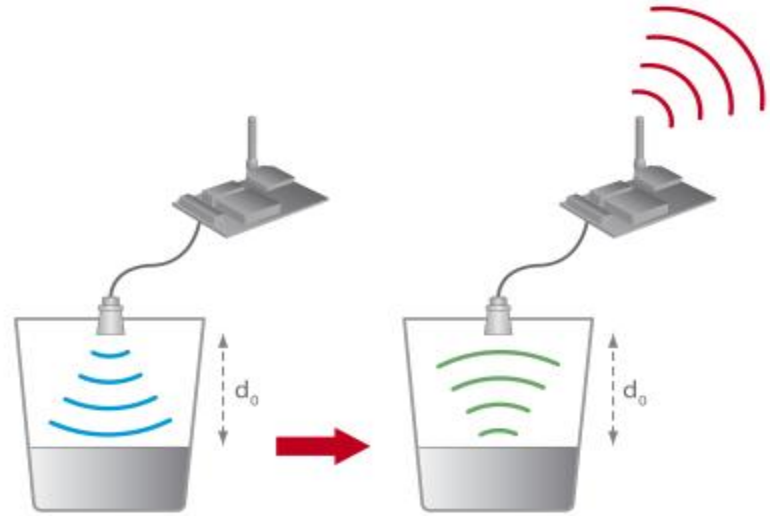
WSN application examples

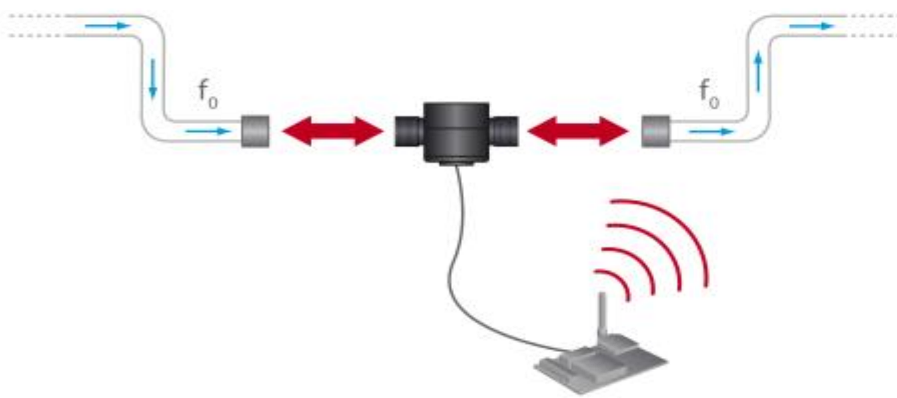


Two different types of radio are connected at the same time: a **Bluetooth** radio is used as a sensor to make inquiries and detect nearby devices, while the **ZigBee** radio sends the information collected using its multi-hop capabilities.

WSN application examples







Smart Metering

WSN application examples

- Objectives
  - **Traffic monitoring** - to calculate the **average speed** of the vehicles which transit over a roadway by taking the time mark at two different points.
  - **Flow and congestion control.** – Understand the flow and congestion of vehicular traffic for efficient road systems in cities: reduce journey times, reduce emissions and save energy.

WSN application examples

- Objectives: Measurement of the following key parameters:
  - Electric current
  - Water flow
  - Weight of materials and goods
  - Liquid level
  - Distance by ultrasounds
  - Distance and displacement of an object

WSN application examples

Applications include:

- Electric consumption
- Water consumption
- Pipe leakage detection
- Liquid storage management
- Tanks and silos level control
- Supplies control in manufacturing
- Industrial Automation
- Agricultural Irrigation

WSN application examples

[CodeBlue: Harvard]

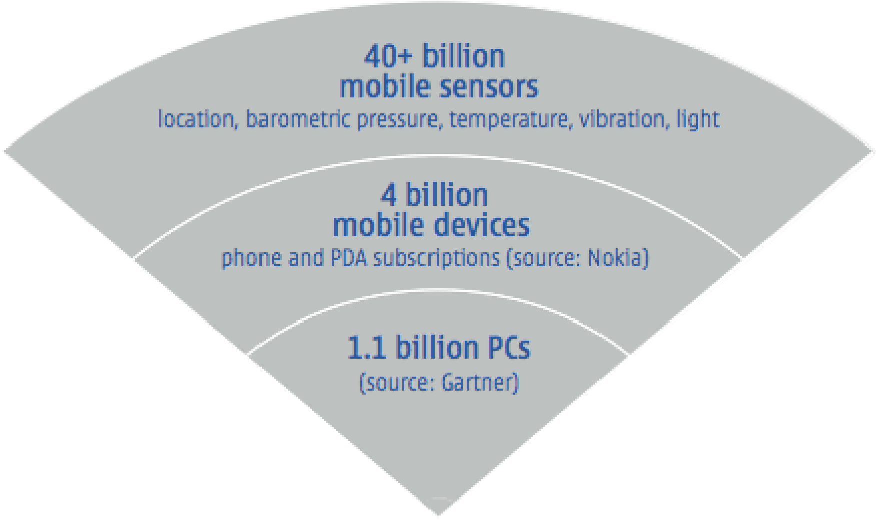
V. Future

Future: mobiles as sensors?

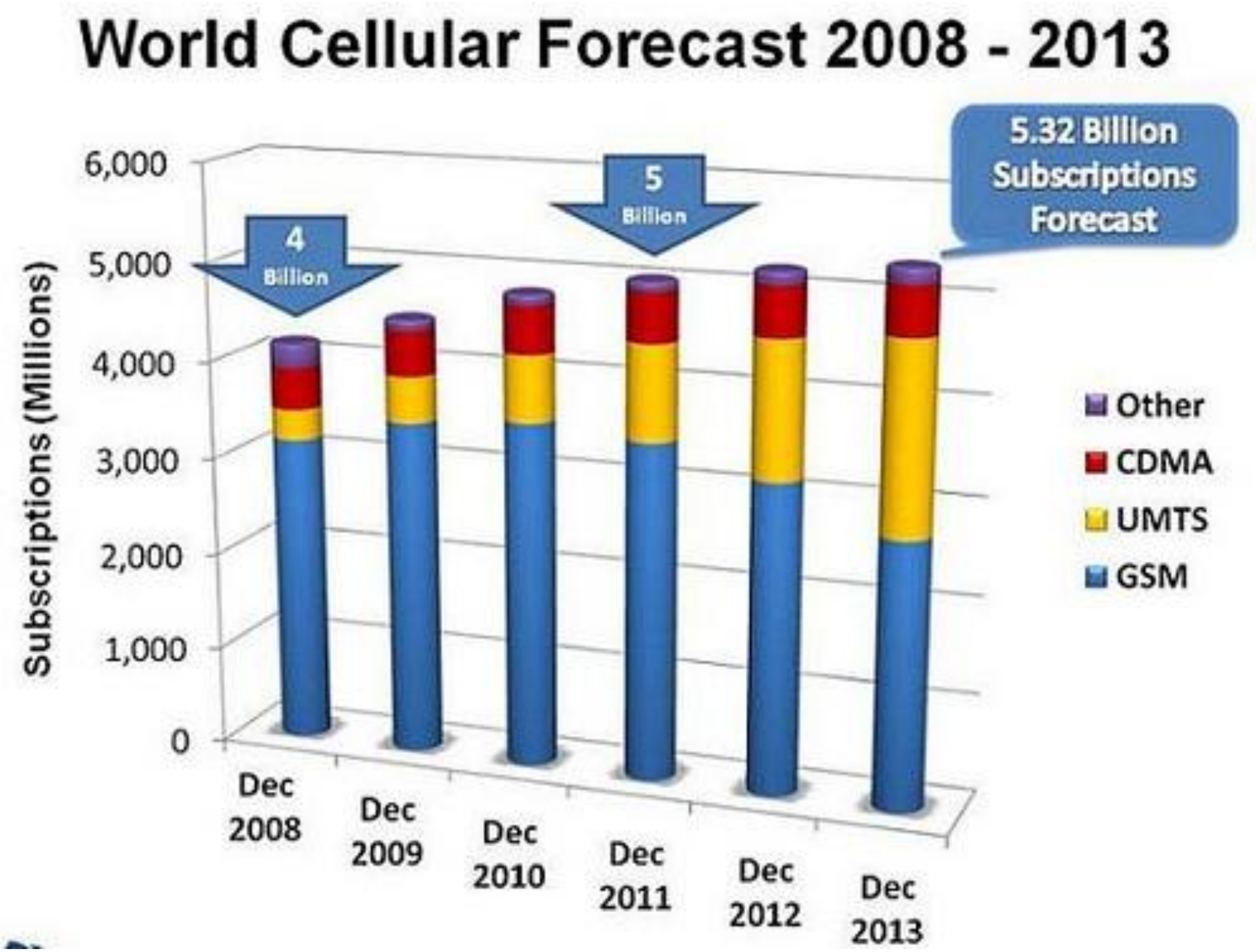
Sensing and sensors everywhere

As mobile device subscriptions pass the four billion mark, we're looking at the world's most distributed and pervasive sensing instrument. Thanks to an increasing number of built-in sensors—ambient light, orientation, acoustical, video, velocity, GPS—each device can capture, classify, and transmit many types of data with exceptional granularity. The perfect platform for sensing the world is already in our hands.

2009 Projection



Future: mobiles as sensors?



Future: mobiles as sensors?

2002	2008
Traditional sensor networks	**Participatory sensing**
Specially designed and deployed hardware	Leveraging available devices
Fully automatic and standalone systems	Humans in the loop
Thousands of small devices	Systems of heterogeneous devices
Fixed, static devices	Total mobility

Future: mobiles as sensors?

Mobile devices can bridge the visibility gap left by professional weather stations.

Future: mobiles as sensors?

- Personalized estimates of environmental exposure and impact
- PEIR, the Personal Environmental Impact Report, is a new kind of online tool that allows you to use your mobile phone to explore and share how you impact the environment and how the environment impacts you.

Rempod

Conclusion

- Work done on WSNs, both simulation and Testbed has revealed that It's an interesting, complex, new technology.

- However, we have been witnessing poor deployment resulting from many causes: slow adoption ? Lack of standardization ? Need for more applications ?

Credits

- Credits for the slides go to:
  - Libelium
  - Marco Zennaro
  - Holger Karl

Thanks

Antoine Bagula

bagula@cs.uct.ac.za

http://isat.cs.uct.ac.za