APPLICATIONS OF WIRELESS SENSOR NETWORKS

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Outline

- **Application areas**
  - Smart cities
  - Smart Environment
  - Smart Water
  - Smart Metering
  - Security & Emergencies
  - Retail

- **Specific applications**
  - Great Duck Island
  - ZebraNet
  - Volcano monitoring
  - Logistics
  - Industrial control
  - Smart Agriculture
  - Smart Animal Farming
  - Domotic & Home automation
  - E-Health
  - Smart Energy
  - Ubiquitous Healthcare
  - Weather Monitoring
  - Asset Tracking
Application Areas

**Smart Planet - Green Environment**
- Environmental sensors
- Water, power leak detection
- Pollution, weather monitoring

**Smart Buildings - Buildings, Smart Homes**
- Thermostats, HVAC, lighting
- Presence sensors, lockers, actuators
- Meters, smart-plugs, HEC

**Smart Industry - Industrial Environments**
- Lightning, security, actuators
- Production control
- Robotics

**Smart Health - Healthcare System**
- People monitoring
- Bio sensors, probes
- Remote health

**Smart Energy - Electric Grid**
- Voltage and power sensors
- Meters and breakers
- Fault detection

**Smart Transport - ITS, HEVs, EVs**
- Electric Mobility, EVs and HEVs
- High Speed Trains
- Infrastructure, V2I, V2V, V2I+I

**Smart Living - Entertaining, Leisure**
- Independence through technology
- Information when you need it
- Connected when you need it

**Future Internet**

**Internet of Things**
Application Areas

- Smart Cities
- Smart Transport
- Smart Buildings
- Smart Energy
- Smart Industry
- Smart Health

- Sensors/Actuators
  - Micro sensors
  - Nano sensors
  - Bio sensors
  - Lab on chip
  - Actuators

- Semiconductors/Electronics
  - Technology
  - Components, Circuits
  - Processors, µCs, NoC
  - More Moore
  - More than Moore

- Sensors Networks
  - Networks
  - Topology
  - Protocols/Standards
  - Re-configurability
  - Security

- Future Networks
  - Software Defined Networks
  - Network Overlay, Virtualization
  - Seamless Service
  - Self-Management

- Knowledge Creation
  - Data aggregation
  - Cloud computing
  - Event management
  - Data processing
Smart Cities

- **Smart Parking:** Monitoring of parking spaces availability in the city.
- **Structural health:** Monitoring of vibrations and material conditions in buildings, bridges and historical monuments.
- **Noise Urban Maps:** Sound monitoring in bar areas and centric zones in real time.
- **Traffic Congestion:** Monitoring of vehicles and pedestrian levels to optimize driving and walking routes.
- **Smart Lightning:** Intelligent and weather adaptive lighting in street lights.
Smart Cities

- **Waste Management**: Detection of rubbish levels in containers to optimize the trash collection routes.

- **Intelligent Transportation Systems**: Smart Roads and Intelligent Highways with warning messages and diversions according to climate conditions and unexpected events like accidents or traffic jams.
Forest Fire Detection: Monitoring of combustion gases and preemptive fire conditions to define alert zones.

Air Pollution: Control of CO2 emissions of factories, pollution emitted by cars and toxic gases generated in farms.

Landslide and Avalanche Prevention: Monitoring of soil moisture, vibrations and earth density to detect dangerous patterns in land conditions.

Earthquake Early Detection: Distributed control in specific places of tremors.
Smart Water

- **Water Quality**: Study of water suitability in rivers and the sea for fauna and eligibility for drinkable use.

- **Water Leakages**: Detection of liquid presence outside tanks and pressure variations along pipes.

- **River Floods**: Monitoring of water level variations in rivers, dams and reservoirs.
Smart Metering

- **Smart Grid:** Energy consumption monitoring and management.
- **Tank level:** Monitoring of water, oil and gas levels in storage tanks and cisterns.
- **Photovoltaic Installations:** Monitoring and optimization of performance in solar energy plants.
- **Water Flow:** Measurement of water pressure in water transportation systems.
- **Silos Stock Calculation:** Measurement of emptiness level and weight of the goods.
Security & Emergencies

- **Perimeter Access Control:** Access control to restricted areas and detection of people in non-authorized areas.

- **Liquid Presence:** Liquid detection in data centers, warehouses and sensitive building grounds to prevent break downs and corrosion.

- **Radiation Levels:** Distributed measurement of radiation levels in nuclear power stations surroundings to generate leakage alerts.

- **Explosive and Hazardous Gases:** Detection of gas levels and leakages in industrial environments, surroundings of chemical factories and inside mines.
Retail

- **Supply Chain Control:** Monitoring of storage conditions along the supply chain and product tracking for traceability purposes.

- **NFC Payment:** Payment processing based in location or activity duration for public transport, gyms, theme parks, etc.

- **Intelligent Shopping Applications:** Getting advice at the point of sale according to customer habits, preferences, presence of allergic components for them or expiring dates.

- **Smart Product Management:** Control of rotation of products in shelves and warehouses to automate restocking processes.
Quality of Shipment Conditions: Monitoring of vibrations, strokes, container openings or cold chain maintenance for insurance purposes.

Item Location: Search of individual items in big surfaces like warehouses or harbours.

Storage Incompatibility Detection: Warning emission on containers storing inflammable goods closed to others containing explosive material.

Fleet Tracking: Control of routes followed for delicate goods like medical drugs, jewels or dangerous merchandises.
Industrial Control

- **M2M Applications**: Machine auto-diagnosis and assets control.
- **Indoor Air Quality**: Monitoring of toxic gas and oxygen levels inside chemical plants to ensure workers and goods safety.
- **Temperature Monitoring**: Control of temperature inside industrial and medical fridges with sensitive merchandise.
- **Ozone Presence**: Monitoring of ozone levels during the drying meat process in food factories.
- **Indoor Location**: Asset indoor location by using active (ZigBee) and passive tags (RFID/NFC).
- **Vehicle Auto-diagnosis**: Information collection from CanBus to send real time alarms to emergencies or provide advice to drivers.
Smart Agriculture

- **Wine Quality Enhancing**: Monitoring soil moisture and trunk diameter in vineyards to control the amount of sugar in grapes and grapevine health.
- **Green Houses**: Control micro-climate conditions to maximize the production of fruits and vegetables and its quality.
- **Golf Courses**: Selective irrigation in dry zones to reduce the water resources required in the green.
- **Meteorological Station Network**: Study of weather conditions in fields to forecast ice formation, rain, drought, snow or wind changes.
- **Compost**: Control of humidity and temperature levels in alfalfa, hay, straw, etc. to prevent fungus and other microbial contaminants.
Smart Animal Farming

- **Offspring Care:** Control of growing conditions of the offspring in animal farms to ensure its survival and health.

- **Animal Tracking:** Location and identification of animals grazing in open pastures or location in big stables.

- **Toxic Gas Levels:** Study of ventilation and air quality in farms and detection of harmful gases from excrements.
Domotic & Home Automation

- **Energy and Water Use:** Energy and water supply consumption monitoring to obtain advice on how to save cost and resources.

- **Remote Control Appliances:** Switching on and off remotely appliances to avoid accidents and save energy.

- **Intrusion Detection Systems:** Detection of window and door openings and violations to prevent intruders.

- **Art and Goods Preservation:** Monitoring of conditions inside museums and art warehouses.
Fall Detection: Assistance for elderly or disabled people living independent.

Medical Fridges: Control of conditions inside freezers storing vaccines, medicines and organic elements.

Sportsmen Care: Vital signs monitoring in high performance centers and fields.

Patients Surveillance: Monitoring of conditions of patients inside hospitals and in old people's home.

Ultraviolet Radiation: Measurement of UV sun rays to warn people not to be exposed in certain hours.
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Great Duck Island
Great Duck Island

- 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

**Example Data**

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

ZebraNet

[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.
Volcano Monitoring

1) Earthquake or eruption occurs
2) Nodes detect seismic event
3) Each node sends event report to base station

GPS receiver for time sync
Base station at observatory
FreeWave radio modem
Long-distance radio link (4km)
WSN application examples


- 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
Smart Energy Monitoring
Smart Energy Monitoring System
Ubiquitous Healthcare
Ubiquitous Healthcare System

E-health sensor platform

- Patient Position Sensor (Accelerometer)
- Airflow Sensor (Breathing)
- Electrocardiogram Sensor (ECG)
- Pulse and Oxygen in Blood Sensor (SpO2)
- Body Temperature Sensor
- Galvanic Skin Response Sensor (GSR - Sweating)
- e-Health Sensor Shield for Arduino and Raspberry Pi

Wi-Fi

IEEE802.15.4

Wi-Fi

CliniYOU

Deceased
Immediate
Delayed
Minor
Ubiquitous Healthcare System
Ubiquitous Healthcare Mesh Network
Laptop Tracking and Monitoring System (LMTS)

LMTS middleware architecture
Laptop Tracking and Monitoring System (LMTS)

LMTS System prototype implementation

Introduction to Wireless Sensor Networks - January 2010
SenseWeather: Sensor-Based Weather Monitoring System for Kenya

SenseWeather: System Logic
SenseWeather: Sensor-Based Weather Monitoring System for Kenya

A Traditional Granary in one of the Mbeeres’ Testing Location
SenseWeather: Sensor-Based Weather Monitoring System for Kenya

Kenya’s Drought Monitoring and Forecasting Solution

Employing ICTs to Build an Effective, Relevant and Affordable Solution to Droughts!

Introduction to Wireless Sensor Networks - January 2010
## Medium Term Drought Forecast: Aug-2012

<table>
<thead>
<tr>
<th>Counter</th>
<th>Station Name</th>
<th>Month-Year</th>
<th>Precipitation</th>
<th>AWRI Value</th>
<th>EDI Value</th>
<th>Drought Description</th>
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<tr>
<td>1.</td>
<td>Embu</td>
<td>Aug-2012</td>
<td>50</td>
<td>8</td>
<td>-1.3</td>
<td>Moderate Drought</td>
</tr>
<tr>
<td>2.</td>
<td>Nairobi / Dagoretti</td>
<td>Aug-2012</td>
<td>10</td>
<td>900</td>
<td>-1.7</td>
<td>Severe Drought</td>
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<tr>
<td>3.</td>
<td>Lodwar</td>
<td>Aug-2012</td>
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<td>70</td>
<td>-2.1</td>
<td>Extreme Drought</td>
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<tr>
<td>4.</td>
<td>CHIROMO OBSERVATORY</td>
<td>Aug-2012</td>
<td>9</td>
<td>809</td>
<td>0</td>
<td>Drought-Near Normal</td>
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<tr>
<td>5.</td>
<td>Kakamega</td>
<td>Aug-2012</td>
<td>90</td>
<td>1020</td>
<td>1.8</td>
<td>Severe Flood</td>
</tr>
</tbody>
</table>

Introduction to Wireless Sensor Networks - January 2010
Conclusion

- We have covered
  - A multitude of application areas
  - Some scientific applications
  - Some local applications
- WSN is an interesting, complex, new technology
- There are still lots of research still to be done
- Local applications are what is needed!
Credits

- Credits for the slides go to:
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Thanks

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