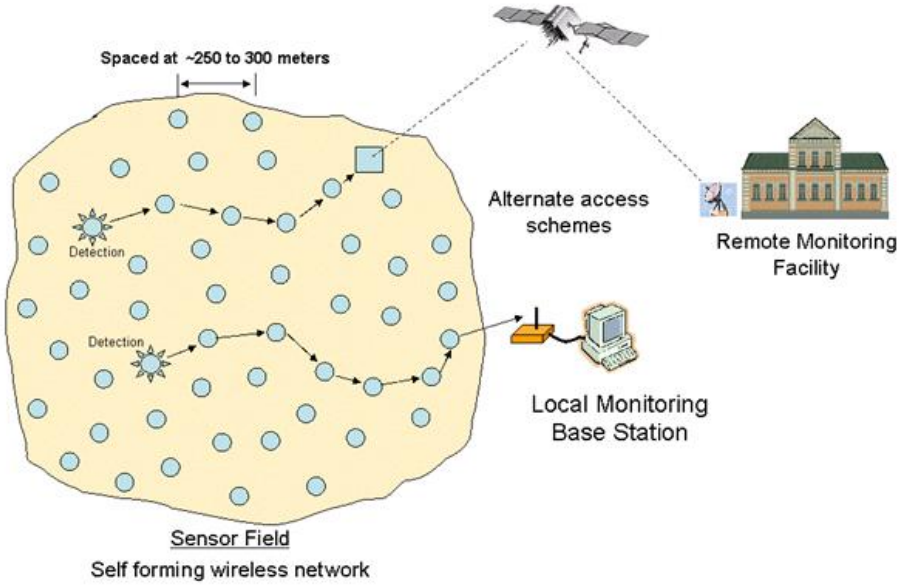
SensorsCon 2012
March 21, 2012
Techmart Center
Santa Clara, CA, USA

Sensor Devices and Sensor Network Applications for the Smart Grid/Smart Cities



Dr. William Kao

Agenda

- Introduction

  - Sensors, Actuators, Transducers
- Sensor Types, Classification
- Wireless Sensor Networks (WSN)
- Sensor Devices and WSN Applications in Smart Grid, HEMS ,Smart Cities
- Summary and Future Work

Introduction

Sensors/Senses

Ubiquitous, Everywhere

The iPhone has a built-in accelerometer (motion detector). Uses include:

- Game control
- Navigation functions
- Augmented Reality
- Context-awareness apps

The iPhone also has:

- Microphone (noise sensor)
- Proximity sensor
- Ambient light sensor

Introduction: Need for Sensors for the SG

- There is a general consensus that the current power grid is reaching its limitations and that smart-grid technology will be needed to increase efficiency, reliability, and security. The development of such a smart grid presents **many new opportunities for the sensors** market.
- Sensors will be a key enabler for the smart grid to reach its potential. The idea behind the "smart" grid is that the grid will respond to real-time demand; in order to do this, it will require sensors to provide this "real-time" information.
- The current grid is dominated by a system that is mostly electromechanical in nature, radial in its layout with centralized generating capacity and one way in its communication with little or no sensor feedback to centralized decision makers.
- The transition to a digital network with two-way communication, a network topology with distributed generation, grid storage and pervasive control systems and self monitoring presents extremely attractive opportunities for sensor firms.

Transducers : Sensors, Actuators

- **Sensors** are devices that responds to a physical stimulus heat, light, sound, pressure, magnetism, motion, etc , and convert that into an electrical signal. They perform an input function.
- Devices which perform an output function are generally called **Actuators** and are used to control some external device, for example movement.
- Both sensors and actuators are collectively known as **Transducers.** Transducers are devices used to convert energy of one kind into energy of another kind.

Common Transducers Inputs or Outputs, What it measures?

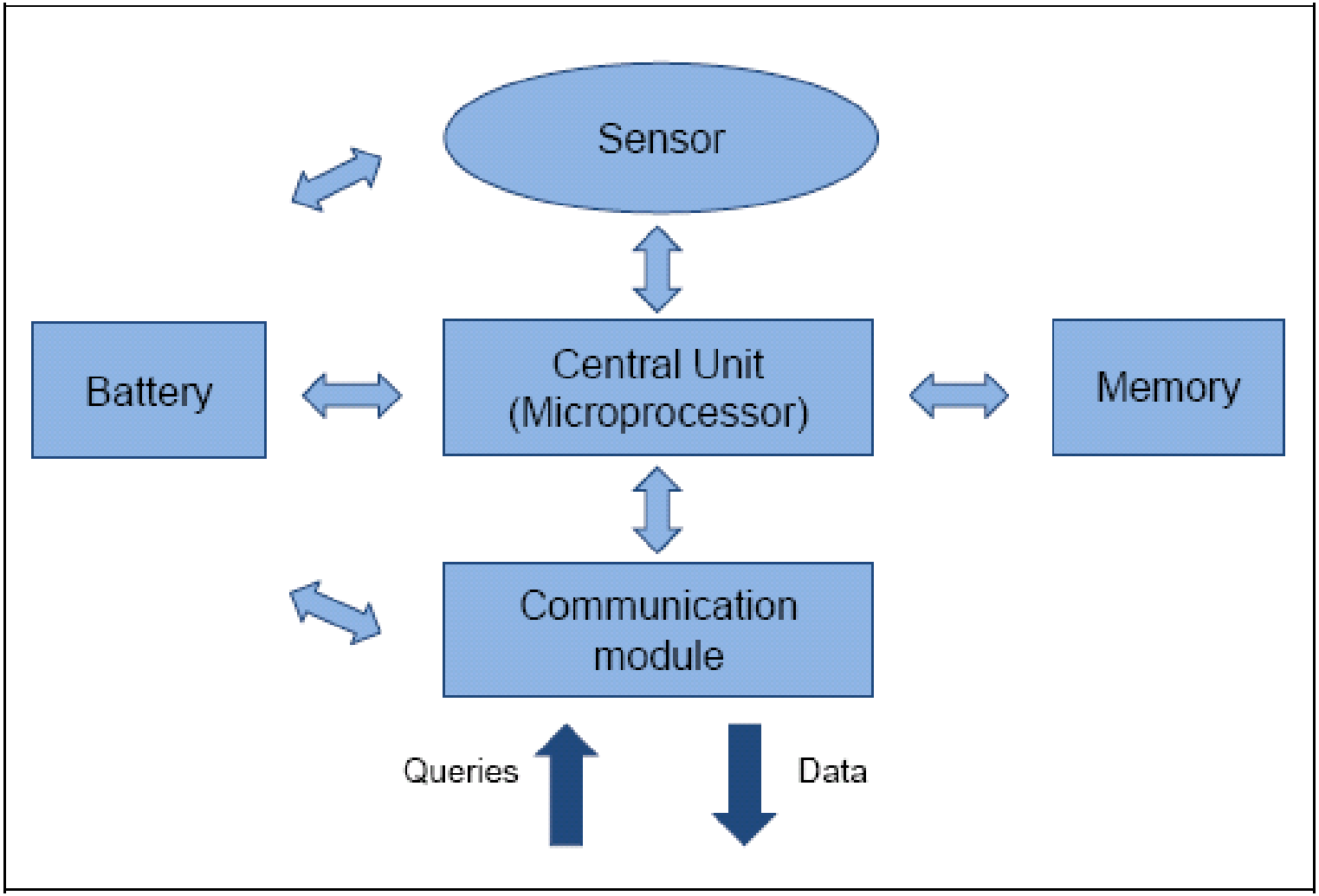
Quantity being Measured	Input Device (Sensor)	Output Device (Actuator)
Light Level	Light Dependant Resistor (LDR) Photodiode Photo-transistor Solar Cell	Lights & Lamps LED's & Displays Fibre Optics
Temperature	Thermocouple Thermistor Thermostat Resistive temperature detectors (RTD)	Heater Fan
Force/Pressure	Strain Gauge Pressure Switch Load Cells	Lifts & Jacks Electromagnet Vibration
Position	Potentiometer Encoders Reflective/Slotted Opto-switch LVDT	Motor Solenoid Panel Meters
Speed	Tacho-generator Reflective/Slotted Opto-coupler Doppler Effect Sensors	AC and DC Motors Stepper Motor Brake
Sound	Carbon Microphone Piezo-electric Crystal	Bell Buzzer Loudspeaker

Types of sensor that are growing (at 35%-50% yr-yr) and are projected to stay there for next 5 years

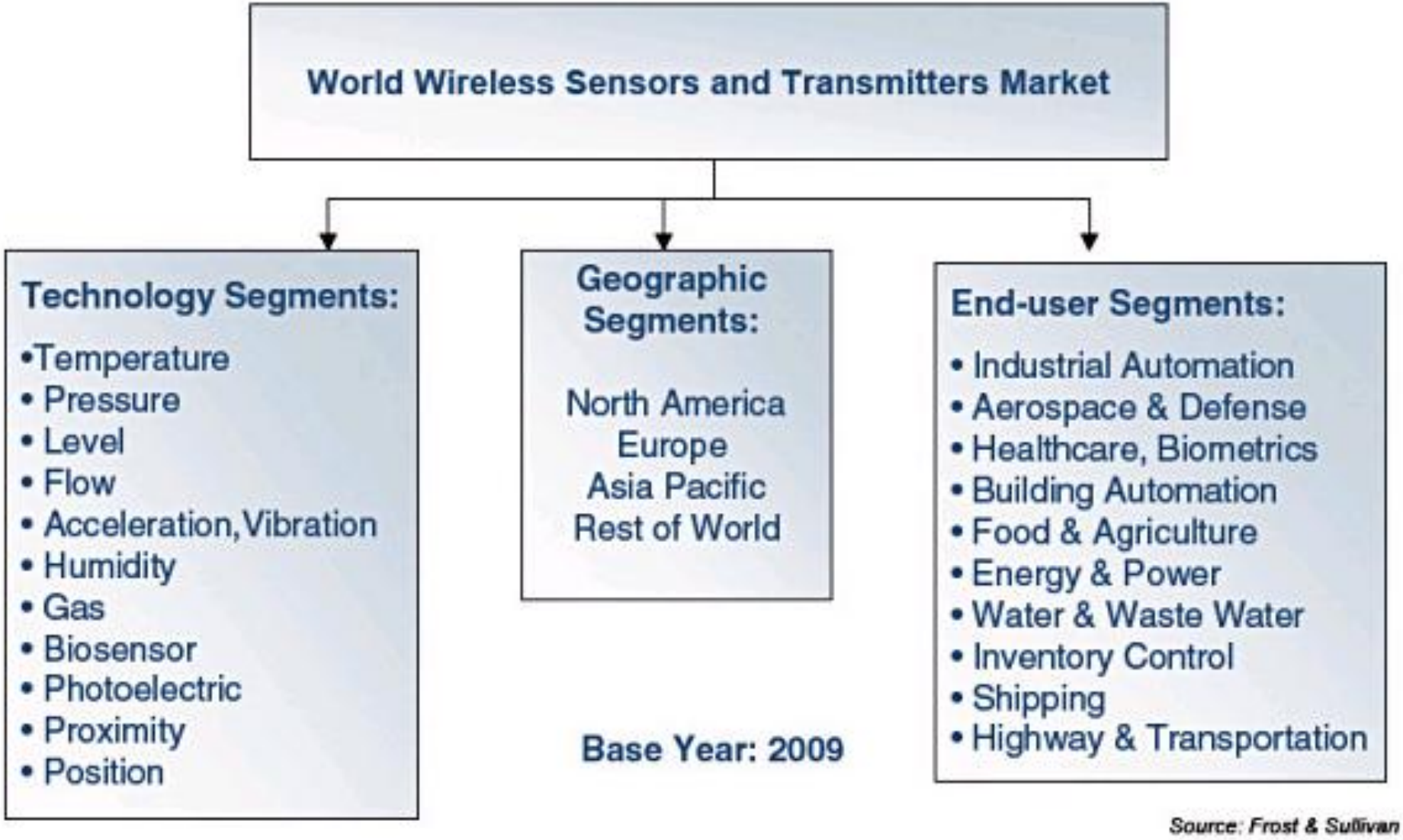
- **Position sensors** - mobile devices, auto applications, white goods, industrial automation - accel/gyro/magnetometer
- **Pressure /air flow sensors**- the single largest application is automotive TPM (tire pressure monitors) as they are now required in 15 countries, also commercial bldg smart air flow control
- **Motion Sensors** - either IR or proximity based - lighting control
- **Image Sensors** - everything is getting into a camera and image processing
- **Strain Sensors** - this is an insurance and infrastructure item for bldg/ bridges/ roads / mfg materials, detects wear and service schedule
- **Audio Sensors -** MEMS and Solid state microphones for medical, phones, auto, smart appliances, mobile devices for voice command.

Architecture of a Sensor Node

Figure 2: Architecture of a sensor node

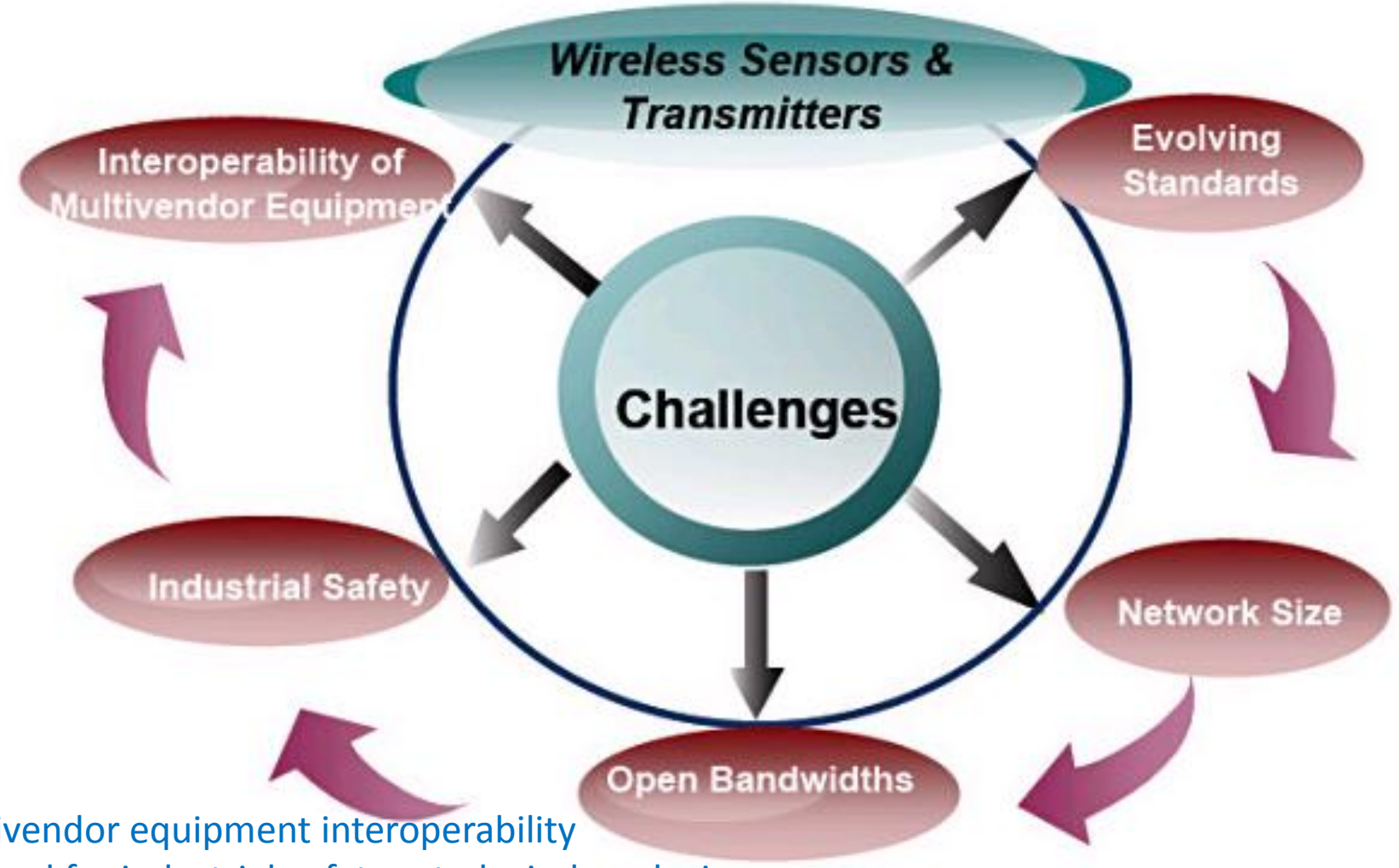


Sought after Wireless Sensor Attributes



Source: Frost & Sullivan

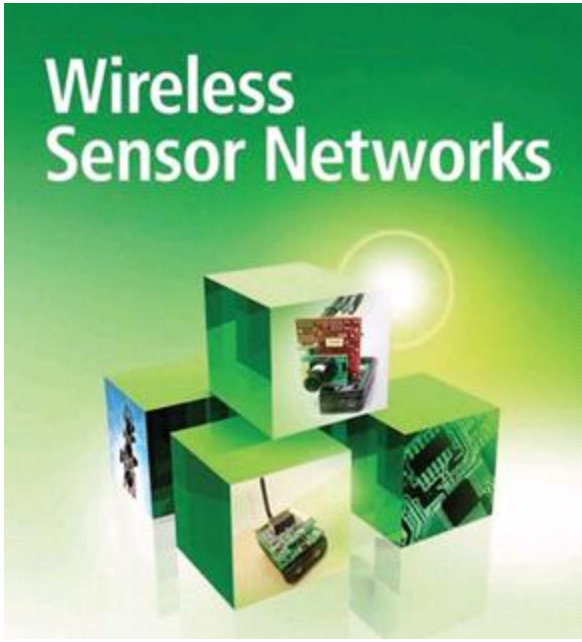
Key challenges for the Wireless Sensor Market



Multivendor equipment interoperability
Demand for industrial-safety-rated wireless devices
Lack of adequate open bandwidth
Deployable network size and hopping challenge
Constantly evolving standards

Wireless Sensor Network (WSN)

- A **wireless sensor network (WSN)** consists of spatially distributed autonomous sensors to *monitor* physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants and to cooperatively pass their data through the network to a main location.
- Modern networks are bi-directional, also enabling *control* of sensor activity. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance;
- Today such networks are used in many industrial and consumer applications, such as industrial process monitoring and control, machine health monitoring, and so on.



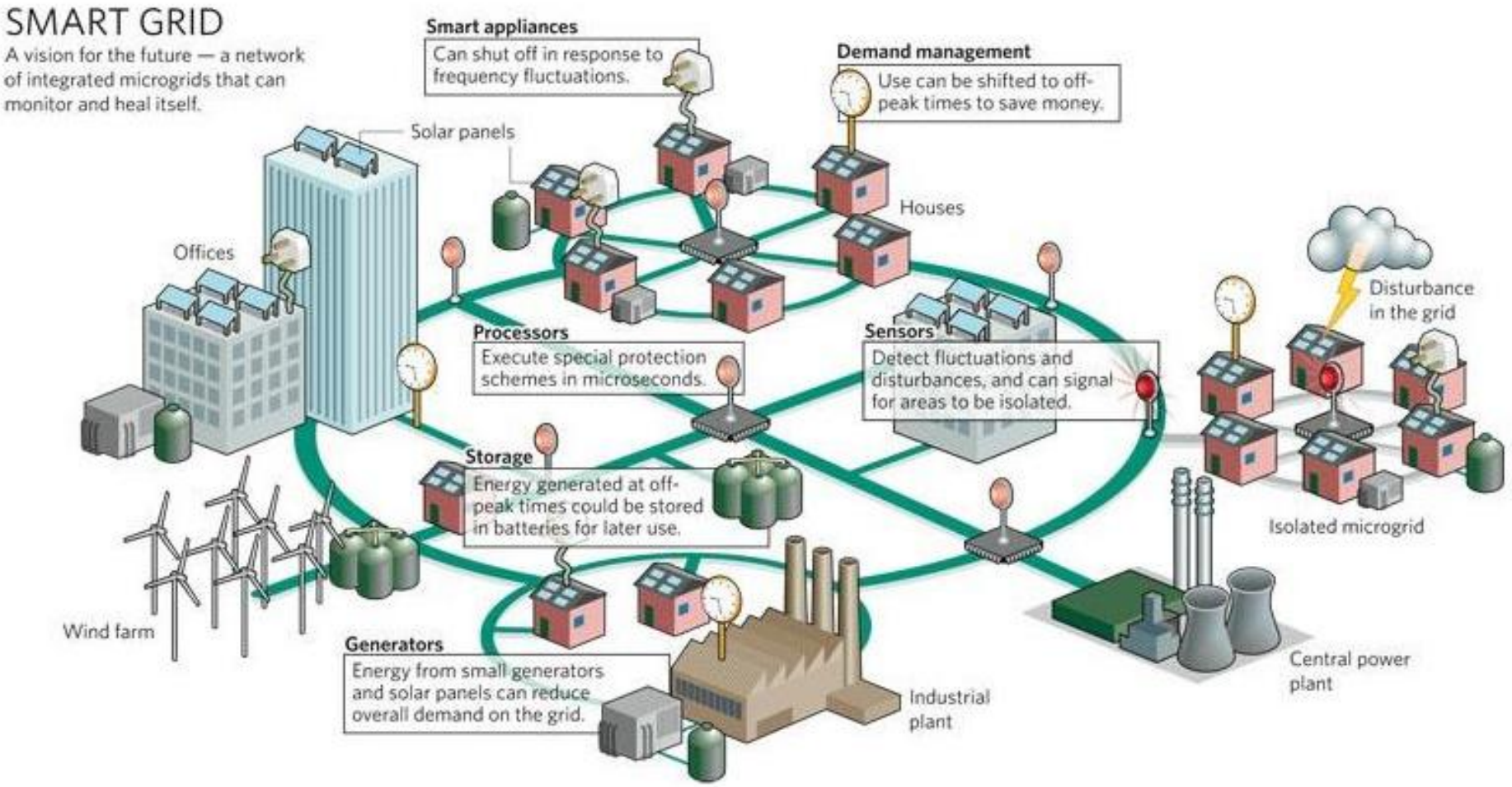
WSN Requirements

- **Large number of sensors**: Networks of 10,000 or even 100,000 nodes are envisioned, so scalability is a major issue.
- **Low energy use:** Since in many applications the sensor nodes will be placed in a remote area, service of a node may not be possible. The lifetime of a node may be determined by the battery life, thereby requiring the minimization of energy expenditure.
- **Network self-organization:** Given the large number of nodes and their potential placement in hostile locations, it is essential that the network be able to self-organize; manual configuration is not feasible. The network must be able to periodically reconfigure itself so that it can continue to function.
- **Collaborative signal processing:** The end goal is detection/estimation of some events of interest, not just communications.
- **Querying ability:** An user may want to query an individual node or a group of nodes for information collected in the region. A query may be directed to the sink node nearest to the desired location.

APPLICATIONS OF WSNS

1. Area monitoring
2. Environmental monitoring
   - Greenhouse monitoring
   - Landslide detection
3. Industrial monitoring
   - Machine health monitoring
4. Water/Wastewater monitoring
   - Landfill ground well level monitoring and pump counter
   - Agriculture
5. Fleet monitoring
6. Health Monitoring
7. Security

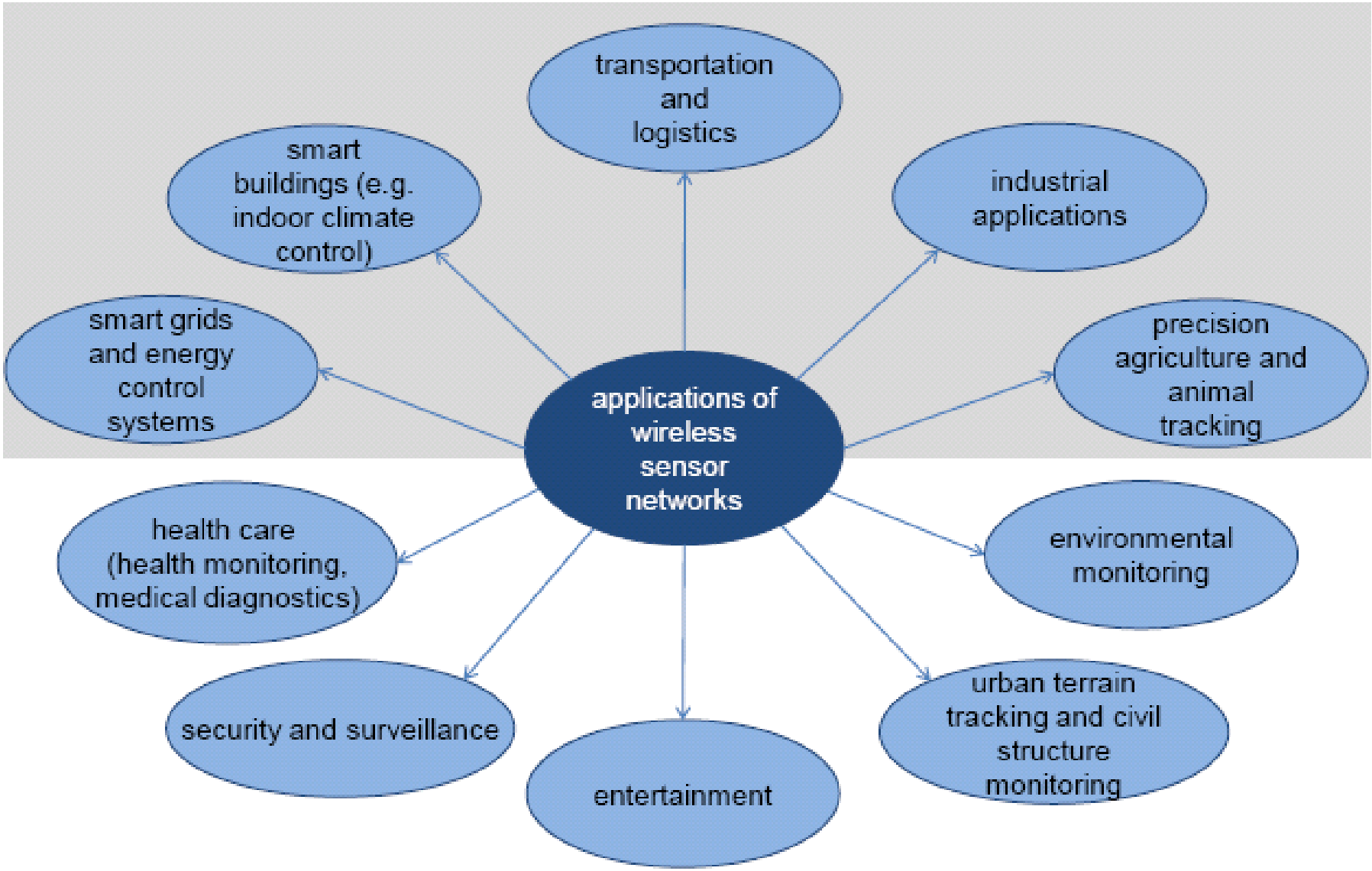
Smart Grid


SMART GRID
A vision for the future — a network of integrated microgrids that can monitor and heal itself.
Smart appliances
Can shut off in response to frequency fluctuations.
Demand management
Use can be shifted to off-peak times to save money.
Solar panels
Houses
Offices
Disturbance in the grid
Processors
Execute special protection schemes in microseconds.
Sensors
Detect fluctuations and disturbances, and can signal for areas to be isolated.
Storage
Energy generated at off-peak times could be stored in batteries for later use.
Isolated microgrid
Wind farm
Generators
Energy from small generators and solar panels can reduce overall demand on the grid.
Industrial plant
Central power plant

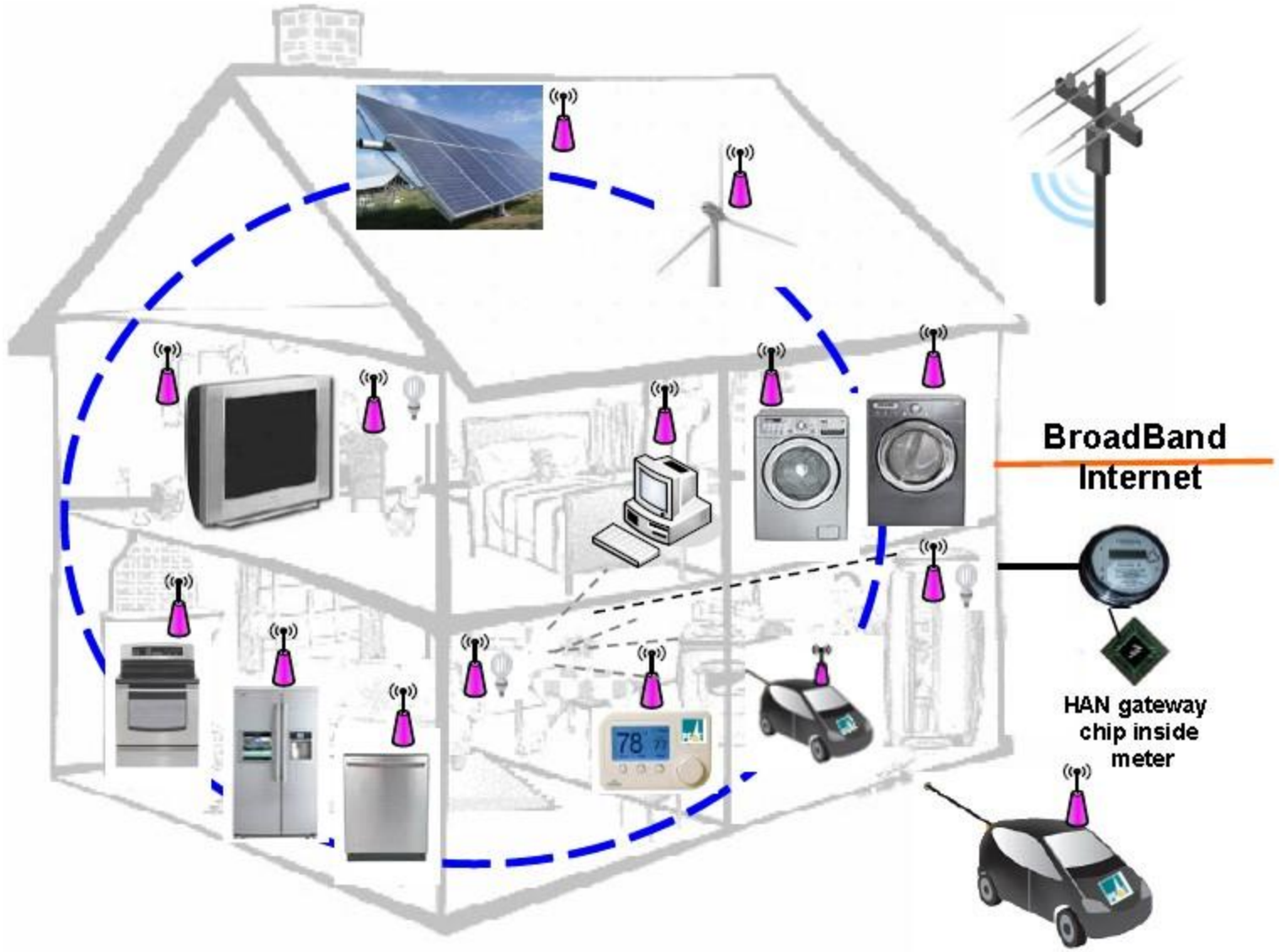
Sensors for the Smart Grid

- **Basic measurements** :voltage sensing, current sensing, temperature sensing, moisture sensing, continuity sensing and phase measurements.
- **Wireless Sensor Networks for Automated Meter Infrastructure (AMI)**
- **Smart Voltage Sensors**
- **Smart Capacitor Control ,** that can monitor and control capacitor banks remotely
- **Smart Sensors for Outage Detection.**
- **Smart Sensors for Transformer Monitoring.**
- **High Voltage Line Temperature and Weather Condition Sensors.**
- **Distributed Generation S**ensors for load balancing
- **Smart Grid Storage** and in load monitoring and dispatch of energy .

Application of WSN to Smart Cities



HAN : Sensors in a Home



 Source: “Home Area Network (HAN) Overview”, PG & E, January 2009

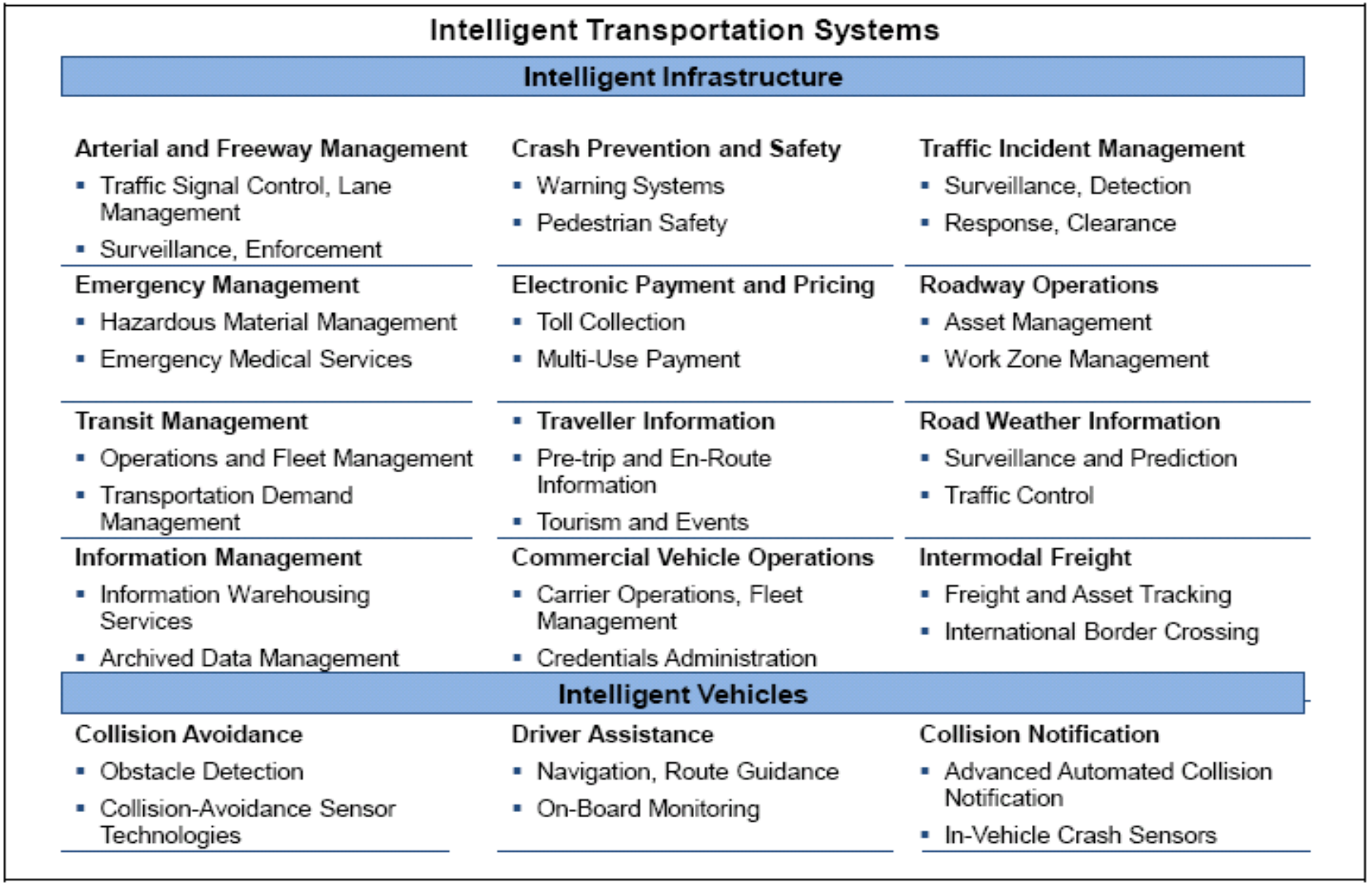
Sensors and Sensor Networks used in **Smart Home *Applications***

- Heating, ventilation, and air conditioning systems (HVAC)
- Lightning
- Shading
- Air quality and window control
- Systems switching off devices
- Metering (smart meters)
- Standard household applications (*e.g. televisions, washing machines)*
- Security and safety (access control).

Different types of Sensors for Smart Buildings

- Temperature sensors and heat detectors
- Light level detectors
- Movement and occupancy sensors
- Smoke and gas detectors
- Status sensors (*e.g. air quality, open windows)*
- Glass break sensors

Applications onto Intelligent Transportation Systems



Parking Lot Sensors: The Smart Santander Project

- This is a new milestone in line with the target for the city of Santander, Spain to become a smart city and improve the quality of life in urban spaces through the use of **ICT (Information and Communication Technologies).**
- The creation of a network architecture composed of **parking sensors**, gateways that gather the information sent by the sensor nodes and forward it to some central servers managed by the **Smart Santander Project.**
- The initiative will involve the design, deployment and validation of a platform composed by **20,000 devices (sensors, actuators, cameras, mobile terminals, etc.)** all of them integrated under the umbrella of the so called **"Internet of Things",** where every gadget has the ability to communicate to transmit information that is useful to the user (temperature, air pressure, noise level, CO_2 concentration, etc.)
- Once the sensors are installed, the city will continuously monitor parking spaces. The system will **report of every change on the occupancy status of the parking spaces.**

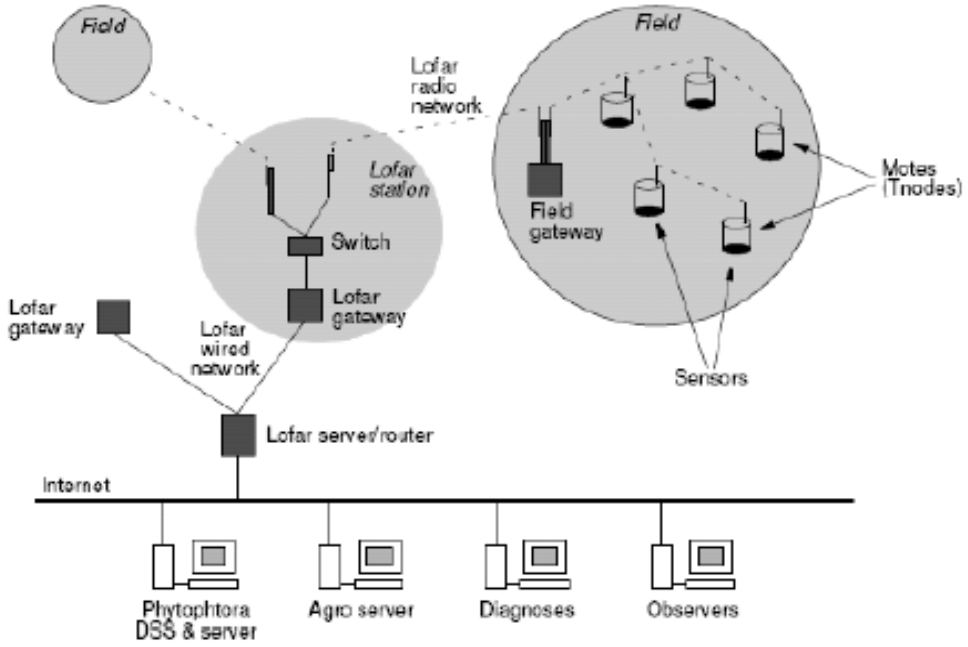
Applications onto Precision Agriculture

- Sensors and sensor networks are important components of precision agriculture which aims at "maximum production efficiency with minimum environmental impact".
- Sensors and sensor networks play a critical role in measuring and monitoring the health of the soil and water quality at various stages, from pre- to post-production.
- In precision agriculture, sensor networks can be used for:

  1) plant/crop monitoring, 2) soil monitoring, 3) climate monitoring and iv) insect-disease-weed monitoring.
- Wireless sensors are further used for **precision irrigation**, and systems developed for remotely controlled, automatic irrigation.
- *Finally, sensors are used to assist in **precision fertilization**. Based on sensor data, decision support systems calculate the **"optimal quantity and spread pattern for a fertilizer".***

Sensor Application in Precision Agriculture

150 sensor nodes have been deployed in the field for the experiment. These nodes are equipped with sensors which measure both temperature and relative humidity (see Figure). Additional sensors are deployed in the soil to monitor soil humidity. A weather station "registering the luminosity, air pressure, precipitation, wind strength and direction" (Baggio, 2005) complements the setting.



Sensor nodes send the gathered data via a wireless connection every 10 minutes to field gateways which send it to an ordinary PC for data logging (the Lofar gateway in the figure). The data is further transmitted to other servers for data analysis via a wired Internet connection. A decision support system maps the temperature distribution together with other information. Based on this information, farmers can take different actions and vary the amount of fertilizer and pesticide used.

Summary and Future Work

- This report presented an overview of sensor devices and sensor networks , and their applications on smart grid, and smart cities.
- Sample Smart City application areas included:

  - Smart Homes and Buildings

  - City Transportation, Traffic, Parking

  - Precision Agriculture

- **Future Work**

  - Data fusion: processing sensor data by filtering, aggregating, and making inferences about the gathered combination of data from multiple sources to obtain **improved information**: cheaper, greater quality, greater relevance.

  - Self organized/grouping of sensors

  - Node failure, fault tolerant sensor networks

  - Standards: Wireless

For your attention