PART III. APPLICATIONS

III.1. SMART OBJECTS APPLICATIONS/MARKETS

Applications/Markets

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"… many appliances around the house, in the office, in the car, on our persons, in the buildings that we work and live in will be instrumented and will be part of the net… When those appliances are Internet-enabled… you open up an opportunity for new businesses to manage those devices."

Vint Cerf

Vice President and Chief Internet Evangelist

Google Inc.

Markets

- Industrial Monitoring

Markets

- Industrial Monitoring
- Energy

Markets

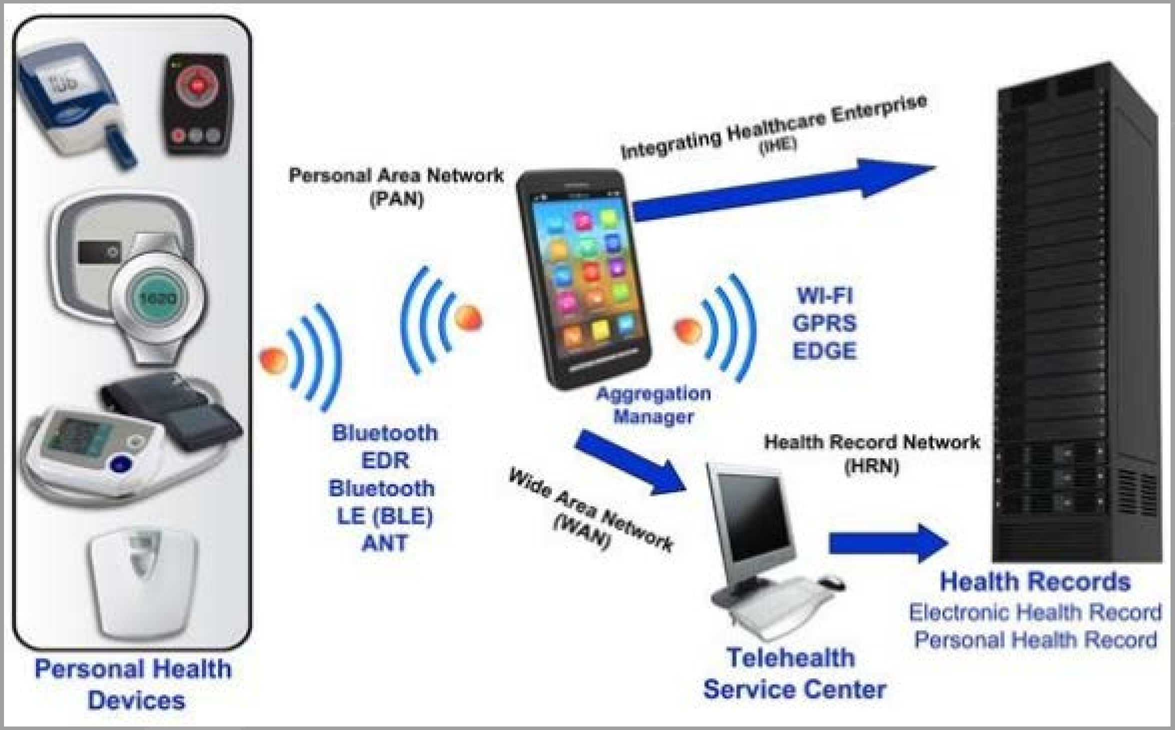
- Industrial Monitoring
- Energy
- Structural Monitoring

Markets

- Industrial Monitoring
- Energy
- Structural Monitoring
- Connected Home

Markets

- Industrial Monitoring
- Energy
- Structural Monitoring
- Connected Home
- Healthcare



Markets

- Industrial Monitoring
- Energy
- Structural Monitoring
- Connected Home
- Healthcare
- Vehicle Telematics

Markets

- Industrial Monitoring
- Energy
- Structural Monitoring
- Connected Home
- Healthcare
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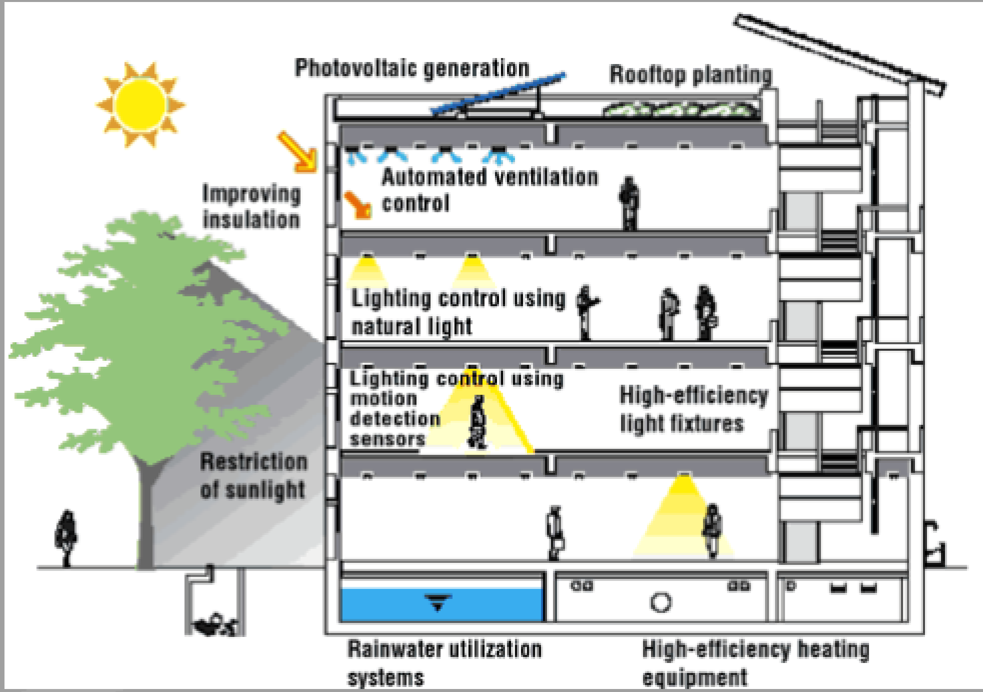
- Agricultural Monitoring

Markets

- Industrial Monitoring
- Energy
- Structural Monitoring
- Connected Home
- Healthcare
- Vehicle Telematics
- Agricultural Monitoring
- Building Management



Examples

Texas Instruments CC-6LoWPAN Development Kit

Examples


JenNet-IP
JenNet-IP EK040
Evaluation Kit
NXP
NXP Jennet-IP Evaluation Kit

Examples

Belkin WeMo Home Automation System

Examples

Examples

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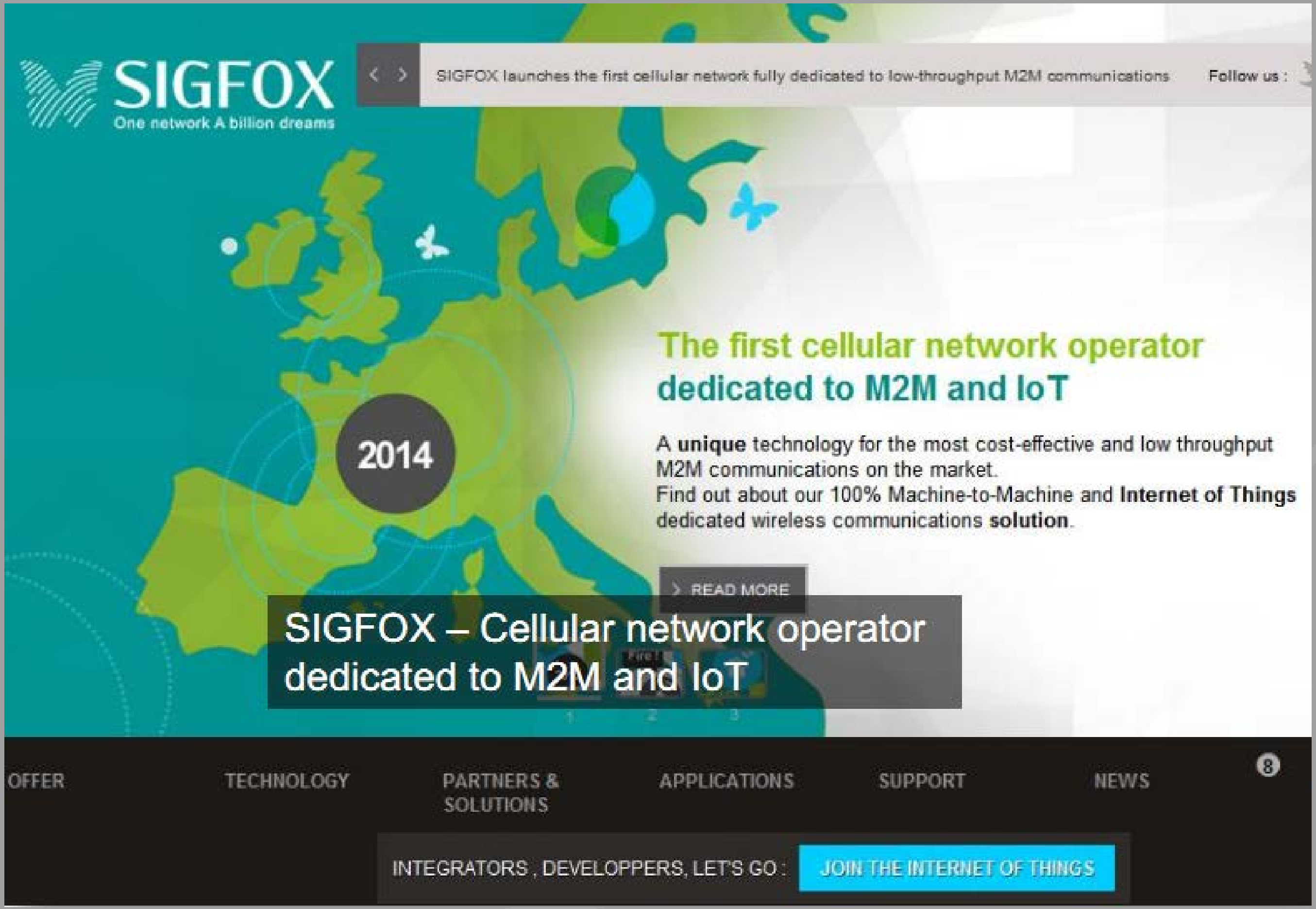
Deutsche Telekom marketplace for M2M communication technologies

Examples



SIGFOX – Cellular network operator dedicated to M2M and IoT

Examples

Public cloud resource for smart devices

Conclusion

- Tremendous market potential in M2M/IoT/Smart Object networks.
- Much of these data will need to be uploaded, stored and processed.
- IPv6 is an ideal candidate.
- Opportunities for new businesses and channels.

Applications

- Smart Grid
- Industrial Automation
- Smart Cities and Urban Networks
- Home Automation
- Building Automation
- Structural Health Monitoring
- Container Tracking

Simulate with Cooja

- To start, go to /tools/cooja and run

  $ ant run
- To try a precompiled example for the Z1 mote do:

  File->Open Simulation -> Browse -> /examples/hello-world/hello-world-example.csc
- Then, in the simulation control window “Start” the simulation
- You can see the simulated expected output of the serial port in the mote output window.
- To create your own simulation scenario go to:

  File->New Simulation
- Configure the simulation settings and then add some Z1 motes:

  Motes->Add motes ->Create new mote type->Z1 mote
- In browse window select the source file of any of the available Z1 mote examples, for example:

  /contiki-2.6/examples/z1/test-adxl345.c
- Click on « Compile », after the compilation process is over click on « Create » and place as many of Z1 motes as you like, then click « Add motes » and « Start » simulation.

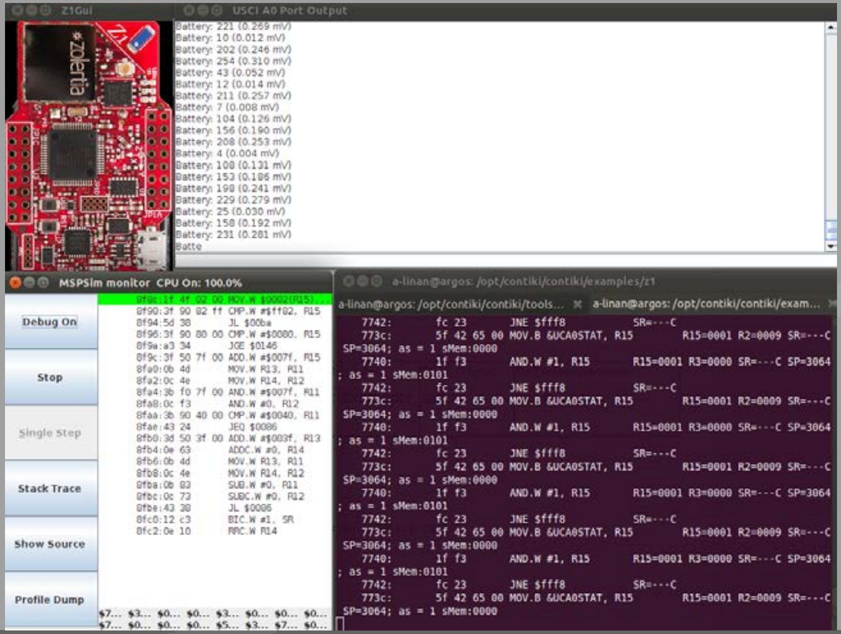
Simulate with MSPSIM

- **MSPSIM**: a Java simulator for the TI msp430 processors developed by SICS.

- To start testing, go to /examples/z1 and compile/run any of the available test programs like the following

  $ make TARGET=z1 test-battery.mspsim

- The MSPSIM window will pop-up and the simulation will start:

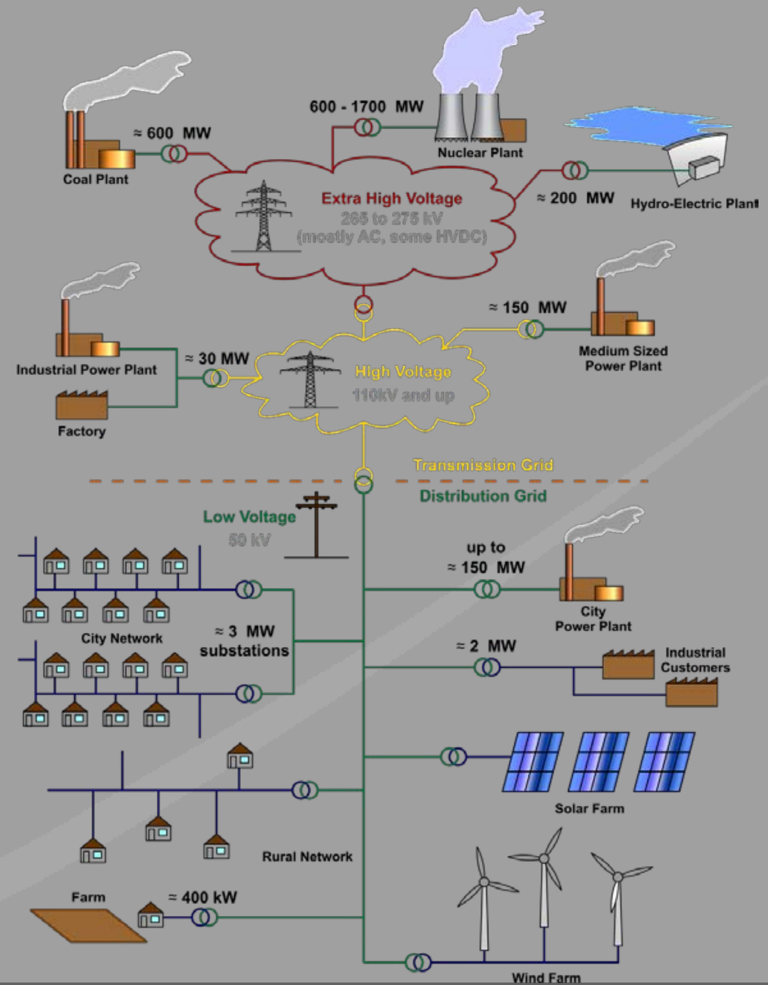


III.2. SMART GRID

Introduction

Power grid: electrical network delivering electricity to houses, offices, and industrial users:

- Produced by **plants** (nuclear, solar, geothermal, wind, etc.).
- Transported through a hierarchical power grid network from **power generation sources** to **homes** after a succession of voltage transformations performed in **substations**:
  - Primary substations (Europe): several thousands.
  - Secondary substations (largest countries in Europe): several hundred of thousands.
- Mostly managed and designed according to power consumption forecast using monodirectional information flow.



Introduction

But …

- the user has changed its power consumption behaviour → demand less predictable.
- more users have access to electricity → there has been an increased energy consumption.
- generation of power from distributed renewable energy sources (e.g., solar panels, wind turbines, etc.) → increase the level of unpredictability.

→ Requires fine-grained monitoring and management of the grid to maintain a <u>high level of reliability</u> and <u>reduce the number of network outages</u>.

→ Need for an **advanced networking infrastructure** in the Smart Grid from generation to distribution and finally homes and buildings made of **billions of smart objects** performing sensing and actuating in the grid to provide **“real-time” information** about the grid health and **consumer demand** to optimize the grid operation.

Definition of Smart Grid

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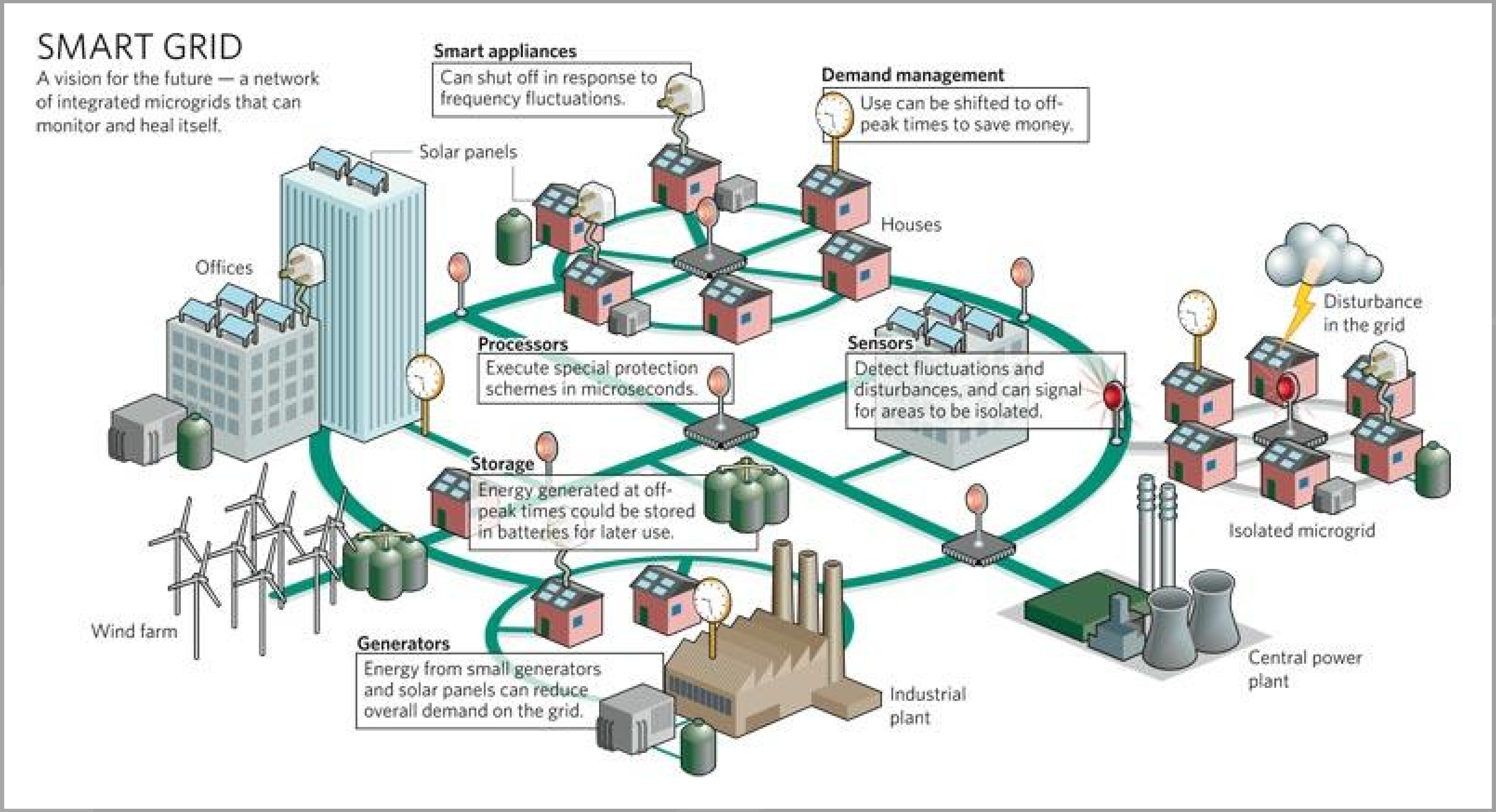
- Smart Grid must enhance the current grid network with **advanced sensing actuators** and a **highly secure networking infrastructure** to improve grid efficiency, performance and reliability as well as to support a wide range of new services.

- Smart Grid is one of the major applications for smart object networks; IP protocol will be central to them.

- Most of the expectations and requirements for the Smart Grid involve smart object networks:
  - Sensors: measuring the current, voltage, phase, or reactive power.
  - Actuators: circuit breakers, etc.

Definition of Smart Grid



Use Cases

- Most common use cases for smart object networks in Smart Grid networks:

  - **Substation monitoring and control**
  - **Smart metering**
  - **Home energy management**

- Terminology:
  - Substation automation/integration (**SA/I**): the core grid network from power generation to power distribution (primary and secondary substations).
  - Neighbour area network (**NAN**): network between the substations and the homes (concentrators and smart meters).
  - Home area network (**HAN**): home network (smart appliances, home energy controller (HEC), etc.).

Core Grid Network Monitoring and Control

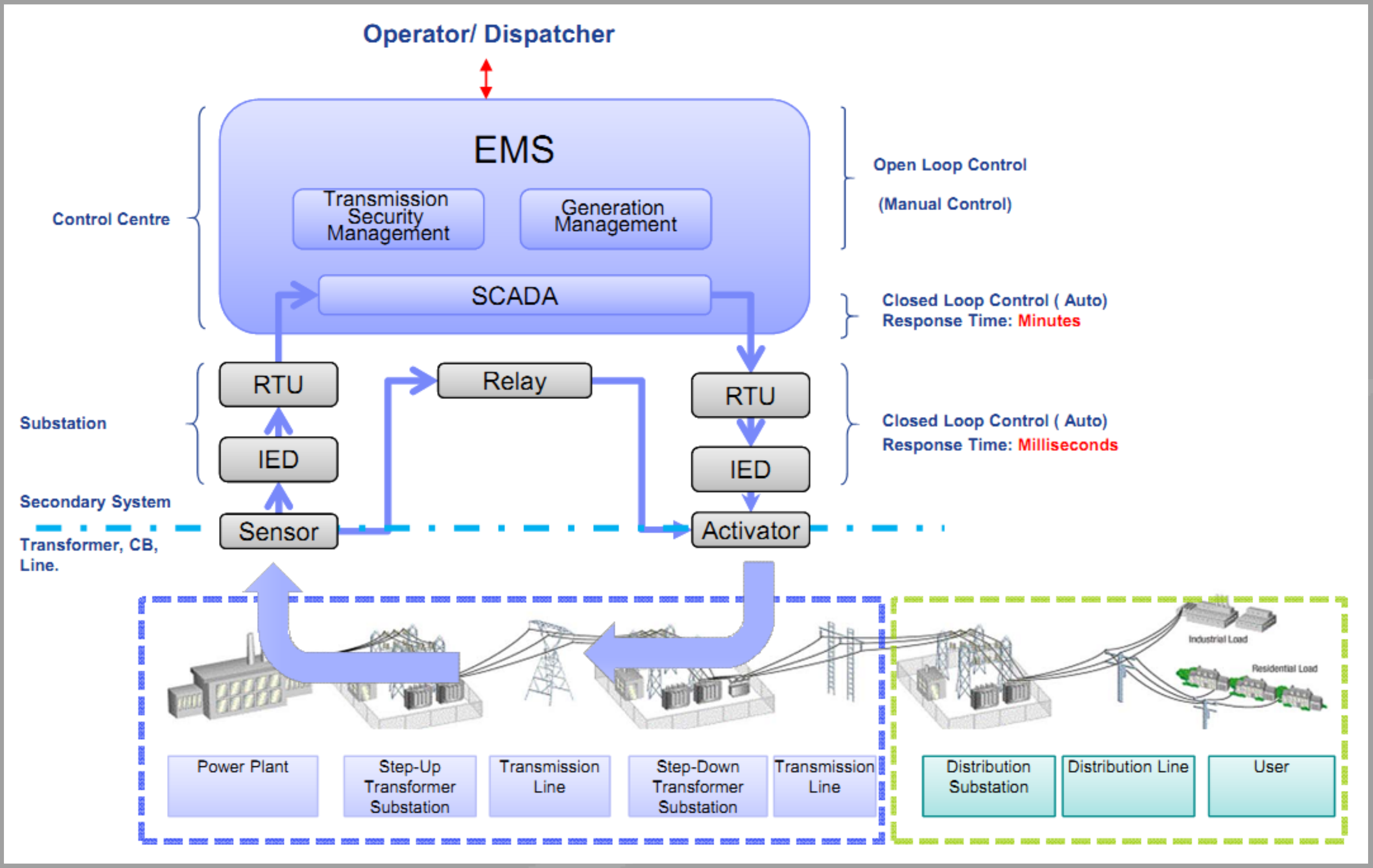
- Role of sensors and actuators in the core grid for monitoring and control.

- Three main applications:
  - Substation monitoring and control
  - Substation condition-based maintenance (CBM)
  - Line dynamic rating

Secondary Substation Monitoring and Control

- Secondary substation: step down the power voltage from medium (40-60kV) to low voltage (110/220V):
  - Transformers.
  - **Intelligent End Devices** (**IEDs**): such as circuit breakers, voltage sensors, etc.
  - **Remote Terminal Units** (**RTUs**): receive data from sensors and trigger local actions.
  - IEDs are managed by a centralized system located at the **Network Control Center** (NCC) called the **Supervisory Control and Data Acquisition** (**SCADA**) application.

Secondary Substation Monitoring and Control



Secondary Substation Monitoring and Control

- Smart Grid networks tend to introduce distributed intelligence in the grid in contrast with a purely centralized system.

- Smart objects:
  - Primarily used to monitor the MV and LV power lines and report a number of quality metrics (such as the voltage and current levels for each phase).
  - Also report ground faults, fuse status, cable temperature, and voltage or current values exceeding some pre-configured thresholds.
  - Actuators, such as circuit breakers, controlled by the RTU or by the SCADA application.

- RTU has historically been using protocols defined by IEC (International Electrotechnical Commission), but there is a trend toward a truly end-to-end IP architecture from smart objects such as sensors and actuators to the SCADA application.

Substation Condition-based Maintenance (CBM)

- By monitoring the device, utilities can perform maintenance before a failure occurs → save the cost of the device but also indirect costs due to network outages.
- CBM includes the periodic sending of health reports by a smart object to a central system in addition to sending alarms triggered by specific events.
- They have been used for years using proprietary solutions → unified communication infrastructure (IP).
- A subset of the wide set of sensors used in today's environments:
  - Partial discharge detectors
  - Infrared thermographic imaging monitors
  - Vibration sensors or rotating equipment
  - Acoustic emission defect sensors
  - Moisture in oil sensors
  - Load current measurement sensors
  - Backscatter sensors
  - Wind speed sensors
  - Temperature sensors
  - Humidity sensors
  - Dissolved gas analysis sensors
  - Liquid leaks

Line Dynamic Rating

- With the emergence of distributed generation –> power generation exceeds the grid transmission capability.

- Transmission line capacity is limited.
- Grid transmission capacity is usually expressed in **static ratings** using worst-case weather scenarios (high air temperature and minimal wind).
- But static ratings do not take into account real-time conditions.
- Unlike static rating, **dynamic rating** makes use of real-time measurements of parameters such as temperature. It makes uses of various techniques:
  - Based on weather (equations using air temperature, solar heating, and wind speed) → does not require sensors mounted on the power line.
  - Use of several sensors on the line → use of several sensors along the power line that communicate with each other.

- Gain in power transmission capacity can vary between 10% and 20% and even up 30% in some cases.

Technical Characteristics and Challenges

- **Networking environment**: fairly harsh environments due to high temperature or strong electromagnetic interferences (EMI).
- **Traffic Flows**: tend to move to a more distributed model.
- **Link Characteristics**: both wired and wireless, usually with low speed and with a relatively high error rate.
- **Quality of Service and Network Reliability**: although some data are not critical, others have real-time requirements and the networking infrastructure must guarantee reliable delivery, minimized delays, and bounded jitters → IP supports QoS!
- **Scalability**: number of smart objects in Smart Grid networks is extremely high (up to several millions in a single power network) → IP is scalable!

Technical Characteristics and Challenges

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- **Reliability**: the smart object networks must be operational at all times and they must be able to recover various types of failures within usually bounded times.
- **Mobility**: low to moderate
- **Security**: one of the most critical concerns in Smart Grid networks → IP has been enhanced with a number of security mechanisms (authentication, encryption).
- **Network Management**: autoconfiguration and device/service discovery is highly desirable.

Smart Metering (NAN)

- Electrical meters have been enhanced with added features:
  - **Automatic Meter Reading** (AMR): adding communication functionality t the meters to perform automatic collection of different parameters as well as device monitoring. Real-time power consumption helps provide accurate billing (instead of predictions).
  - **Advanced Metering Infrastructure** (AMI): more advanced functionalities such as sensing for power-quality monitoring and power fault reports.

- Communication between a central system (SCADA) and smart meters → two way, in order to support advanced sensing capabilities required by advanced services:
  - Dynamic pricing
  - Demand-response (DR)
  - Grid monitoring

- Several large-scale deployments of smart meters already took place and many are planned in the future.

Technical Characteristics and Challenges

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- **Networking environment**: smart meter networks are mostly outdoors.
- **Traffic Flows and Network Topologies**: start topologies up to a concentrator, meshed topologies made of routers, and smart meters acting as routers or a mix of both. Trend is to migrate these networks to IP end to end.
- **Link Characteristics**: smart meters are main powered devices (with a battery for redundancy purposes) forming a complex multi-hop network of smart objects (end devices and routers). They are interconnected by wireless links or PLC technology. For both, link reliability is usually low and fairly limited (from a few Kbit/s to a few hundreds of Kbit/s).
- **Quality of Service and Network Reliability**: meter reading is not a critical application → QoS and network reliability are low. Nevertheless, the requirements tend to increase with the emergence of new applications (e.g., dynamic pricing).

Technical Characteristics and Challenges

- **Scalability**: extremely high since smart meters are made of millions of devices → RPL designed to support a large number of IP smart objects in a single network.
- **Mobility**: no mobility requirement.
- **Security**: is a paramount concern, since the hacking of a smart meter could lead to cutting power to potentially thousands of homes. Authentication and encryption technologies are a must.
- **Longevity**: smart meters are required to last for at least two decades with no human intervention → support of dynamic software upgrades and flexible hardware and software functionalities.

Home Area Network (HAN)

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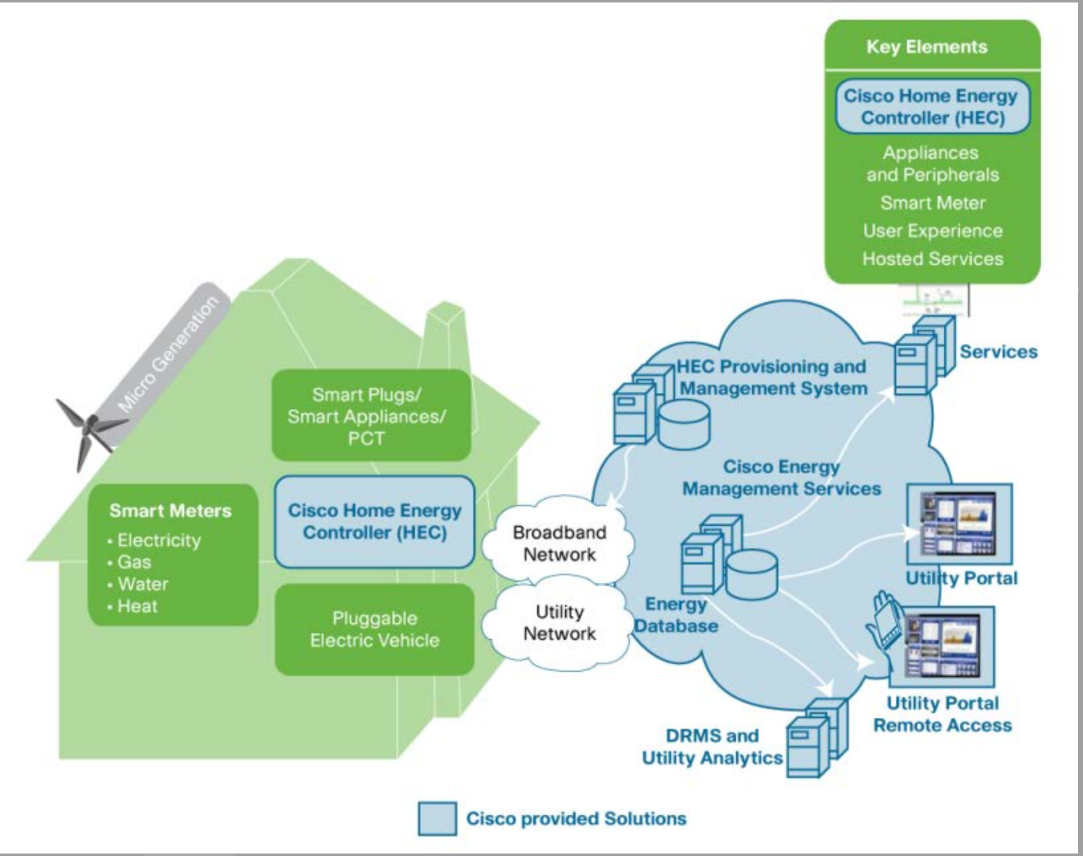
- A typical HAN configuration:
  - **HEC** connected to the HAN and to the grid (via Internet or smart meter).
  - HAN composed of a variety of smart objects connected via both <u>wireless</u> (e.g., IEEE 802.11, IEEE 802.15.4) and <u>PLC links</u>.



HAN – The Role of Smart Objects

- Smart objects are at the heart of the HAN and provide efficient energy management solutions:
  - **Smart appliance**: an appliance equipped with a smart object capable of sensing, actuating, and communicating with the HEC. It reports energy consumption to the HEC and could be also controlled by the HEC according to DR signals and to user-defined rules on the HEC.
  - **Smart plugs**: intermediate solution is to use an electrical wall-plug adaptor equipped with a sensor to measure the energy consumption in near real-time and allow for appliance control.
  - **Smart thermostats**: control the temperature setting of the room based on the received DR signal from the HEC and could lower the temperature by several degrees for a period of time and report energy savings.

HAN – The Role of Smart Objects – End User Applications

- **Home Energy Management**:
  - Imperative to provide user-friendly tools that allow access to the power usage in the home via a simple display or other forms of data access (→ energy saving between 5% and 15%).
  - Other useful information: tips from utilities to help save energy and main sources of energy consumption (e.g., energy usage in kWh, energy cost, and CO_2 consumption).
  - Another service: detect a malfunctioning device by observing the power consumption and compare it to energy consumption profiles of similar devices.
  - Other services will emerge, such as micro-generation management.

HAN – The Role of Smart Objects – End User Applications

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- **Demand-Response**:
  - Ability of the grid to dynamically interact with the home to regulate the power demand according to the grid capacity with some pricing incentive for the end user.
  - Upon peak load on the grid, the utility sends a signal to the end user via the HEC requesting power consumption reduction to perform load shedding at peak times.
  - Additional features:
    - **Dynamic pricing**: in accordance with the grid load, the energy price is dynamically adjusted and communicated to the HEC.
    - **Critical alarms**: can be sent at any time to cope with unexpected events in the grid that require lower energy consumption. Higher priority than dynamic pricing signals.
  - DR is <u>two-way communication</u>: signals are sent to the HEC and energy consumption reduction reports are provided back to the power grid. Such reports are then used for energy bill discounts.
  - Full control is given to the end user who may even decide to ignore near real-time pricing indications.
  - **HEC** controls the HAN and all of the connected devices.
  - A friendly user interface can then be used by end users to control their devices and appliances in the home according to real-time energy pricing.

Technical Characteristics and Challenges

- **Networking environment**: less challenging than a HV substation environment.
- **Traffic Flows and Network Topologies**: PLC able to reach out to almost all devices. Smart objects could also be connected in a mesh wireless IP network. Most of the traffic flow is between smart devices and the HEC.
- **Link Characteristics**: mix of main- and battery-powered devices equipped with low bandwidth communication capabilities (a few dozen Kbit/s).
- **Quality of Service and Network Reliability**: all messages have similar QoS requirements. Requirements for reliability are not high (a temporary HAN failure has limited consequences).
- **Scalability**: is not a primary concern.

Technical Characteristics and Challenges

- **Mobility**: required but moderate (most devices are fixed).
- **Security**: security requirements are high. Authentication and encryption technologies are a must.
- **Network Management**: a HAN must be self-managed and must require minimal configuration from the end user. Smart devices must be self-configured with autodiscovery. Several powerful HAN management solutions with a very friendly user interface are already available.

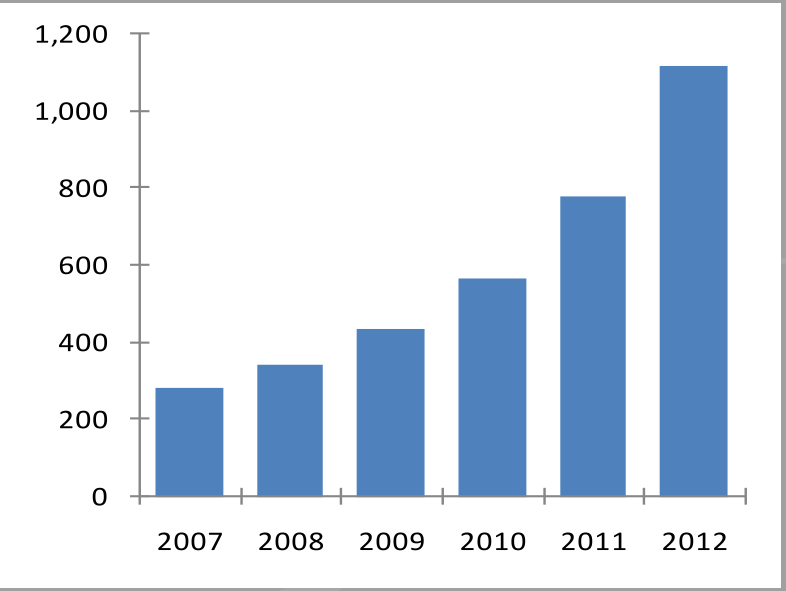
III.3. INDUSTRIAL AUTOMATION

Introduction

Automation of industrial processes by means of modern computer-assisted technology.

- **Process manufacturing** (continuous processes)
- **Discrete manufacturing** (discrete units)

Opportunities for wireless communication within the industrial automation market are growing at a rapid rate, mainly due to the <u>available access to difficult locations and hazardous areas in the plant</u>.



Worldwide Market for Wireless Devices in Process Manufacturing

($Millions) ©2008 ARC Advisory Group

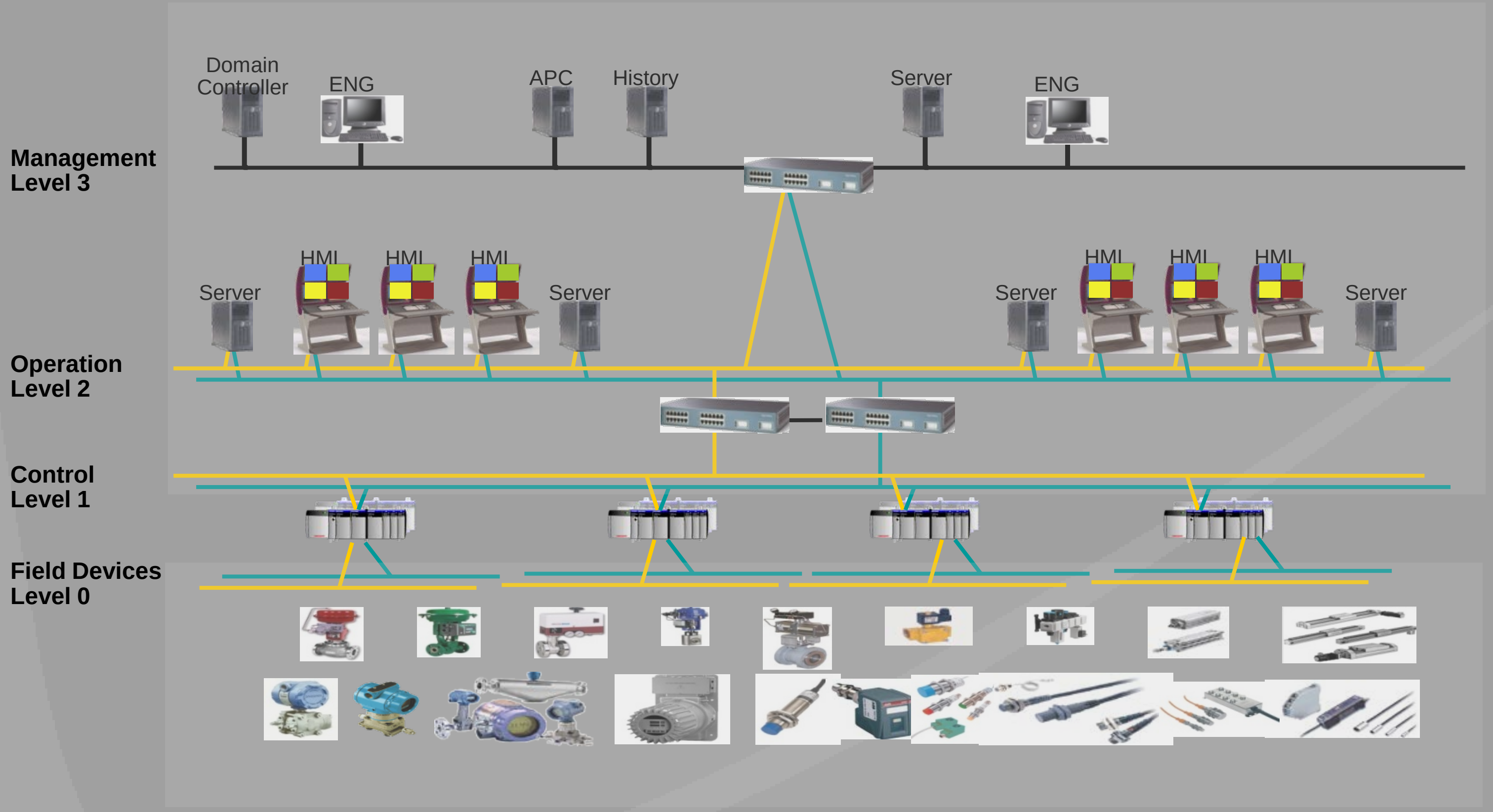
Opportunities

- Wireless communication is becoming more widespread in industry, especially since the recent ratifications of standards designed with industrial automation requirements in mind (e.g., WirelessHART).
- Attractive features:
  - **Non-intrusive** nature → easy access to information.
  - **Scalability** → easier installation.
  - **Mobility** → scaling.
  - Possibility of mounting **sensors on rotating equipment** → opens up a range of new applications.
  - **Cost-effective** way to use temporary installations.
  - Provide **remote access** possibilities to plants → control room no longer has to be located on site.

→ Wireless technology will open up many new possibilities within the industrial automation area.

Opportunities

- Trend → provide a wireless backbone for everything in the plant from sensor information to portable HMIs to mobile phones.



Generic Requirements

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Process Attribute	Continuous Process Manufacturing Unit	Discrete Manufacturing Unit
Sensor types	Predominately Analog	Predominantly Discrete
Sensor count per unit	1000	100
Unit Physical Size	1000 Meter	10 Meter
Units per Plant	10s	100s
Production Cycle Length	100 Days	1 Day
Unit Startup Time	Hours	Minutes
Control Loop Time	.1-1000 Sec	.001-.5 Sec
Field Device Cost	$1000	$100
Installation Cost/device cost	10 X	4 X
Automation Technology	DCS	PAC/PLC
Commonly Used Device Networks	HART, Foundation Fieldbus, Profibus-PA, Ethernet	Profibus-DP, DeviceNet, Interbus, AS-i, Ethernet

Challenges

- **Reliability**: different approaches for reliable communication, such as using mesh network topology or add error control techniques.
- **Global availability**: requires the use of globally available frequency bands → solutions are operating in the unlicensed 2.4 GHz ISM band.
- **Coexistence**: a solution has to coexist in a radio environment with a large amount of interference.
- **Lifetime**: it has to provide good availability and require a minimum of maintenance during tens of years.
- **Security**: security, authenticity, and integrity are very important.
- **Interoperability**: using standardized equipment and communication to be able to use equipment from different vendors.

Use Cases:
Condition Monitoring

- Collection of data related to the condition and status of machinery → used to predict failures, generate alarms, and schedule maintenance.
- Wireless condition monitoring → ability to easily install a condition monitoring solution in an existing plan and hook it up to a condition analysis system.
- Parameters to monitor: vibration, temperature, oil, etc.
- Requirements for condition monitoring applications:
  - Latency: not very important.
  - Duty cycle: from ms to weeks.
  - Throughput: varies from app. to app.
  - Range: few 100m with line-of-sight.

Use Cases: Wireless Control

- For real-time control applications, process signals must be received within a specified amount of time to correctly operate the process → networks must be able to guarantee end-to-end communication deadlines.
- Event-based control applications wait until the signal is received before making any decision.
- Requirements for wireless communication systems for industrial automation and control:
  - Device mounting: orientation of the sensor is very important.
  - Latency: from ms to minutes.
  - Duty cycle: from a few ms to seconds.

Use Cases:
Mobile Workforce

- With the advent of wireless technologies, engineering tasks carried out through portable or detachable HMI units are now very common in all industries.
- Main objective of the mobile workforce area → optimize the workflow of a plant throughout its life cycle.
- Requirements to mobile workforce applications:
  - Latency
  - Throughput
  - Range
  - Multiprotocol

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III.4. SMART CITIES AND URBAN NETWORKS

Introduction

- In 1900, **13%** of world's population lived in cities; By 2050 it will raise to **70%**.

- The integration of Information and Communication Technology (ICT) with development projects can change the urban landscape by developing **Smart Cities**.
- Smart objects will play a critical role in making Smart Cities a reality.

→ new services improving the quality of life of citizens in cities, reducing the carbon footprint, and contributing to green initiatives:

  - **Transport**: Traffic flow management, seep control, congestion charging, information systems, vehicle tracking, onboard safety, parking management.
  - **Public safety and security**: Access control systems, alarm monitoring, emergency warning, and situation management.
  - **Public services**: remote patient monitoring, patient records management, education/learning networks.
  - **Identity**: Biometric/smart card systems.
  - **Utilities**: Facilities management, climate control, energy generation and storage management, water/gas leak detection, and network management.
  - **Environment**: Data collection and monitoring (noise, pollution, etc.).
  - **Social networking**

Urban Environmental Monitoring

- **Urban Ecosystem Monitoring**:
  - The information measured by pervasive sensing can help determine the <u>source of pollution</u> and the <u>appropriate action</u> to preserve the environment → “healthy” environment.
  - Requires the deployment of a dense smart object network across the city to enable real-time monitoring of the urban ecosystem.
  - These smart objects gather data autonomously transmitted to data centres via a private IP network or the Internet for further analysis.
  - Networks: **static**, **multipoint-to-point** traffic patterns with **moderate QoS** requirements.
  - Environmental data of interest:
    - Air-quality monitoring
    - Water-quality monitoring
    - Temperature and humidity monitoring
    - Mircroenvironmental sunlight monitoring
    - Weather condition monitoring
    - Environmental pollution monitoring
    - Exhaust emission monitoring
    - Waste discharge monitoring
    - Soil pollution monitoring

Urban Environmental Monitoring

- **Natural Hazards Monitoring and Early Detection**:
  - More stringent and complicated design requirements than urban ecosystem monitoring.
  - Typical smart objects used in hazard monitoring:
    - **Volcano** monitoring sensors
    - **Seismic** sensors
    - **Tsunami** early warning systems
    - **Slope deformation** monitoring sensors
  - <u>Early warning flood detection</u>: Current systems in developing countries rely on human observations. More sophisticated SO networks performing continuous measurements are required to improve the level of prediction.
  - <u>Forest fire modelling and early detection</u>: Current systems rely on fire lookout towers located at high points equipped with CCD cameras and IR detectors. But they are largely affected by weather conditions → SO networks are critical for building near real-time forest fire detection systems.

Technical Characteristics and Challenges

- **Networking environment**: Mostly outdoors networks. The connectivity between smart objects may be greatly affected by the nature of the links used in these environments.
- **Traffic Flows and Network Topologies**: Between nodes and information collectors and data centres. Mesh network topologies are very frequent.
- **Smart Objects and Link Characteristics**: Miniturization, cost reduction, and low-power consumption are necessary together with high level sensitivity, stability, and accuracy of sensors even in extremely harsh environments.
- **Quality of Service and Network Reliability**: Vary with the application.
- **Scalability**: The network used in urban sensing must be scalable from medium scale (district area) to large scale (metropolitan area).

Technical Characteristics and Challenges

- **Mobility**: Fixed nodes with higher computational and power resources deployed as urban infrastructures in some hot spots, whereas mobile nodes used to augment the sensing coverage.
- **Security**: Very high security requirements. Authentication and encryption technologies are mandatory.
- **Network Management**: Is a key concern. Nowadays they require considerable technical expertise to be deployed and managed. Ongoing efforts in self-management and self-configuration to evolve toward remote and unattended usability.

Social Networking

- **Extension of Web-based Social Network Systems (SNSs)**:
  - E.g., **CenceMe**: component of the **MetroSense Project**, a collaborative project sponsored by Darthmouth College, NSF, Intel, Nokia and Motorola, that is developing new applications, classification techniques, privacy approaches, and sensing paradigms for mobile phones to establish a global mobile sensor network capable of societal-scale sensing. CenceMe is a personal sensing system that enables members of social networks to share their sensing presence with their friends in a secure manner.

    http://www.youtube.com/watch?v=8rDFbTF47PA

  - The CenceMe system is implemented as a thin-client on a number of standard and sensor-enabled cell phones and offers a number of services.

  - Mobile devices integrated into the CenceMe system: Nokia N800 Internet Tablet, Nokia N95, Nokia 5500 Sport, Moteiv Tmote Mini, and the prototype BleCel accessory.

Social Networking

- **Monitoring the Elderly and Kids**:
  - Social networks and wireless sensor networks can also be combined to support independent living and healthcare for the elderly.
  - By deriving a semantic presence based on context from sensor-enabled social networking devices, useful tasks can be carried out for the elderly (e.g., the system can send alerts based on abnormal activity patterns or a change in life dynamics).
  - Monitoring kids another important application (e.g., “num8” watch by Lok8u has a GPS tracking device and satellite positioning system concealed inside so that parents can locate the wearer to within 10 feet on Google maps).

Technical Characteristics and Challenges

- **Networking environment**: Most SO networks operate in fairly harsh environments due to the channel uncertainty and complex, strong interferences in the ISM band.
- **Traffic Flows and Network Topologies**: Most traffic flows are burst traffic embedded with audio, video, or SMS services. P2MP, MP2P, and P2P flows.
- **Smart Objects and Link Characteristics**: SOs in these networks: cheap, flexible, spatially distributed, and autonomous.
- **Quality of Service and Network Reliability**: multi-QoS system (e.g., real-time data quite demanding regarding throughput, delay, jitter, and so on).
- **Scalability**: Limited to a few dozen or a few hundred SOs.

Technical Characteristics and Challenges

- **Mobility**: One of the keys to success for the integration of SO networks and SNSs → real challenge to build and maintain mobile sensing systems in both complex urban environments and outdoor terrains.

- **Security**: Another priority of social applications → privacy.

- **Network Management**: Smart devices must be self-configured with autodiscovery and automatic computing.

Intelligent Transport Systems

- As the demand of transportation increases, traffic congestion becomes a major concern in most large cities → Intelligent Transport Systems (ITS) is one of the key challenges for the future. Most ITS rely on SO networks for communication.

- **Traffic Monitoring and Controlling**
  - **Dynamic Traffic Light Sequence**: New technologies based on SO; e.g., each vehicle is identified by a WiFi Access Point from an RFID tag, thus forming a wireless sensor network. The WAP collects and relays the information through the wireless network to the data centre, which analyzes and processes it for optimized traffic light sequence.
  - **Traffic Condition Monitoring and Control**: E.g., **COOPERS** (CO-OPerative systEms for intelligent Road Safety), an European research and development and innovation activity within the Call 4 of the 6th Framework Program→ extends the concept of in-vehicle autonomous systems and vehicle-to-vehicle communication (V2V) with tactical and strategic traffic information provided in real time by the infrastructure operator (I2V).
  - **Parking Lot Monitoring**: A SO network such as a WSN provides a cheap infrastructure that can be easily installed after construction. E.g., UCLA implemented a low-cost, easy-to-install parking lot occupancy monitoring system that integrates with an online database to provide parking space information locally and remotely.

Intelligent Transport Systems

- **Automatic Charging and Fining**
  - **Automatic Road Enforcement**: The prime objective of the Automatic Electronic Enforcement Project is to reduce the number of road accident victims by deploying automatic electronic enforcement mechanisms to detect traffic law violations (e.g., digital speed-limit enforcement cameras that detect and identify speeding motorists).
  - **Automatic Congestion Pricing for Cordon Zones**: Promising opportunities to cost-effectively reduce traffic congestions, improve the reliability of highway system performance, and improve the quality of life for residents. Automatic charging technology is crucial to the effectiveness of the strategy based, for example, on Automatic License Plate Recognition (ALPR).

Technical Characteristics and Challenges

- **Networking environment**: Most SO networks operate in open roadside environments → high interferences. On-vehicle nodes, mobility causes other problems (Doppler effect, transient connectivity, etc.).
- **Quality of Service and Network Reliability**: high QoS due to the need for real-time traffic information.
- **Scalability**: Depends on the scale of the urban area.
- **Reliability Requirement**: The value of the ITS depends on its reliability.
- **Mobility**: the WSN for ITS is a mixture of both mobile and fixed nodes.
- **Security**: Relatively high, although security issues have not been a primary concern thus far.

III.5. HOME AUTOMATION

Introduction

- A large and growing market for home control solutions has emerged for high-end solutions, especially in the United States (cost $20,000 – 30,000).
- A shift toward the mass market not yet occured.
- On the other hand, there is a market segment largely driven by enthusiasts → skilled customers who are willing to perform their own integration work.
- **Overall market opportunity** estimated to be **huge**: 50-100 devices per home and 200-300 million households worldwide.
- **Standardization** plays a pivotal role in approaching the mass market.

Main Applications and Use Cases

Lighting Control:

- First application area in the home automation space.
- It may be expected that lighting control devices will be the device types with the largest number of units deployed.

- Type of devices:
  - Controllers: Handheld controls, key fobs, in-wall controllers, room occupancy sensors, movement sensors, etc.
  - Actuators: Switches, dimmers, LED lighting actuators.

- Key differentiations:
  - Mounting location: Switch panel, gang box, wall-mount box.
  - Number of channels: Single channel, dual channel, multichannel actuators and controllers.
  - Power source: Main-powered, battery-operated, energy “scavenger”.

Main Applications and Use Cases

Safety and Security:

- The integration of alarm systems with home automation is one potential path the industry may take.
- Devices for safety and security include movement sensors and door and window contacts as well as RF-based smoke detectors, gas sensor, and water leakage sensors.
- Access control can be seen as an extension of safety and security.

Main Applications and Use Cases

Comfort and Convenience:

- Term for a solution area.
- It encompasses devices from multiple areas: Lighting control, adding energy conservation, access control, and safety and security.

Main Applications and Use Cases

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Energy Management:

- Controlling heating, ventilation, and air conditioning (HVAC) in homes and integrating it into the overall home automation.
- Examples:
  - Programming the temperature profile with a graphical user interface in a PC or web browser.
  - Adding lighting control from an energy conservation perspective.
  - Heating control: electronic thermostats with timed programs can save as much as 30% of the heating energy.
  - Wireless communication enables remote control of thermostats and allows integrating window contacts (→ energy saving).
- This application area is highly challenging with its demand for battery-to-battery communication.

Main Applications and Use Cases

Remote Home Management:

- Ability to control home automation devices from outside the home.
- With access to the **Internet** so ubiquitous, remote home management can be provided at very low cost, creating a simple, yet powerful business case.
- Applications:
  - Checking on the home from abroad.
  - Receiving alarms from smoke sensors, doors contacts, movement detectors or water leakage sensors.
  - Controlling heating and HVAC before returning back home.
  - Use cases in aging independently and assisted living.

Main Applications and Use Cases

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Aging Independently and Assisted Living:

- Supporting older people through home automation becomes an important application for emergency assistance or monitoring changes in life dynamics.

→ Age people stay longer in their private residences, thus reducing the burden on public funding of retirement homes and increasing the quality of life.

Technical Challenges and Network Characteristics

- **Type of Topology**: Communication topologies in home automation are mixed (communication between a central controller and/or gateways device from and to sensor and actuator devices, as well as direct communication between sensors and actuators).

- **Traffic Matrix**: Communication occurs infrequently on a per-device basis.

- **Number of Devices**: The majority of deployments is expected to be in the range of 50 to 100 nodes.

- **Degree of Mobility**: The vast majority of devices are stationary.

- **Robustness and Reliability**: Hard real-time requirements basically do not exist and individual packets may be lost and retransmitted. Nevertheless, home automation networks must be easy to install and extremely reliable (two-way communication is strongly preferred over unidirectional links).

Technical Challenges and Network Characteristics

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- **Requirements for Quality of Service**: Requirements for fine-grained control of QoS are relatively rare in home automation.

- **Battery Operation**: Long-term battery operation is a key requirement in home automation (i.e., includes initiating and accepting communication to, from, and also between battery-based devices). Battery-less operation in devices on a long-term basis would be desirable for home automation devices. PLC is also an interesting option for this type of devices.

- **Operating Environment**: Much less demanding than in other environments, except the use of the 2.4 GHz band, which is very crowded in densely populated areas. In Europe, practically all significant wireless home control technologies are using the 868 MHz band, where the risk of interferences is much lower.

- **Security**: Originally, the level of security required in home control applications was seen as low. Security is provided today in home automation typically in devices for access control only.

- **Ease of Installation and Setup**: Easy setup and configuration are critical for success (it must truly be plug and play).