Internet of Things in Industry 4.0 (Διαδίκτυο των Πραγμάτων 4η Βιομηχανική επανάσταση)

ΛΑΛΛΑΣ ΕΥΘΥΜΙΟΣ

ΕΠΙΚΟΥΡΟΣ ΚΑΘΗΓΗΤΗΣ

ΠΑΝ/ΜΙΟ ΘΕΣΣΑΛΙΑΣ

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Τμήμα Δασολογίας Επιστημων Ξύλου & Σχεδιασμού
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- Sensors
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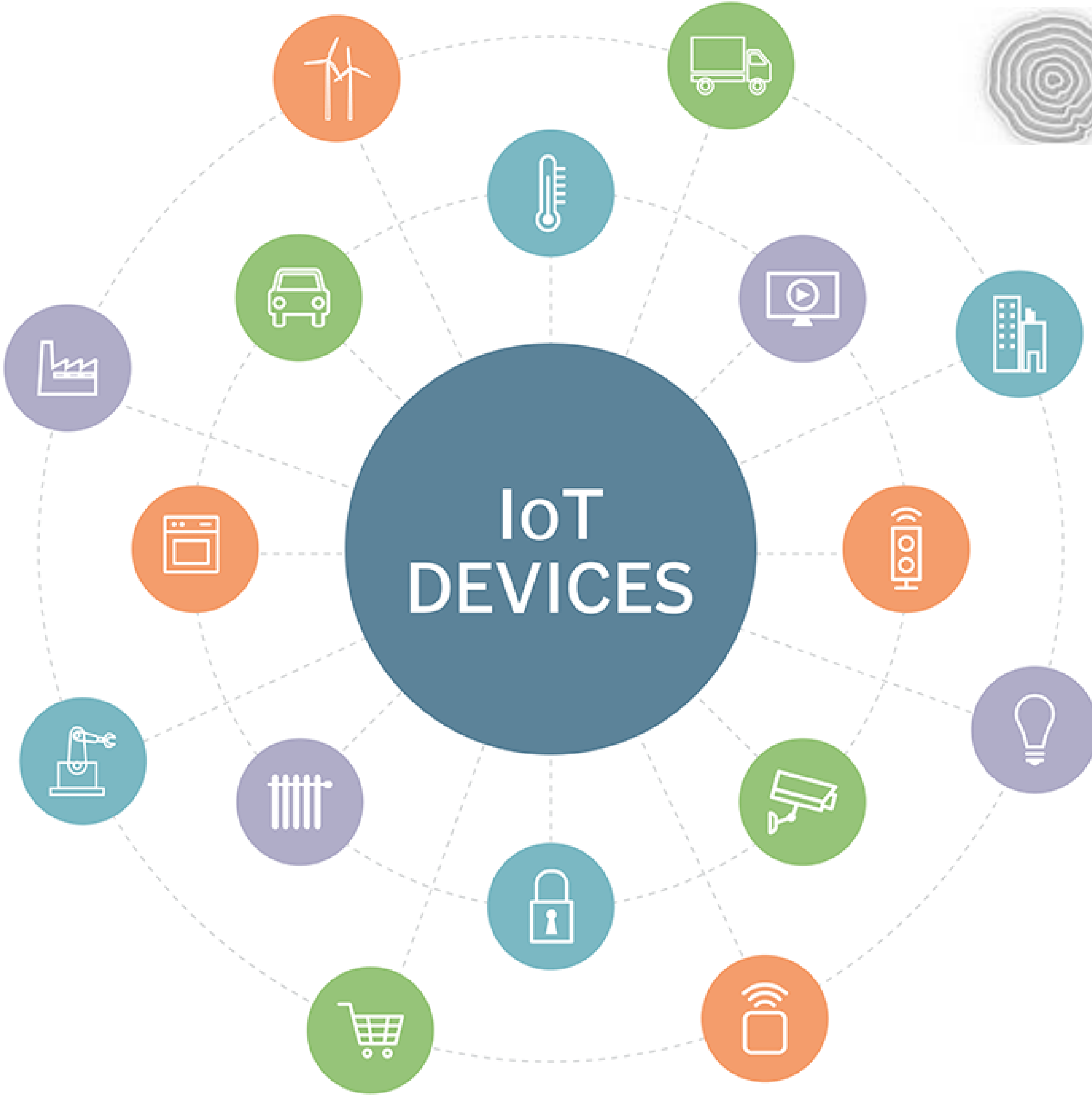
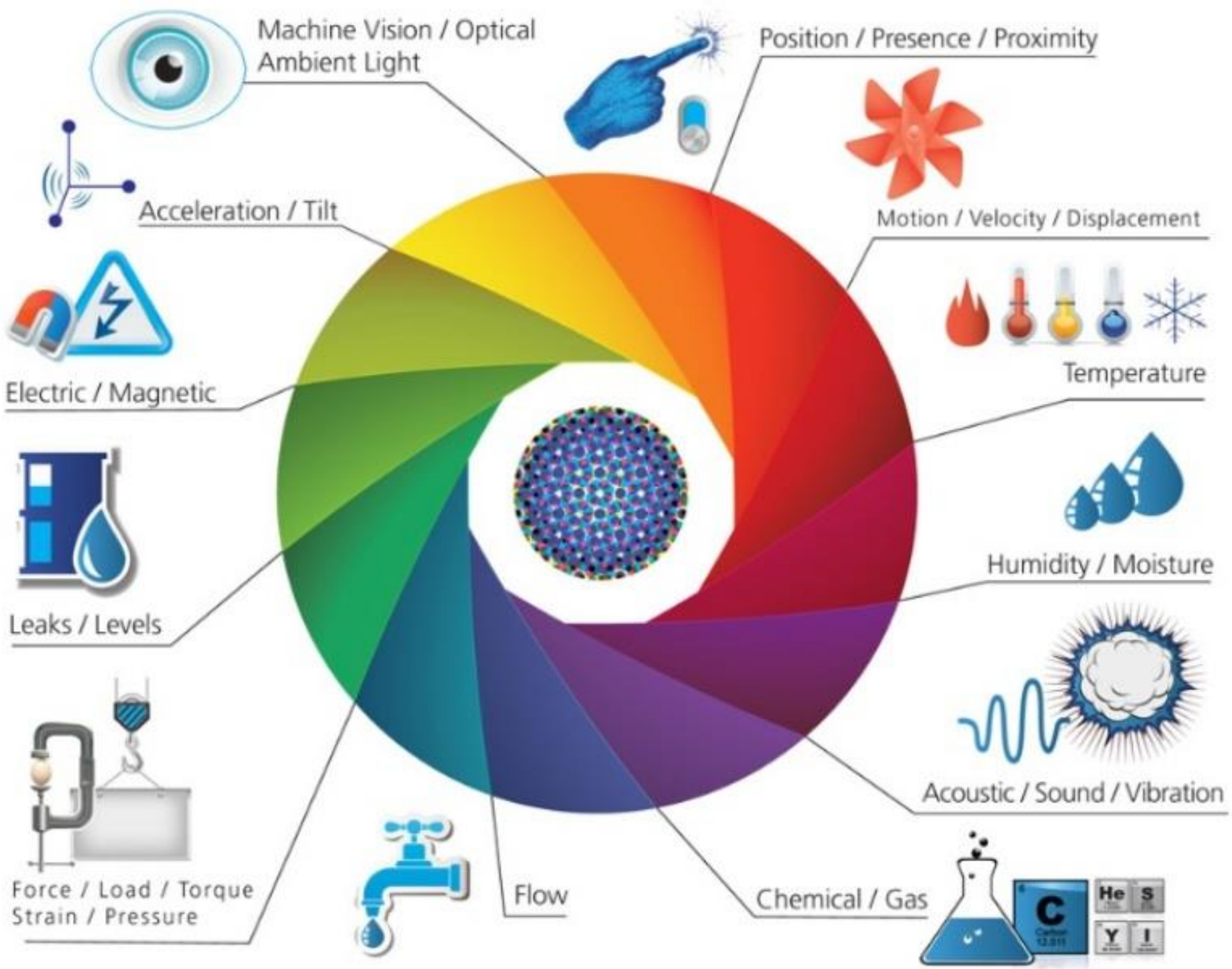


1 SENSORS & ACTUATORS

We are giving our world a digital nervous system. Location data using GPS sensors. Eyes and ears using cameras and microphones, along with sensory organs that can measure everything from temperature to pressure changes.



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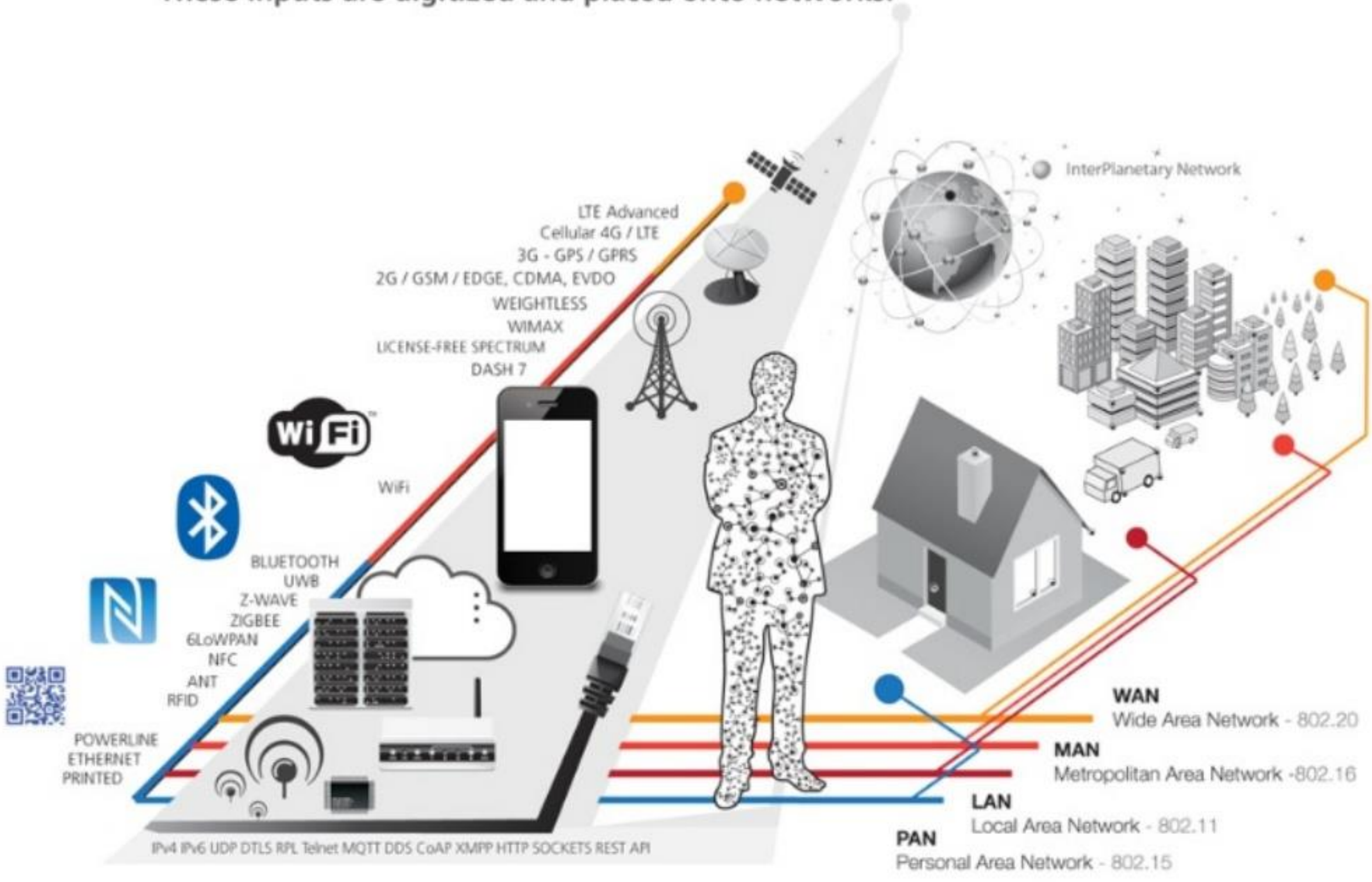
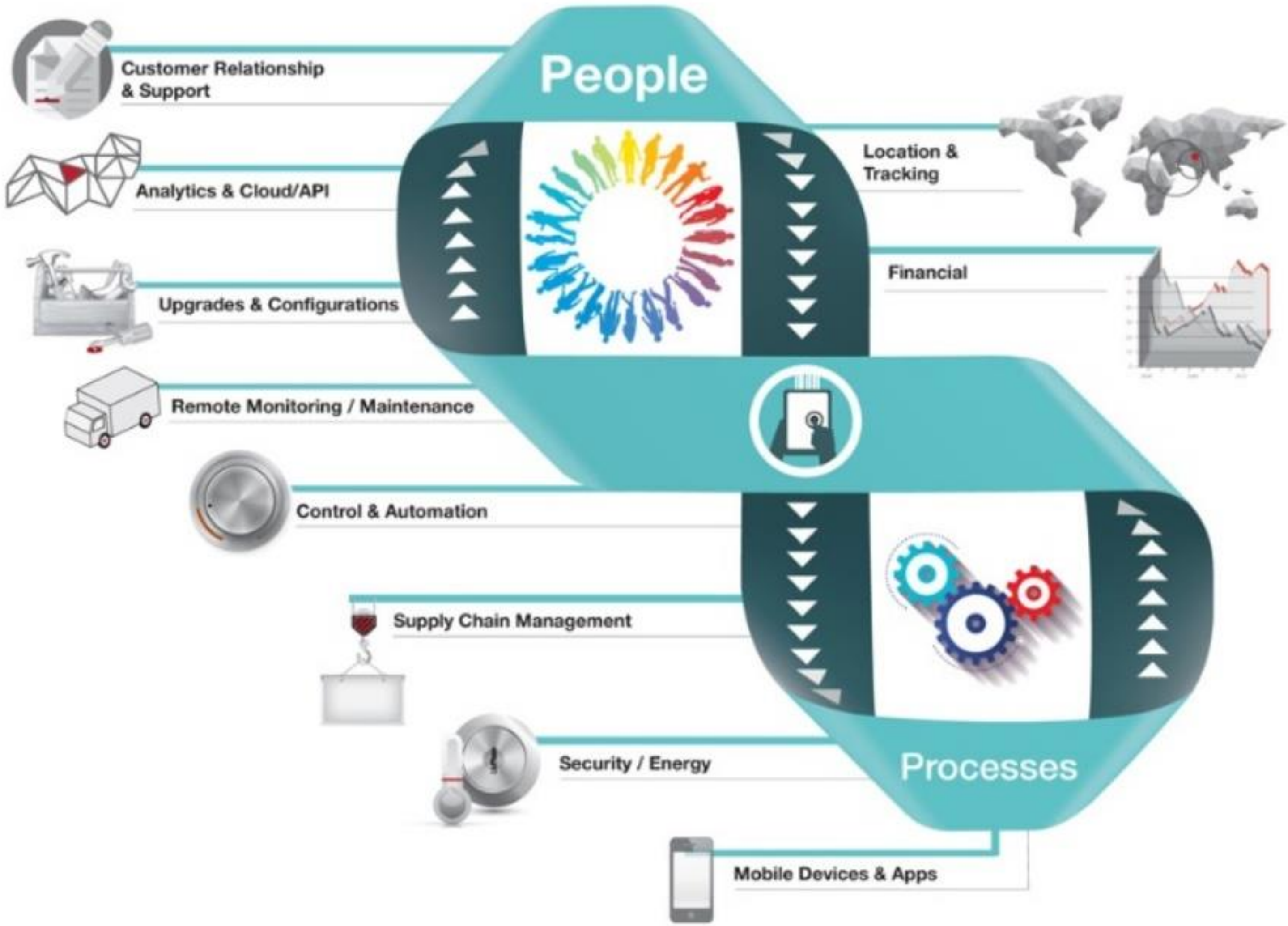
2 CONNECTIVITY

These inputs are digitized and placed onto networks.



3 PEOPLE & *PROCESSES*

These networked inputs can then be combined into bi-directional systems that integrate data, people, processes and systems for better decision making.



The interactions between these entities are creating new types of smart applications and services.

SENSORS + CONNECTIVITY + PEOPLE + PROCESSES

Starting with popular connected devices already on the market

SMART THERMOSTATS

nest

Save resources and money on your heating bills by adapting to your usage patterns and turning the temperature down when you're away from home.

CONNECTED CARS

CAR 2GO

Tracked and rented using a smartphone. Car2Go also handles billing, parking and insurance automatically.

ACTIVITY TRACKERS

BASIS

Continuously capture heart rate patterns, activity levels, calorie expenditure and skin temperature on your wrist 24/7.

SMART OUTLETS

belkin

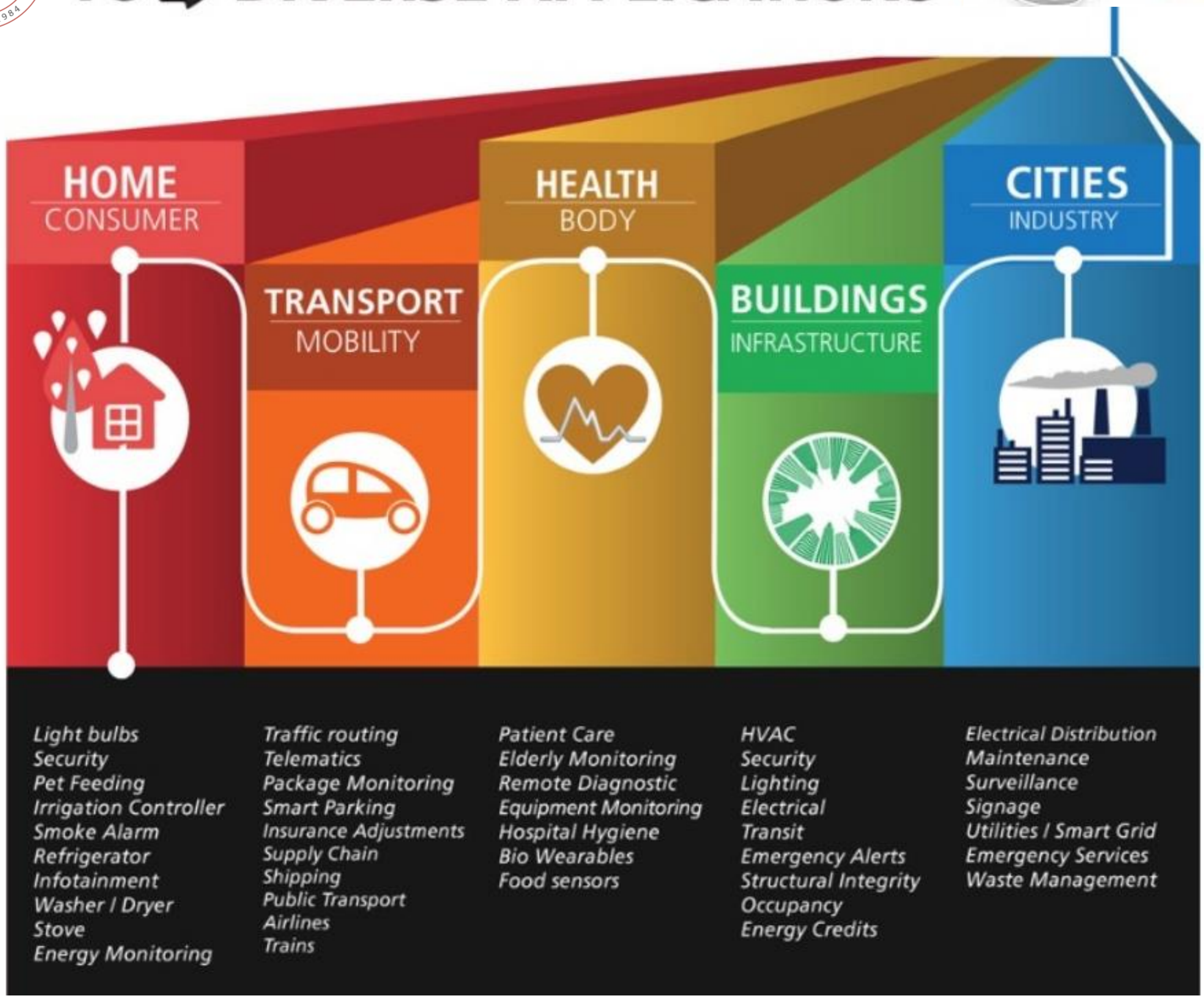
Remotely turn any device or appliance on or off. Track a device's energy usage and receive personalized notifications from your smartphone.

PARKING SENSORS

STREETLINE
CONNECTING THE REAL WORLD

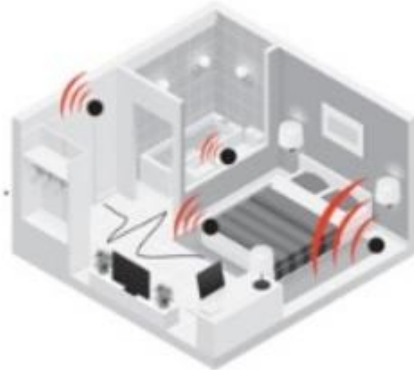
Using embedded street sensors, users can identify real-time availability of parking spaces on their phone. City officials can manage and price their resources based on actual use.

TO ➡ DIVERSE APPLICATIONS



HEALTHCARE + SMART HOME

Aging uncle Earl is still living isolated at his home and you are concerned about his safety.



Wireless sensors throughout his house help measure healthy activity levels, sleeping patterns and medication schedules.

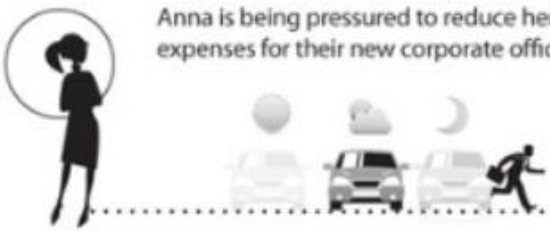
Alerts are automatically sent to health care services and authorized family members if any abnormal activity is detected.

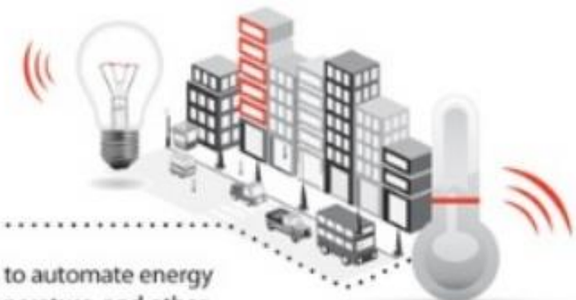
40 million adults age 65 and over will be living alone in the U.S, Canada and Europe.

- U.S. Department of Health and Human Services: Administration for Community Living (ACL)

SMART BUILDINGS + MOBILITY

Anna is being pressured to reduce her company's expenses for their new corporate office.





After speaking with experts she decides to install sensors to automate energy usage according to building occupancy, people flow, temperature, and other ambient conditions -- improving the building's overall efficiency.

Energy used by commercial and industrial buildings in the US creates nearly 50% of our national emissions of greenhouse gases.

- United States Environmental Protection Agency

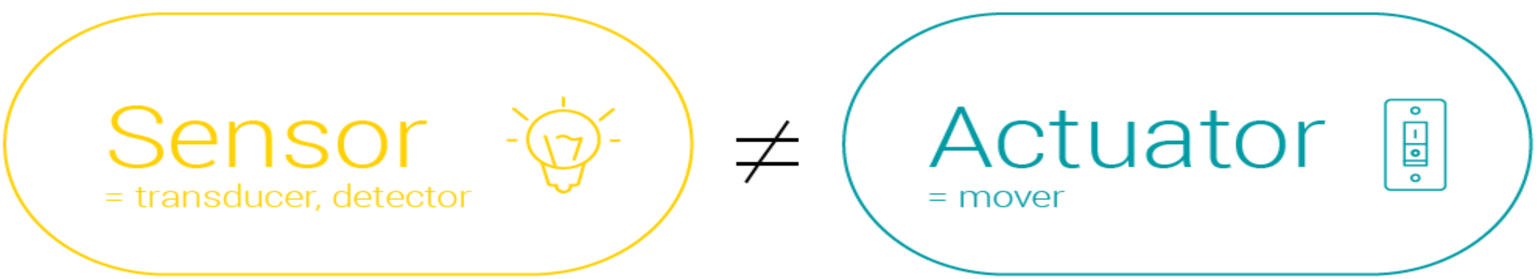

Smart Parking
Public Safety
Smart Buildings
Smart Health
Waste Management
Open Data
Education
Traffic Management
Smart Environment
Electromagnetic
Emissions
Internet of Things
Smart Energy
Gas & Water
Leak Detection
Smart Street Lights
SMART CITY
Air Pollution
Water Quality
Intelligent Shopping
Smart Home
Electric Vehicle Charging

Sensors and transducers

- Sensor is a device used to measure a physical quantity and convert it into an electrical signal.
- Examples of physical quantities measured by sensors are temperature, position and displacement of an object, liquid level, velocity and acceleration of a moving object, force, fluid flow, voltage, current, humidity, radiation

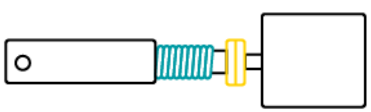
Sensors and actuators

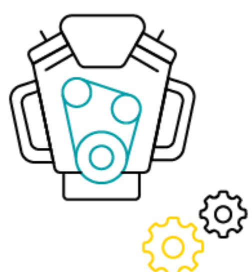
- An actuator is a component of a machine that is responsible for moving and controlling a mechanism or system, for example by opening a valve. In simple terms, it is a "mover". An actuator requires a control signal and a source of energy.

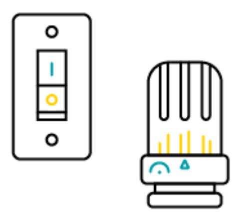


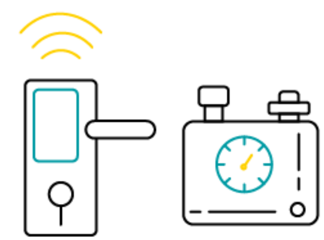
IoT actuator types

- **Linear actuators** –used to enable motion of objects or elements in a straight line.
- **Motors** – they enable precise rotational movements of device components or whole objects.
- **Relays** –electromagnet-based actuators to operate power switches in lamps, heaters or even smart vehicles.
- **Solenoids** –used in home appliances as part of locking or triggering mechanisms, they also act as controllers in IoT-based gas and water leak monitoring systems.


Linear actuators


Motors

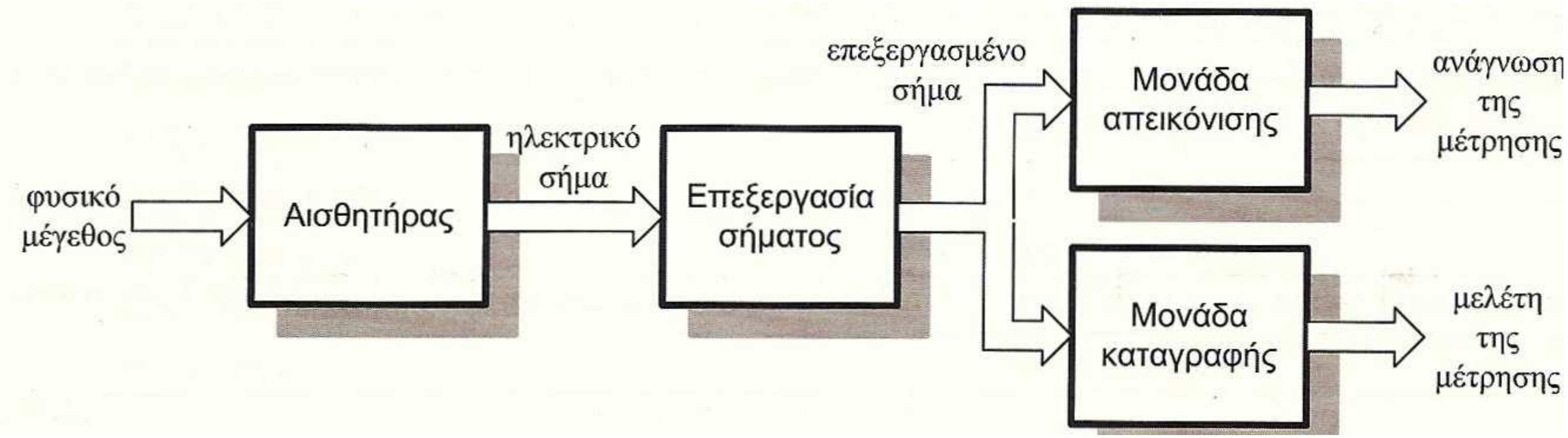

Relays

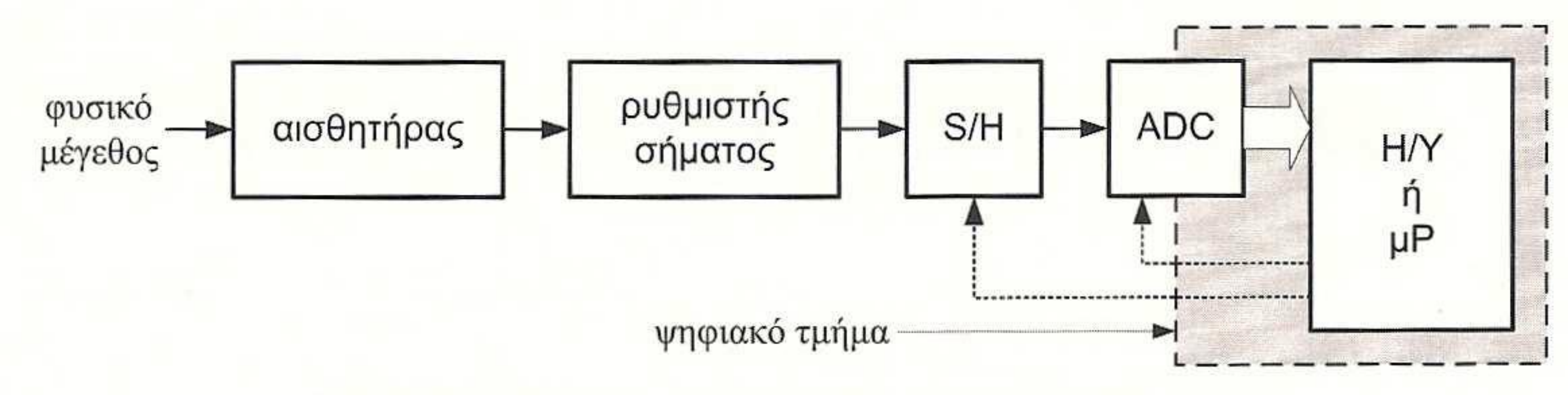

Solenoids

Sensors and Measurement systems

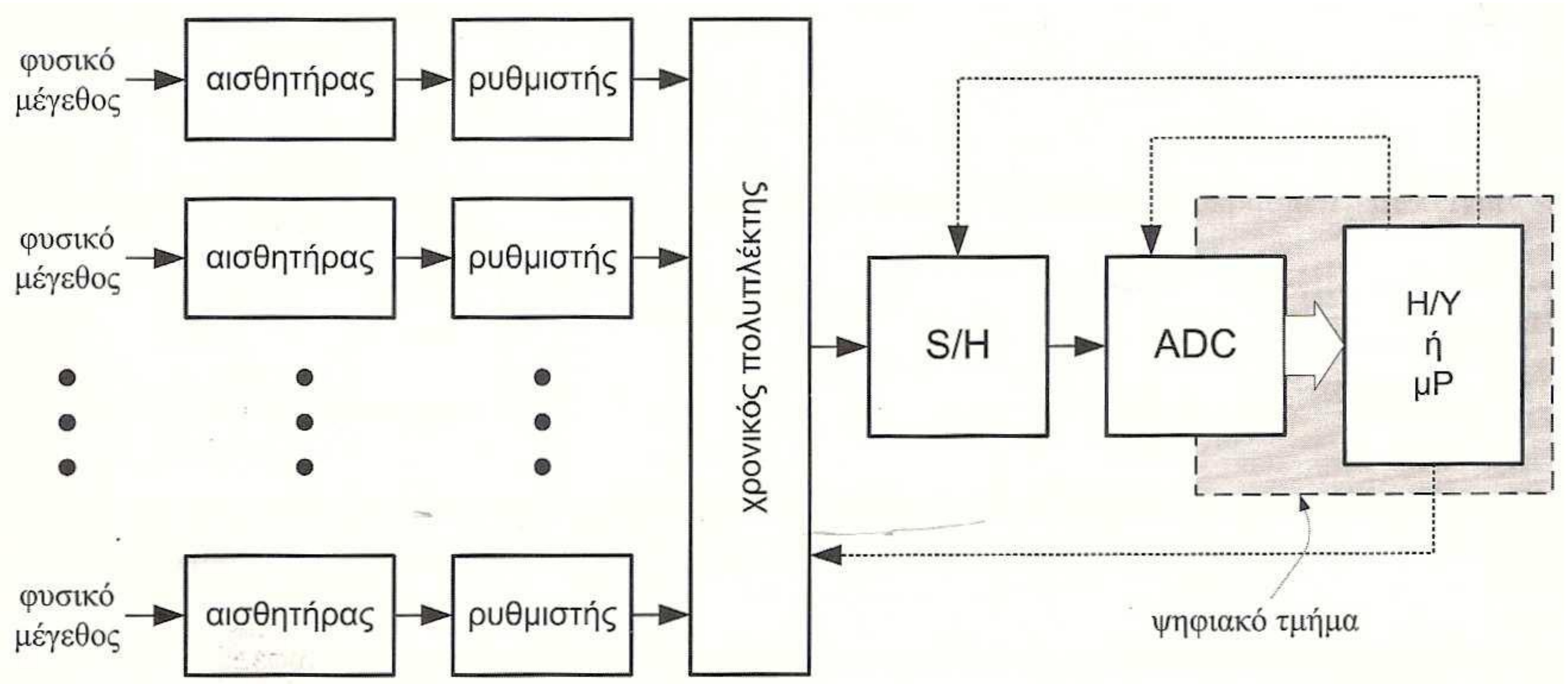
- Measurement is the determination of a quantity or amount based on a reference quantity of the same type (unit of measurement).
- Measurement systems consist of analog and / or digital electronic components
- The conversion of physical size to the corresponding electrical signal is undertaken by a unit called a sensor.

Measurement System Layout





Measurement System Layout(II)



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Sensor Attributes(I)

- Accuracy (low dispersion)
- Fidelity (percentage on sensor operating range)
- Calibration
- Neutral (Dead) zone (value range around 0, no sensor response)
- Minimum Dimensions
- Shift (slow change of output signal while the measured physical quantity remains constant)
- Error (the difference of measured from the actual value)

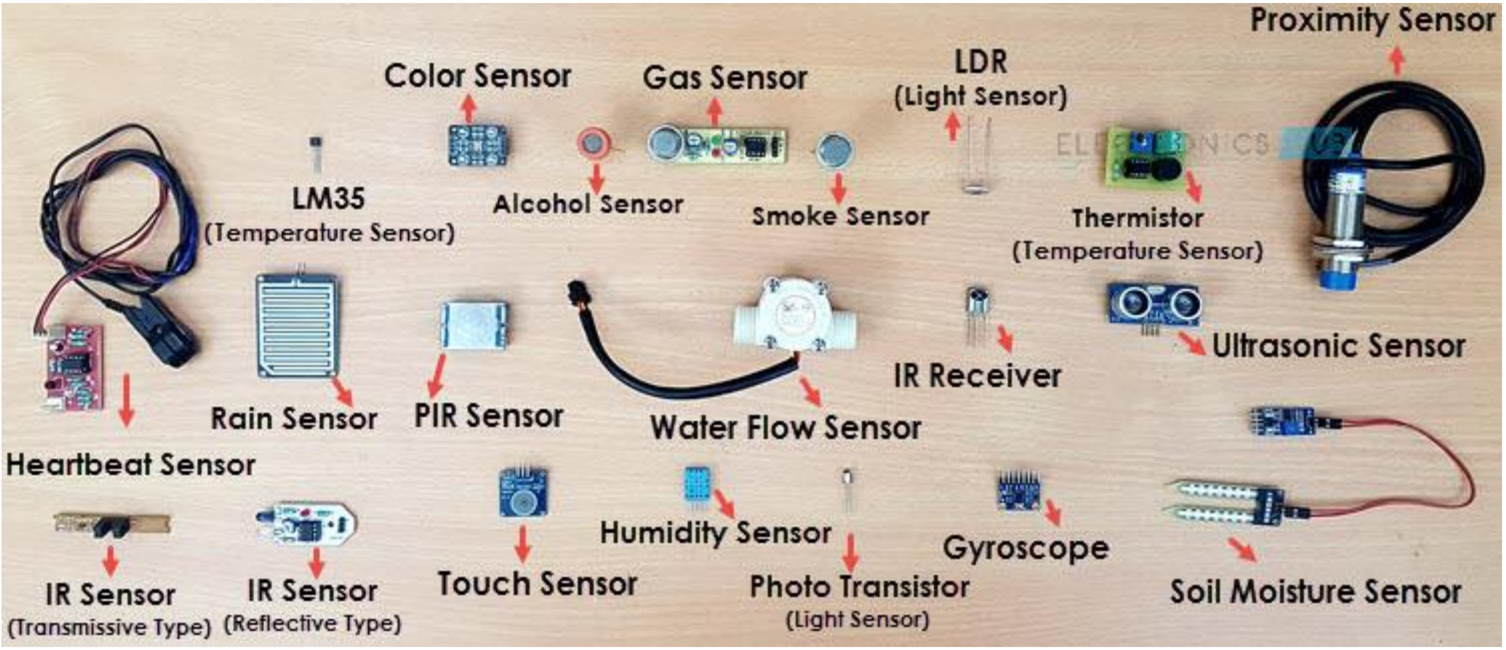
Sensor Attributes(II)

- Polarity (differences in output when the direction of change of input is reversed)
- Relative Delay (change of the output value in relation to the change of the input)
- Linear relation of output- input curve
- Operating life
- Repeatability (percentage of production of the same result for the same input)
- Operating range
- Response

Detailed IoT sensor type list

- Temperature Sensor
- Proximity Sensor
- Accelerometer
- IR Sensor (Infrared Sensor)
- Pressure Sensor
- Light Sensor
- Ultrasonic Sensor
- Smoke, Gas and Alcohol Sensor
- Touch Sensor
- Color Sensor
- Humidity Sensor
- Position Sensor
- Magnetic Sensor (Hall Effect Sensor)
- Microphone (Sound Sensor)
- Tilt Sensor
- Flow and Level Sensor
- Touch Sensor
- Strain and Weight Sensor

Popular sensor types



Smoke Sensors

- Smoke sensors are integrated with an industrial IoT solution, even the slightest leakage of gas or minor occurrence of fire can be reported to the concerned team and major disaster can be averted.

Proximity Sensors

- Measure the distance from itself and the nearest object.
- They are most commonly found on the car bumpers to alert the drivers in the case of an imminent collision.
- Other use cases are assembly lines of different industries like food, chemical, machine tools and many others.

Proximity Sensors (II)

- **Doppler radar**: radar that uses the Doppler effect i.e. the difference in the frequency of the wave sent by its source and the frequency of the wave recorded by the observer who moves relative to this source. The radar is used not only to detect objects and determine their location, but also to learn about their direction and speed.
- **Occupancy sensor**: a type of presence sensor that uses either infrared light or high frequencies to detect movement in office and sanitary facilities, corridors, passages, warehouses etc.

Infrared Sensors

- Infrared sensors are essentially used to detect human presence for Military applications
- As these sensors can detect any infrared radiation including heat, they are deployed in electronics, chemical, and healthcare industries to name a few.

Piezo Sensors

- The piezo sensors measure pressure and data related to pressure changes in real time.
- Using these sensors, for monitoring pressure in pressure-critical equipments such as boilers, water systems, aerospace, oil drilling systems and more.

Temperature sensors

- **Thermistor**: a type of resistor, whose resistance (resistance) depends significantly on the temperature. Thermistors are widely used in systems preventing excessive current increase.
- **Resistance temperature detectors**: instruments for measuring temperature based on a change in resistance that is associated with temperature changes.
- **Thermocouples**: element consisting of two different conductors. By using the fact that the voltage that arises between the connectors of a thermocouple is proportional to the temperature difference, thermocouples can be used as temperature sensors

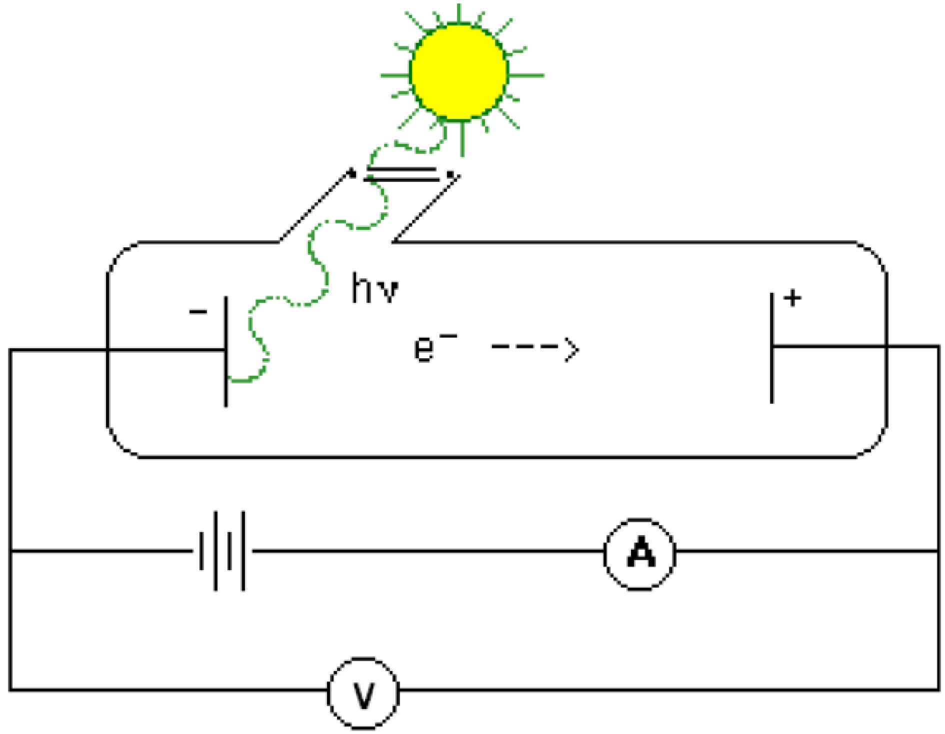
Optical Sensors

- Optical sensors are capable of sensing more than just light, but any kind of electromagnetic radiation, i.e. light, electricity, and a magnetic field etc.
- Telecom, elevators, construction, healthcare, safety systems are some of the Industrial automation applications of Optical Sensors.

Optical Sensors(II)

- **Photoresistor**: it’s a photosensitive element, whose resistance changes through radiation. It can easily be connected to for example Arduino as an analog light sensor. Thanks to this it is possible to build e.g. lamps that turn on automatically after dark.
- **Photodiode**: a diode which works based on photoelectric effect. Photodiodes are widely used in industrial automation (signaling and control systems), telecommunications (optocouplers, optoelectronic links) and many more industries.

Photoelectric phenomenon principle



Photodetector applications

- **Astronomy** - space telescopes - particle detectors
- **Medicine** - inclinometer (MEMS mass - optical sensors - photodiode ring)
- **Nuclear Medicine** - Gamma camera (display of concentration of γ particles in an organism)
- **Telephones - VLC** (LED light emission and conversion to electrical pulses by photodetectors)
- **Industry** - hot metal position detection sensor due to heat radiation
- **Industry** - 3D vision sensor (pixels, chip)
- **Industry** - color sensor, transparent surface detection sensor IR, UV sensors LIDAR sensors (Light Detection And Ranging) laser backdrop
- **Control systems** - light sensors (light level change), Motion control sensors
- **Scanner** - light sensor image / photo / document converter to data
- **Security systems** - alarms: PIR (Passive InfraRed detectors)

Image sensors

- **Active-pixel (CMOS) sensor**: arrangement of many photosensitive elements made in CMOS technology, found in many devices such as webcams, compact digital cameras, DSLR cameras, digital x-ray cameras, and more.
- **Charge-coupled device**: a system of many photosensitive elements that enable reading an electric signal proportional to the amount of light falling on it. Color filters used in CCD sensors can be very often found in digital cameras giving them the ability to record the intensity of a specific width of the light spectrum at a given point of the matrix.

Moisture and Humidity sensors

- **Hair tension moisture sensor**: The design of the device is based on human or horse hair, or fibers change their length upon contact with moisture. The pointer, which shows the reading on the scale, is connected to the hair (or fiber) and reacts to a change in its length.
- **Psychrometer**: is based on two thermometers (the so-called "dry" and "wet"). It uses the phenomenon of damping evaporation by moist air and accelerating it by dry air. The higher the humidity, the lower the temperature of the wet thermometer. The dry thermometer shows the ambient temperature and the humidity can be calculated from the temperature difference.

Acoustic sensors

- **Hydrophone**: a microphone used to pick up sounds propagating in water or other liquids. Hydrophones are a basic structural element of passive sonars used for example to detect fish in various aquatic environments.
- **Geophone**: it is a sensor that converts ground vibrations (frequency and amplitude) into electrical voltage. It’s a type of a seismometer

Water level monitoring sensors

- **Hydrostatic pressure sensor**: used to measure the hydrostatic pressure of a tank which is proportional only to the height of the liquid filling, regardless of the shape and volume of the tank.
- **Optical sensor**: a sensor that detects the water level implied by refraction of light in the prism after contact with the liquid.

Motion sensors

- **Ultrasonic motion sensor**: sending and receiving ultrasonic passive waves
- **Infrared motion sensor**: detecting changes in infrared radiation
- **Active, radar sensor**: emitting and receiving electromagnetic waves
- There are also sensor versions that combine all of the above motion-related principles. One such example is a **passive infrared sensor (PIR)**: electronic sensor used for motion detection, which is commonly used in alarm systems, automatic lighting and ventilation systems etc.

Gyroscope sensors

- **Accelerometer**: this sensor indicates the angular velocity of the object on which it is located.
- **Heading indicator**: allows you to observe the rotation of the body to which it is attached.

Chemical sensors

- **Electrochemical breathalyzer:** a simple sensor used to determine the alcohol content in blood.
- **Electronic nose:** a chemical detector that reacts to different types of particles and their characteristics contained in the environment so as to about the chemical composition of the environment.

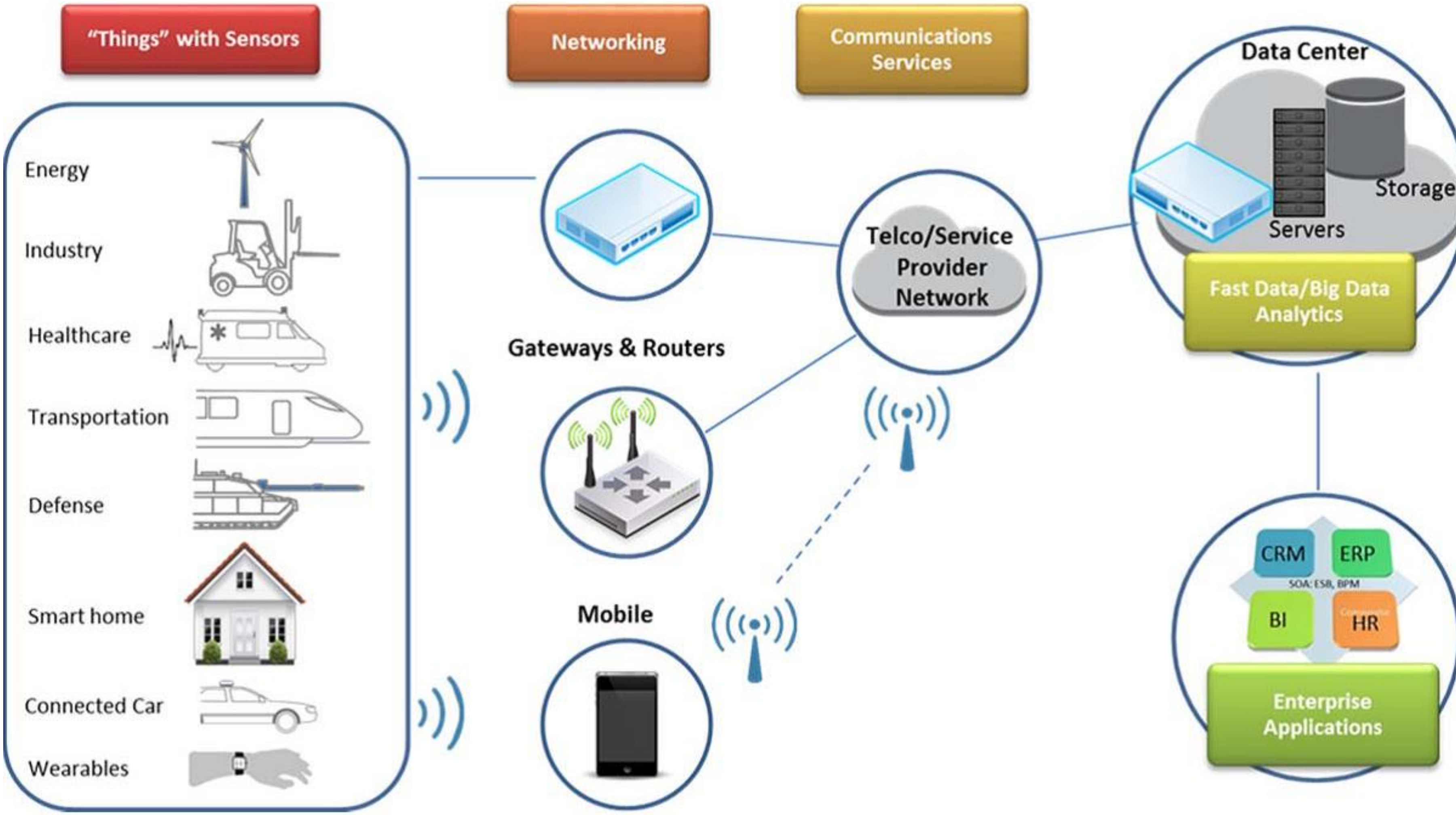
How do IoT devices work?

- IoT devices sense what's happening in the physical world.
- The device itself includes an integrated CPU, network adapter and firmware, which is usually built on an open source platform.
- In most cases, IoT devices connect to a Dynamic Host Configuration Protocol server and acquire an IP address that the device can use to function on the network.
- Many IoT devices are configured and managed through a software application.
- Once an IoT device has been configured and begins to operate, they stream raw sensor data. Some IoT devices do not produce data streams (e.g. smart light bulb).

IoT device connectivity and networking

- The networking, communication and connectivity protocols used with internet-enabled devices largely depend on the specific IoT application deployed.
- Communication protocols include CoAP, DTLS, MQTT, DDS and AMQP. Wireless protocols include IPv6, LPWAN, Zigbee, Bluetooth Low Energy, Z-Wave, RFID and NFC. Cellular, satellite, Wi-Fi and Ethernet can also be used.
- Each option has its tradeoffs in terms of power consumption, range and bandwidth, all of which must be considered when choosing connected devices and protocols for a particular IoT application.
- In most cases, IoT devices connect to an IoT gateway where data can either be analyzed locally or sent to the cloud for analysis. Some devices have integrated data processing capabilities.
- Data processing often uses machine learning capabilities for data fusion and finite yield decision results

IoT communication stack level architecture



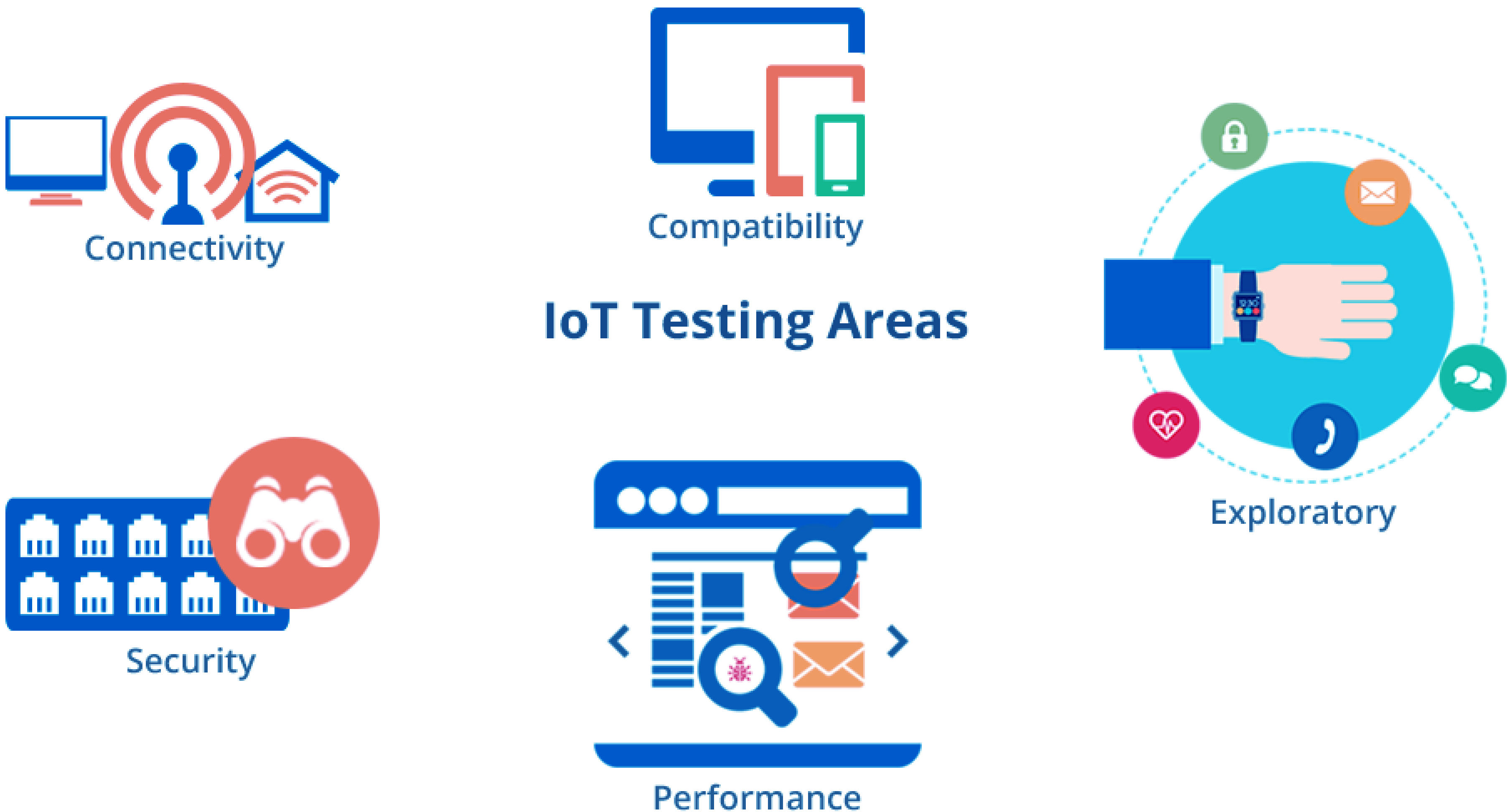
What is IoT device management?

Device management helps companies integrate, organize, monitor and remotely manage internet-enabled devices at scale, offering features critical to maintaining the health, connectivity and security of the IoT devices along their entire lifecycles. Such features include:

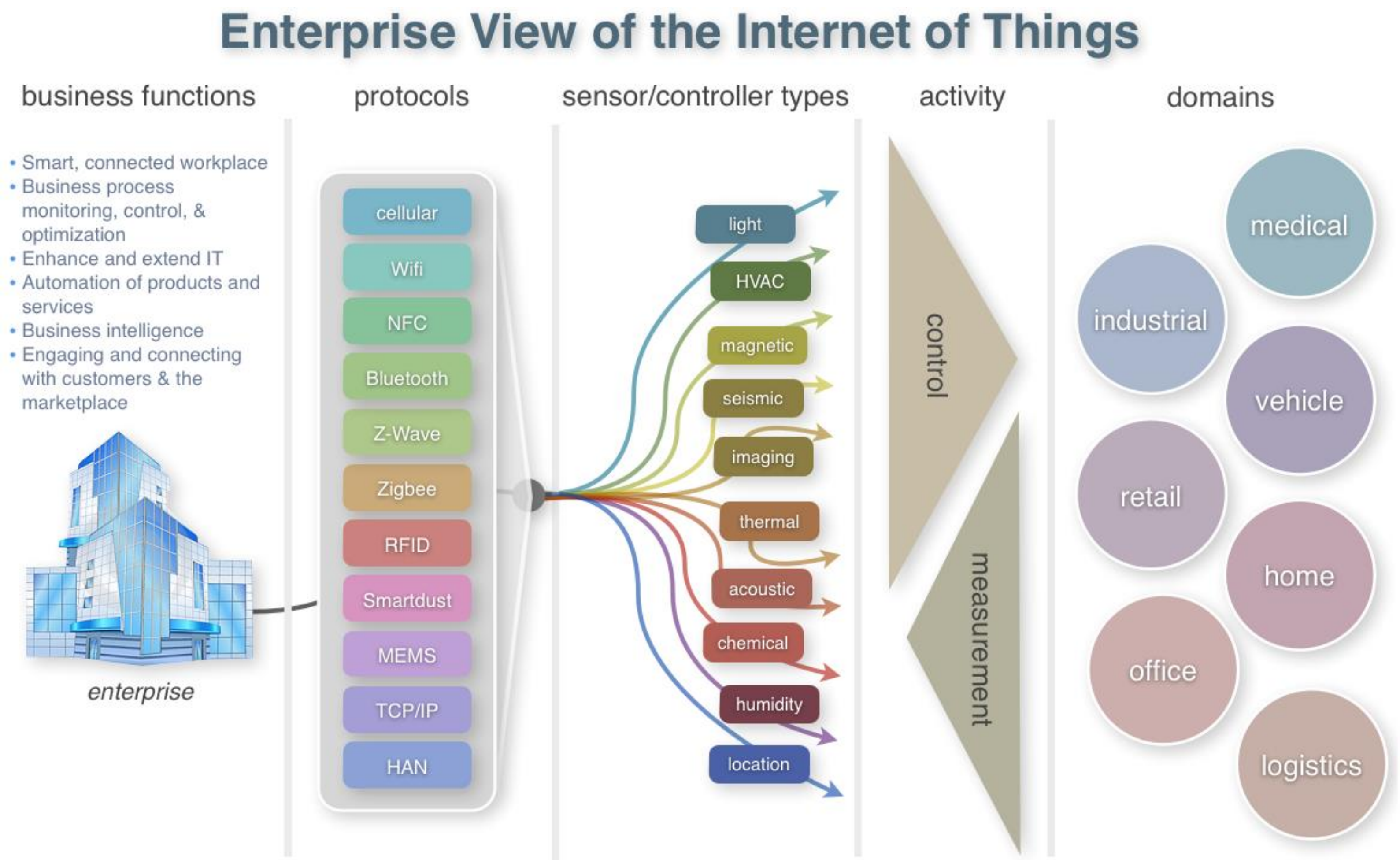
- Device registration and activation
- Device authentication/authorization
- Device configuration
- Device monitoring and diagnostics
- Device troubleshooting
- Device firmware updates

Available standardized device management protocols include the Open Mobile Alliance's Device Management and Lightweight Machine-to-Machine.

IoT Testing areas



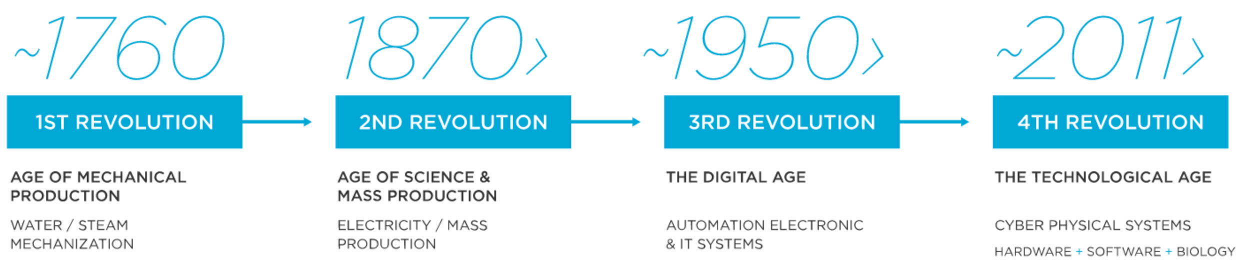
IoT Overall view



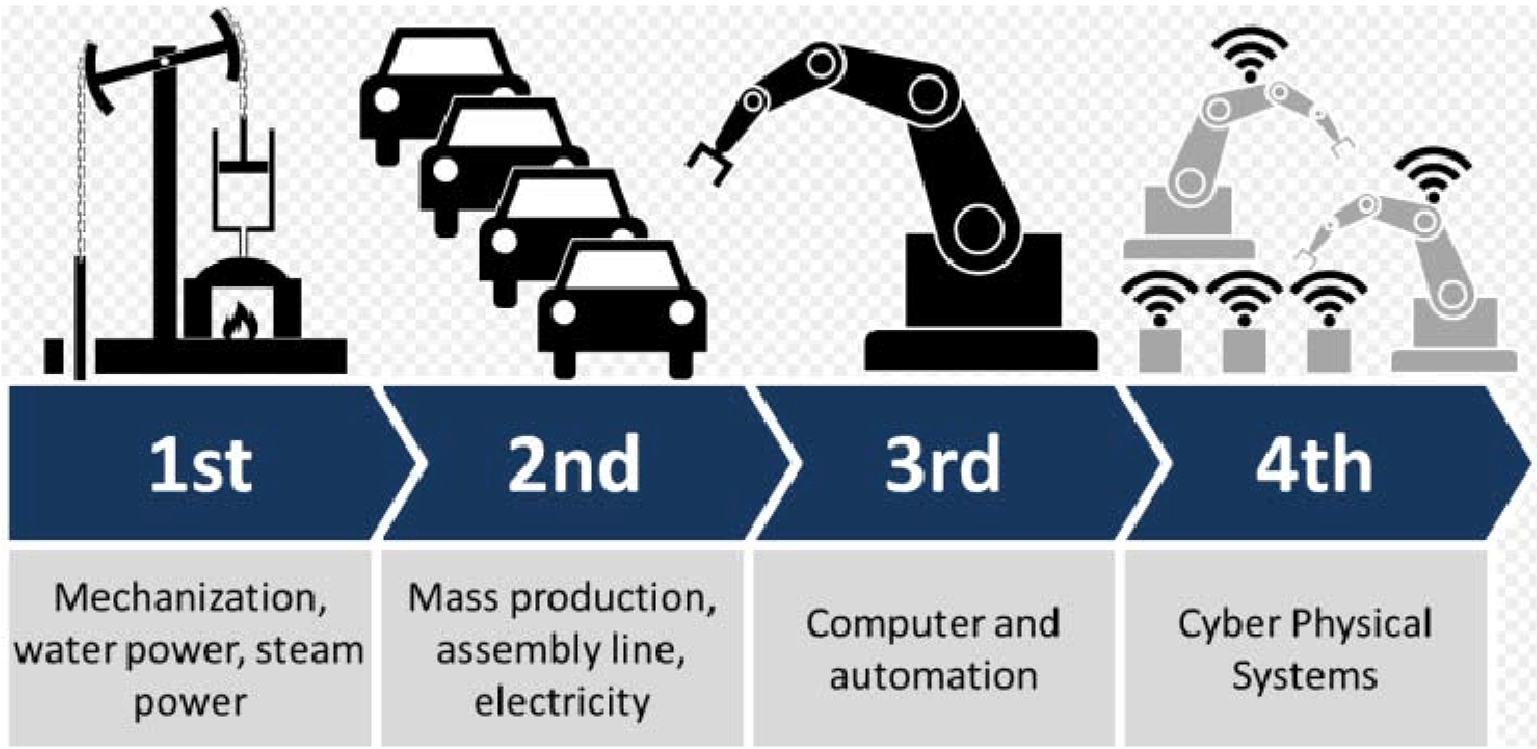
Industry 4.0

What is?

- Industry 4.0 is the name given to the current trend of automation and data exchange in production technologies.
- It is characterized by the intelligent learning / self-training of the Machines themselves (Machine Learning), the data science (Data Science) and the Artificial Intelligence (Artificial Intelligence) that together create challenges and opportunities.



Industry 4.0 evolution



So, what is Industry 4.0?

- Industry 4.0 is much more than just sensing and learning
- It's the delivery of interconnected automated global workflows that automate processes to improve quality and increase machinery availability.
- It is the combination of physical and digital worlds that enable collaboration between departments, partners, and people.
- It is the evolution of factories to self-healing, self-running ecosystems using automation, data virtualization, and wireless connectivity and IoT sensors

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Industry 4.0 main features

- **Interoperability**: CPS (software embedded in hardware such as sensors, processors and communication technologies) allowing humans and factories to connect and communicate with each other.
- **Virtualization**: the creation of a virtual copy of the factory by linking sensor data with virtual plant models and simulation models; known as a **Digital Twin** of the factory.
- **Decentralization**: ability of CPS to make decisions on their own locally
- **Real-Time Capability**: the capability to collect and analyze data and provide the derived insights immediately.
- **Service Orientation**: the services are available over the Internet of Services (IoS) and can be utilized as APIs to exchange information between B2C and B2B.
- **Modularization**: flexible adaptation of the factories to changing requirements by replacing or expanding individual modules.

Big data analysis methodologies of Industry 4.0

- **Predictive Analytics**: Moving from a reactive to a proactive big data/advanced analytics approach can result in a 20 to 25% increase in production volume and up to a 45% reduction in downtime
- **Machine Learning** techniques employ an emerging class of algorithms that actually learn from the data presented to them and automatically construct the best possible model for each dataset. As such, it empowers analysts who have little expertise in statistics and modelling to solve complex problems otherwise beyond their reach. These developments have directly resulted in product quality improvements and reduced waste or product rework.
- **Interoperability and artificial intelligence** The maturity of CPS allows humans, the product itself and smart-factory machines to connect and communicate with each other and derive insights in real time. Not only is there human-machine interaction, but with decentralized CPS, machines can make decisions on their own.

IoT and CPS

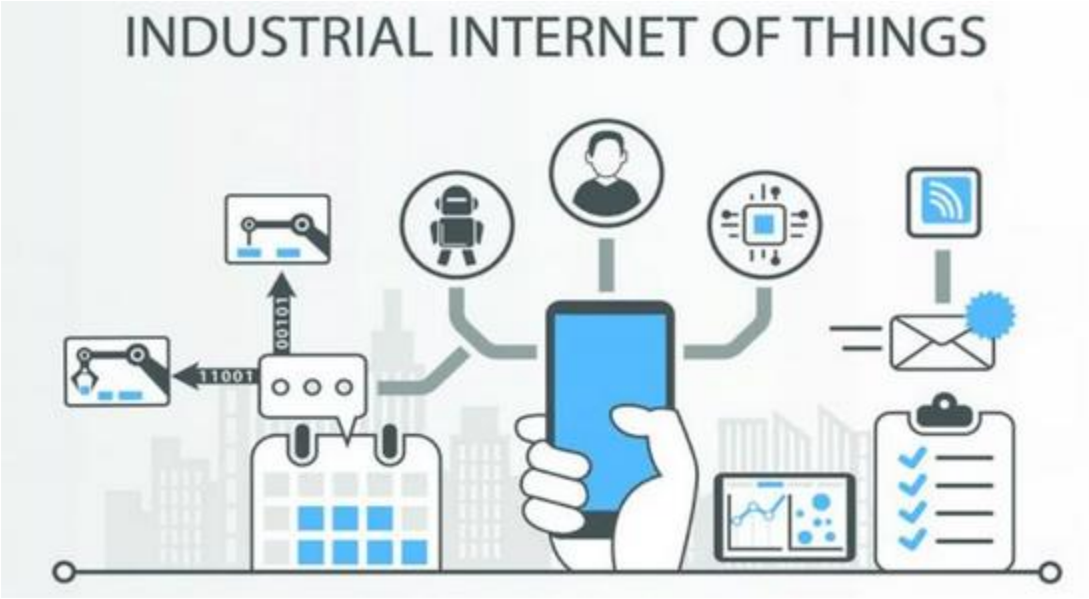
Over the Internet of Things, CPS communicate with each other and with humans in real time and via the Internet of Services. Sensors, devices, people, and processes are part of a connected ecosystem providing:

- Reduced downtime
- Minimized surplus and defects
- Deep insights
- End-to-end real-time visibility
- Digital Twin of the factory

Key areas of guidelines of the Industry 4.0

- Manufacturing Operations
- Factory Productivity
- Predictive maintenance
- Real Time equipment & process monitoring
- Process Optimization
- Real time Quality monitoring
- Product Yield & Root Cause analysis
- Reliability & Warranty

What is Industrial IoT (IIoT)?



What is IIoT?

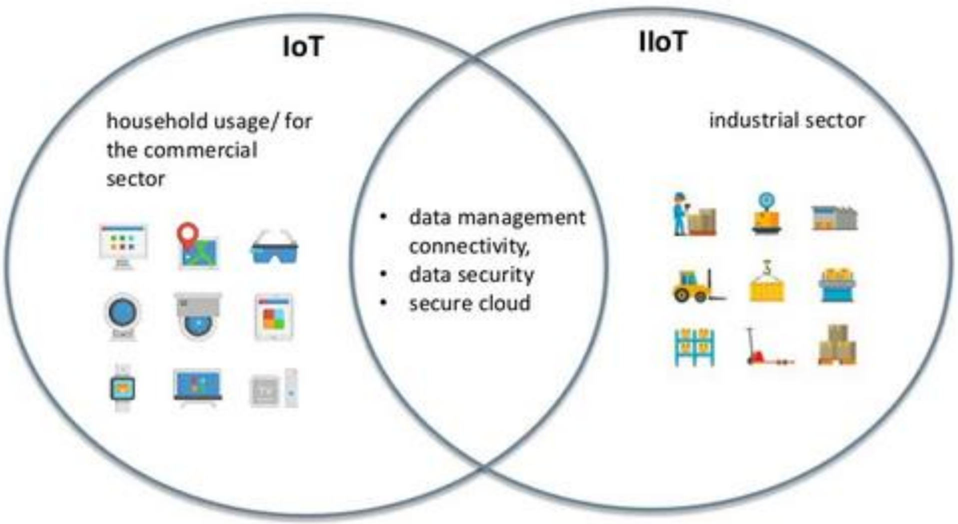
A typical IIoT system comprises of:

- Smart equipment that measures, stores, and communicates information
- Public or private internet networks that serve as a data communication structure
- Analytical applications that process raw data into data insights for optimized processes
- Tools that help decision-makers and employees utilize data for better business outcomes

Industrial IoT devices

- Most IIoT devices are sensors used to monitor an assembly line or other manufacturing process. Data from various types of sensors is transmitted to monitoring applications that ensure key processes are running optimally. These same sensors can also prevent unexpected downtime by predicting when parts will need to be replaced.
- If a problem occurs, the system might be able to send a notification to a service technician informing them what is wrong and what parts they will need to fix the problem.

IoT vs IIoT


IoT
IIoT
household usage/ for the commercial sector
industrial sector
• data management connectivity,
• data security
• secure cloud

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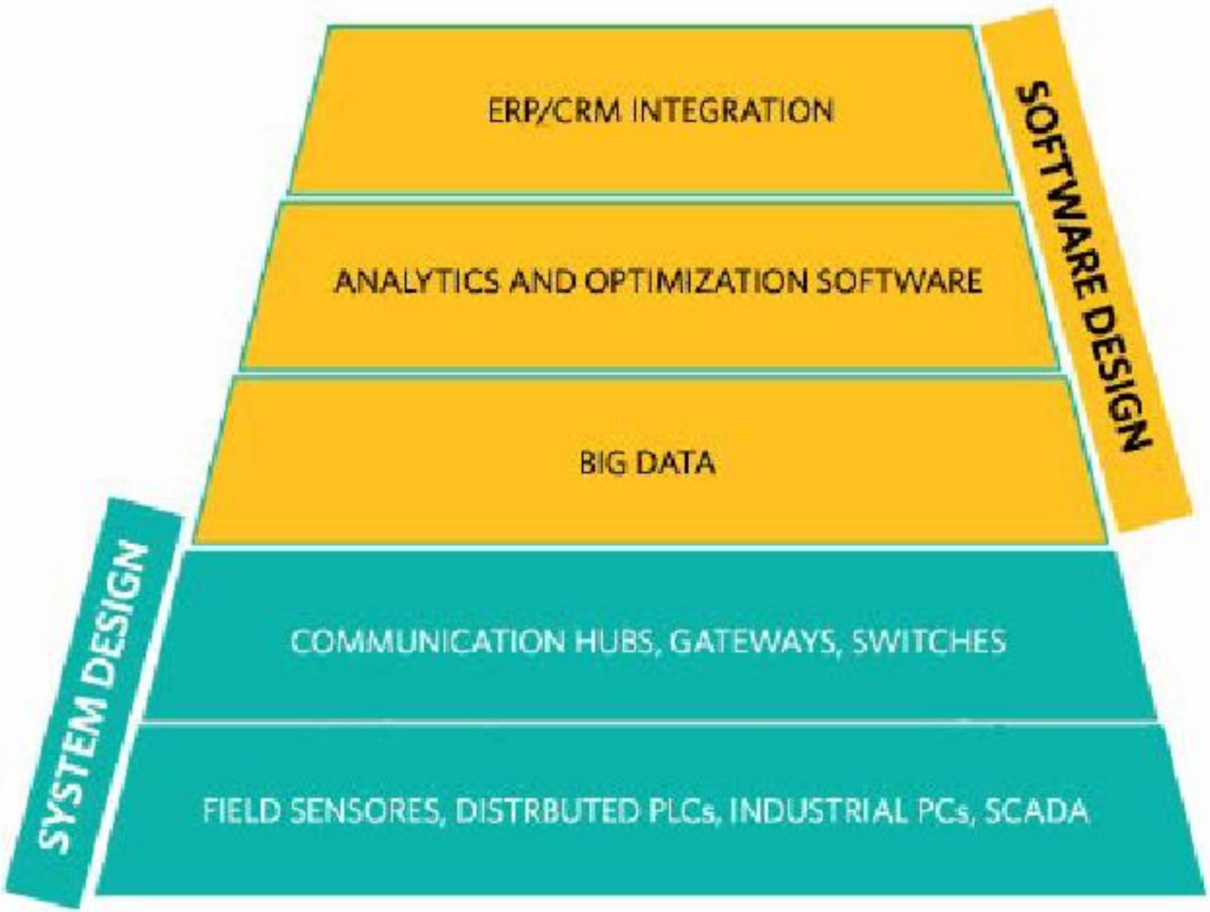
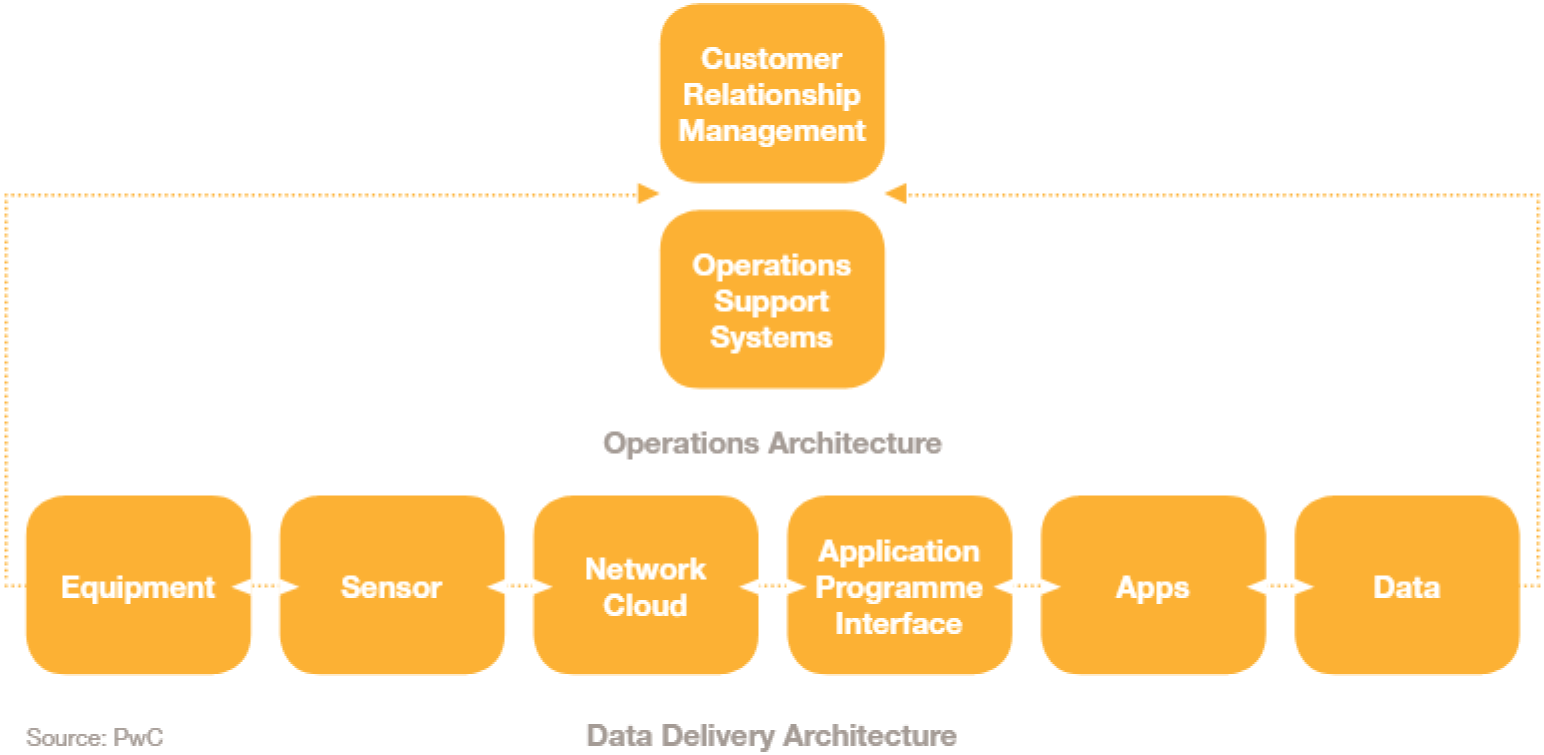
Layered Architecture of IIoT

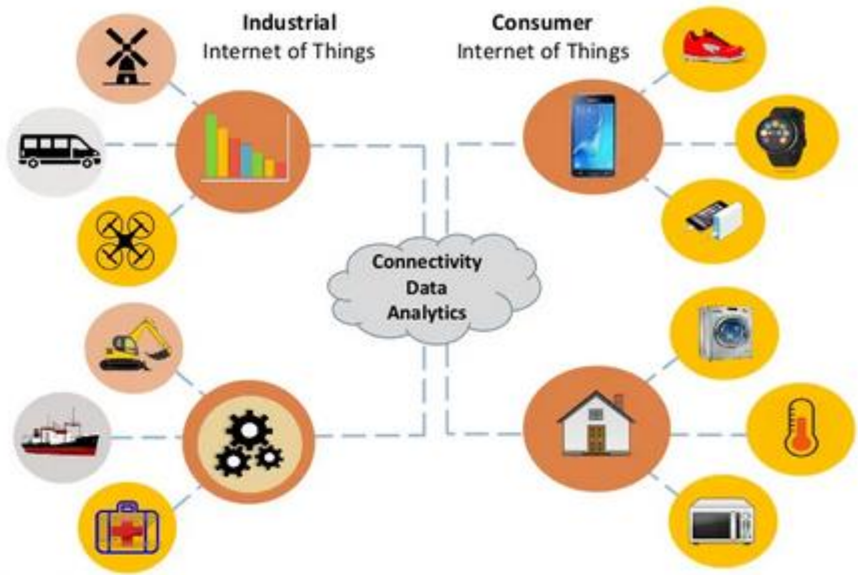


The need for a robust 'operations' architecture alongside the 'data delivery' architecture



Source: PwC

Industrial IoT vs consumer IoT:



Application areas of IIoT

- **Production** . Smart machines, enabled with IIoT, can self-monitor and anticipate possible production hurdles. This results in lowered downtime and better efficiency.
- **Supply Chain** With IIoT, orders can automatically replenish stocks when needed. This reduces waste, maintains stock numbers, and makes sure the right amount of raw materials are always available.
- **Building Management**. Sensor-driven climate control removes all the uncertainty related to managing a building's internal climate and takes all needed factors into consideration--such as the number of people, ventilation spots, machinery, and more. IIoT enhances building security with smart devices that assess possible threats from any entry points of a building.
- **Healthcare** Healthcare professionals can remotely monitor patients and are alerted by any status change. This makes healthcare more precise and personal. In the future, artificial intelligence may be able to assist with diagnoses, enabling doctors to treat patients more accurately and effectively.
- **Retail** IIoT technology in retail enables quick marketing decisions specific to each store. Companies can update storefronts based on region-specific consumer interests, and they can target audiences with smarter promotions. These data-driven insights make a store stand out from its competition.

Digital/Connected Factory

- The machinery that is embedded with an IoT system can transfer information related to operations to the people such as the original equipment manufacturers and to field engineers.
- This way process automation and optimization is made advantageous by enabling operation managers and factory heads to remotely manage the factory units.
- Along with this, a digitally connected unit helps in establishing a better line of command and also helps to identify areas with key results and areas that might have potential problems for managers.

Facility Management

- Most of the machine tools are critical and are designed to function between a specific temperature and vibration ranges.
- Whenever an equipment deviates from its prescribed parameters, IoT sensors can actively monitor machines and send an alert.
- Manufacturers in this way can conserve energy, reduce costs, eliminate machine downtime and increase operational efficiency, by ensuring the prescribed working environment for machinery.

Production Flow Monitoring

- IoT in manufacturing is capable of monitoring an entire production line be it from the refining process completely down to the packaging of final products, in real-time.
- It provides us the scope to recommend any adjustments in operations for better management of the industry’s operational cost, eliminating wastes and unnecessary work.

Inventory Management

- These systems allow one to track the inventory and trace it globally on a line-item level. This way the users are notified if there are any significant deviations from the plan of action.
- As a result, this helps managers in getting realistic estimates of the available material, the work in progress and the estimated arrival time of new materials.
- Ultimately this makes supply more optimal and reduces additional and shared costs that arise in the value chain.

Plant Safety and Security

- The IoT system monitors some ***Key Performance Indicators (KPIs)*** of health and safety, such as the number of injuries, frequent rates of illness, vehicle incidents, and property damage or any kind of loss incurred during daily operations.
- Thus, an effective monitoring system ensures better and effective safety. If there are some indicators that are lagging, they addressed, thus ensuring better *health, safety, and environment (HSE)* issues.

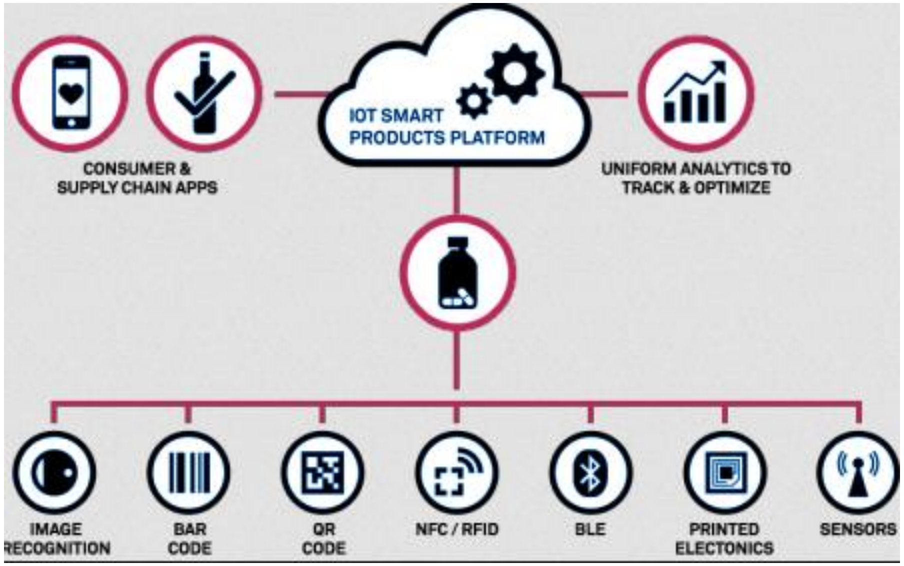
Quality Control

- A product cycle has various stages, IoT sensors collect a mixture of product data and other third-party synchronized data from the stages of a product cycle.
- This data contains information on the composition of raw materials used in the making of a product, the temperature & working environment, different wastes, the importance of transportation etc.
- Moreover, the IoT device can also provide data about the customer sentiments while he/she uses the product.
- All of these inputs from different sources and through IoT systems can analyze to identify and correct potential quality issues.

Packaging Optimization

- There are smart tracking mechanisms that can trace product deterioration during the product transit.
- Other factors such as weather impact, a condition of roads and other environment variables on the product.
- Through these insights, one can re-engineer products and their packaging for delivering better performance in both costs of packaging and customer experience.

Packaging Optimization

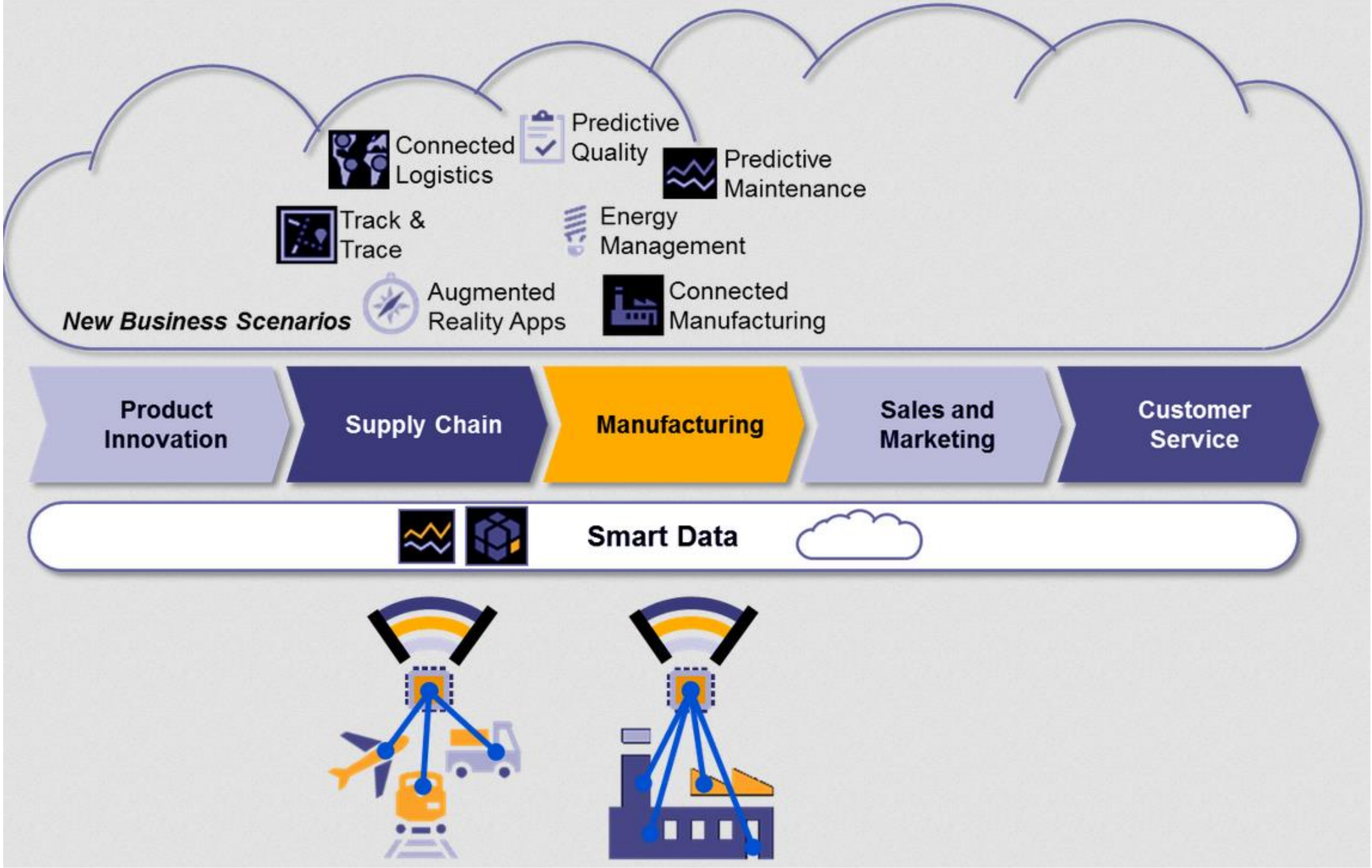


Logistics and Supply Chain Optimization

Προηγμένες Μέθοδοι Κατασκευής
MSc
Προϊόντων από Ξύλο

- Provides access to real-time supply chain information by tracking materials in transit, products, and equipment as they move through the supply chain.
- Through effective reporting manufacturers are able to collect and feed the delivery information into systems like ERP, PLM etc.
- If the plants get to connect to the suppliers, all the concerned parties in the supply chain can trace interdependencies, manufacturing cycle times and material flow.
- As a result, this data will help manufacturers to reduce inventory, predict potential issues and also reduces capital requirements.

Logistics and Supply Chain Optimization



IIoT Security
Considerations and Challenges

- Software vulnerabilities are easy prey for hackers to attack.
- Devices and systems connected to the internet are publicly searchable.
- Hacking attempts increase, leading to targeted attacks and data loss.
- System malfunction results in device damage, or worse still, physical damage to employees.
- Extortion attempts resulting from compromised operational technologies.
- Increased fines if private information is made public against regulations.

How Companies Can Implement IIoT Intelligently?

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- **A Centralized Security Operations Centre** A company keen to implement IIoT must have a security operations center (SOC) in place. This will proactively monitor and defend against a broad spectrum of threats
- **Recruiting Security Experts to Mitigate Threats**
- **Full-Stack Protection**
- **The device**: IIoT adopters should know how manufacturers and service providers use, transmit, and store data. If there is a security breach, manufacturers and service providers must be able to immediately notify companies.
- **The network**: The network area has a gateway through which data is gathered from devices. Organizations need to have state-of-the-art intrusion prevention systems (IPSs) in place to check for potential attacks. This gateway is placed at the control center, sending out commands to various devices. It is critical that security measures are placed at the control center to protect against malware infections and hackers.
- **The cloud**: Providers need to have security that runs server-based protection against hackers trying to gain control of servers and data.

The Critical Role of Sensors in the IIoT(2 case studies)

- A good IIoT case study, is a $170 million **U.S. factory plant** in upstate New York which produces advanced sodium-nickel **batteries for applications** that include powering cell-phone towers. The factory has more than 10,000 sensors spread across 180,000 square feet of manufacturing space; all sensors are connected to a high-speed internal Ethernet. The sensors monitor processes that determine which batches of powder are being used to form the ceramics at the heart of the batteries? How high is the temperature being used to bake them? How much energy is required to make each battery? And even what is the local air pressure? Employees with iPad computers on the plant floor can pull up all the data from Wi-Fi nodes set up around the factory.
- **Airbus** showcased how they have attached RFID tags to objects such as aircraft components and tools. These tags can then be read automatically from distances of up to 100 meters using special glasses (similar to a Google Glass™ head-mounted display) through which Airbus can track and visualize production processes in real time. According to Airbus, this visualization technology has been deployed on the A330 and A350 final assembly lines in Toulouse, France, and on the A400M wing-assembly operations in the U.K.

- Thank You!!!