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MOVET

Modernisation of VET through
Collaboration with the Industry

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The world of IoT

Erasmus+

EXPLANATORY NOTES

$E = m \cdot c^2$	Definition
	Interesting
i	Note
	Example
	Summary
$+$	Advantage
$-$	Disadvantage

ANNOTATION

This module describes the world of Internet of things (IoT). Main technologies involved in the use of IoT are introduced. Moreover, IoT devices and platforms are also described in this module. Finally, a list of real IoT applications is shown for several typical IoT fields.

OBJECTIVES

After studying this module, students will know the meaning of IoT. They will discover the advantages of the new generation mobile phone technologies for the deployment of IoT applications, as well as most common wireless communication technologies of application in the world of IoT.

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1 **Introduction**

This chapter describes some important highlights in the world of the IoT (Internet of things). As it was reported in [1], the Internet of Things (IoT) is the network of physical objects, devices, vehicles, buildings and other items, which are embedded with electronics, software, sensors, and network connectivity, which enables these objects to collect and exchange data.

The (IoT) has been the focus of attention recently. It is the foundation for delivering previously unimagined services by connecting "things", such as sensors, actuators, consumer electronic devices, automobiles and home electrical devices, to the Internet. The communication between IoT devices and systems is via the Internet. Therefore, the IoT allows objects or things to be monitored by sensors or actuated and controlled remotely across existing networks infrastructure, creating opportunities for more-direct integration between the physical world and computer-based systems. The use of IoT results in improving on efficiency, accuracy and it also implies an economic benefit.

Fig. 1. IoT

The field of applications for IoT is very wide. IoT technology allows expanding vehicles interaction with people or surrounding environments: Smart driver, connected ships or vehicle tracking. Moreover, IoT also leverages to improve the use of physical spaces as smart buildings or connected homes and commerce. There is also a wide range of applications in health, as smart hospitals check-in, remote health monitoring or diagnostic. More applications of IoT can be found in smart cities as automatic control of public lighting, parking, garbage, traffic or environmental conditions [2]. Smart City initiatives carry with them many goals. Main focus is centered on improving the life of its citizens. The IoT technologies

are the key to solve urban problems, by monitoring and interpreting the state and usage of city assets.

Nowadays, wearables or these smart devices like smart watches or smart glasses are very popular in the IoT ecosystem. Moreover, there are many applications in security and access control.

On the other hand, IoT technology is also used to optimize and enhance the operational work processes and assets performance to enable productivity enhancements in a wide variety of industrial applications.

Machine to Machine (M2M) refers to devices that are connected to each other capturing events, by means of measurement or observation, measurements of the environment whose data is transmitted over the network to an application that translates it into useful information.

2 **Internet Protocols**

As described in [1] the **IP** *(Internet protocol)* specifies the technical format of packets and the addressing field for all devices connected through a communication network, in this case Internet. **IPv6 (*Internet protocol version 6*)** is the most recent version of the IP, the communications protocol that provides an identification and location system for computers on networks and routes traffic across the Internet.

In order to connect any device to Internet it's necessary to provide an IP address to the device. The first version of an Internet Protocol publicly used was **IPv4** (***Internet protocol version 4***). This protocol was created by the Defense Advanced Research Projects Agency (DARPA). IPv4 included an addressing system that used numerical identifiers consisting of 32 bits. The use of addresses with a length of 32 bits limits the total number of possible addresses to a number of approximately 4.3 billion addresses for devices connected to internet around the world. The expected number of devices connected to Internet by means of IoT applications will be soon bigger than the number of addresses provided by IPv4. For this reason, the agency responsible for standardization of Internet protocols: The **IETF** (***Internet Engineering Task Force)*** has been working in a new IP version from 1998: The IPv6, the successor protocol that is intended to replace IPv4 was first formally described in Internet standard document RFC 2460 [3].

IPv6 uses a 128-bit address format, allowing 2^{128}, or approximately 3.4 10^{38} addresses, approximately 8 10^{28} times as many as IPv4. While increasing the pool of addresses is one of the most important benefits of IPv6, there are other important technological changes in IPv6 that will improve the IP protocol: easier administration, better multicast routing, a simpler header format and more efficient routing, built-in authentication and privacy support among others.

IPv6 addresses are represented as eight groups of four hexadecimal digits. These groups are separated by colons, but methods to abbreviate this full notation exist. The IPv6 header format is shown in Table 1.

Table 1 – Structure of IPv6 Header

Group	Information
Version	4-bit Internet Protocol version number = 6.
Traffic Class	8-bit traffic class field.
Flow Label	20-bit flow label.
Payload Length	16-bit unsigned integer. Length of the IPv6 payload, i.e., the rest of the packet following this IPv6 header, in octets.
Next Header	8-bit selector. Identifies the type of header immediately following the IPv6 header. Uses the same values as the IPv4 protocol field
Hop Limit	8-bit unsigned integer. Decremented by 1 by each node that forwards the packet. The packet is discarded if Hop Limit is decremented to zero.
Source Address	128-bit address of the originator of the packet
Destination Address	Address 128-bit address of the intended recipient of the packet (possibly not the ultimate recipient, if a routing header is present).

The new features introduced with the IPv6 protocol are basically the following: A new header format, an efficient and hierarchical addressing and routing infrastructure, a much larger address space and stateless and both firewall address configuration, IP security, extensibility, a better Quality of Service (QoS) support and a new protocol for neighboring node interaction.

Moreover, the IPv6 protocol has solved some of the security problems found in IPv4 networks by adding the **IPsec** *(IP security)* as mandatory. As a result, IPv6 is more efficient. Security in IoT implementations must be a critical component of the device design and manufacturing processes to ensure that basic security requirements are in place.

IPv6 offers also improvements on mobility security: Any IPv6 node of the network can use a mobile IP both as required. Mobile IPv6 uses two extensions headline: A routing header for registration and a headline target to data delivery between mobile nodes and their corresponding fixed nodes.

Most IoT devices connect to the Internet using wireless communications. The communications speed and device mobility range must be ensured. Wireless communications standards cover various technologies, including Wi-Fi, Bluetooth, ZigBee, long term evolution standard (LTE), Narrowband IoT (NB-IoT) or the IoT-friendly versions of LTE: Cat-M1 and the enhanced machine type communications (eMTC).

On the other hand, indoor installations commonly use Wi-Fi and Bluetooth, while outdoor installations generally use LTE, NB-IoT, and Cat-M1. It must be taken into account that Wi-Fi power consumption is much higher than Bluetooth.

2.1 IoT Platforms

The IoT platforms allow collecting the data sent from the different connected devices. On the other hand, it should facilitate the creation of applications, both mobile and for other devices that clearly visualize the data received from the IoT devices connected to the platform, in addition to the data on which it has been worked.

These IoT platforms are able to manage the information in a solvent manner. IoT platforms must be able to collect the information sent by the devices, store and / or analyze the data and represent or expose the information so that the user can use it. In addition, each IoT platform is specialized in specific services.

Some of the most famous IoT platforms that can be found in the market are depicted in Table 2.

Table 2 – IoT platforms

Platform	URL	Characteristics
AWS IoT Core	https://aws.amazon.com/iot-core/?nc1=h_ls	AWS IoT Core is a managed cloud platform that lets connected devices easily and securely interact with cloud applications and other devices.
Azure IoT hub	https://azure.microsoft.com/en-us/services/iot-hub/	Connect and manage billions of IoT devices and assets. Establish reliable, bi-directional communication and enhance the security of IoT solutions. Ingest real-time data and upload files to the cloud.
Oracle cloud	https://cloud.oracle.com/iot	Interact with virtualized software representations of assets. High-Speed Messaging. Support for industrial protocols. Analyze and Integrate IoT data and services.
Ericsson IoT	https://www.ericsson.com/en/internet-of-things/solutions	Security and connectivity. IoT Accelerator platform. Reliable connectivity.
Watson Internet of Things	https://www.ibm.com/internet-of-things	Asset, facilities and product management.
Xyveli	https://www.xively.com/	Xively offers everything needed to build and launch a connected product.
Samsung ARTIK	https://www.artik.io/	The Samsung ARTIK Smart IoT platform brings hardware modules and cloud services together, with built-in security and an ecosystem of tools and partners to speed up the time-to-market
Adafruit IO	https://io.adafruit.com/	Adafruit IO is a system that makes data useful. It is ease of use, and allows simple data connections with little programming required.

3 5G and IoT

The fourth generation of mobile phone technologies, 4G, was a great improvement in the download speed for users, who could start enjoying live content on their phones. Many applications can be supported on existing 4G networks but some will require 5G. These requirements include higher data rates and higher capacity with shorter latency as well as reductions in energy use and greater system efficiency.

In telecommunications and electrical engineering, 5G is the abbreviation used to refer to the fifth generation of mobile telephony technologies [4].

The 5G is the successor of the 4G technology. Currently it is not standardized yet and telecommunication companies are developing their prototypes.

This next evolution of mobile phone networks called 5G will allow, among other things, to navigate at speeds higher than 1 Gbps. This means multiplying the current navigation speed by ten. Thus, the 5G implies an improvement in speed: if with the 4G a download speed of 150 megabytes per second was achieved, it will go up to 20 Gbps. This fact will allows watching streaming channels with 4K quality or cameras becoming equipped with the ability to record ultra-high definition videos and other services that demand a lot of bandwidth. Moreover, with the use of 5G remote computing will be also possible, that is, it will not be needed to install a large number of processors in some objects because computing could be done in the cloud. Several industries can be the early beneficiaries of IoT technologies. The IoT technologies such as M2M communication complemented with intelligent data analytics are expected to drastically change landscape of various industries. Multiple tracks on industries are moving into mobility and intelligence. Table 2 shows some industrial sectors with mobile broadband requirements than can benefit from 5G IoT advantages.

Table 3 – Industrial applications

Manufacturing	Smart cities	Smart home	Health	Transportation
Production Monitoring	Traffic control	Access control	Helath monitoring	Vehicle diagnostics
Machine condition monitoring	Smart lighting	Energy management	Remote diagnostic	Autonomus driving cars
Robotic control	Parking meters	Smart metering	Robotic surgey	Control of trucs
Stocks traking	Waste management	Alarms and security control	Fall detection	Drone monitoring

This technology will work in the bands of 3.6 and 26 GHz in 2020 at the European Community. The NSA 5G NR or Non-Standalone 5G New Radio is the first standard the fifth generation of mobile networks officially approved by the 3rd Generation Partnership Program (3GPP).

The 5G supposes numerous improvements with respect to the previous generation, which will open a world of possibilities. With the 5G we will go from being connected only to people to a world where everything is connected. The 5G standard must support up to 1 million connected devices per square kilometer offering infinite possibilities to IoT devices to be connected. This density of devices will allow another significant breakthrough: turn real promises like connected cities or the autonomous car.

An important issue for IoT devices and services is the latency. In data communication and digital networking, latency is used in two major contexts. One represents a one-way trip while the other is a round trip. One-way latency is measured by counting the total time it takes a packet to travel from its source to its destination, while round-trip latency is measured by adding one-way latency from the destination to the time it takes the packet to return from the destination and arrive back at the source. The propagation time, delay in transmission and storage or device processing limit the latency in communication networks. A second important improvement of 5G networks should offer users a maximum latency of just 4ms, down from about 20ms on LTE cells. The 5G spec also calls for a latency of just 1ms for ultra-reliable low latency communications (URLLC). In many IoT applications, minimum latency is crucial as actuators and sensors must operate very fast to be useful and make effective operations.

On the other hand, 5G offers another advantage that is also very important for IoT applications; 5G requires lower power consumption than 4G. This reduction offers the possibility to include more sensors in many applications and systems of IoT. Low power consumption is a key requirement to ensure years of battery lifetime. Moreover, various technologies and issues regarding green IoT focused in the reduction of the energy consumption of IoT have been reported in the literature [5-6]. A key design expectation of IoT enabled devices is that they will operate at low powers with battery life of up to 10 years in some applications.

In addition, some of these IoT devices may be powered by harvesting energy from the radio signals all around or solar energy. Researchers, scientists, and engineers face emerging challenges in designing IoT based systems that can efficiently be integrated with the 5G wireless communications. In order to ensure long battery lifetime and to reduce energy consumption, some technologies are enabled with two power saving features: extended discontinuous reception (eDRX) and power saving mode (PSM) [7].

Main requirements for 5G of IoT and M2M are the following: Many more connected devices deep indoor coverage and signaling efficiency.

4 IoT Devices

The complexity of IoT devices can be diverse. Generally speaking, IoT devices are nonstandard computing devices (objects, everyday items, appliances, sensors or actuators) connected to a wired or wirelessly network, that have the ability to transmit and/or receive data, receive instructions, and even take actions based on the data they gather. In some applications, the IoT device can be able to pre-process or process the data gathered from the real world before sending this information to a control unit that will take the appropriate decisions.

The gathered data can be processed on either the IoT device or a remote control unit. Thus, for IoT applications that involve data processing, a major challenge is to decide where the computation load should be done.

An IoT device is an embedded device which can be characterized by at least three basic blocks:

- **Sensors**: Their main function is to monitor and measure activity in the world.

- **Connectivity block**: This block provides Internet connectivity to the device. According to the nature of devices, they can be divided into two broad categories:

- **Industrial IoT devices**. The local network is based on any of the many different existing technologies. The IoT device will typically be connected through an IP network to the global Internet.

- **Commercial IoT devices**. The local communication is typically either ZigBee, Bluetooth or Ethernet (wired or wireless). The IoT device will typically communicate only with local devices.

- **Processing unit**: It is the brain of the IoT device. Depending on the IoT device complexity, it can include a microcontroller, a microprocessor or a DSP together with some specialized hardware to process incoming data or encrypt/decrypt information.

Figure 2 shows a general block diagram with the main components of an IoT device. It can have many other blocks but at least the RF component for the connectivity in common to all of them.
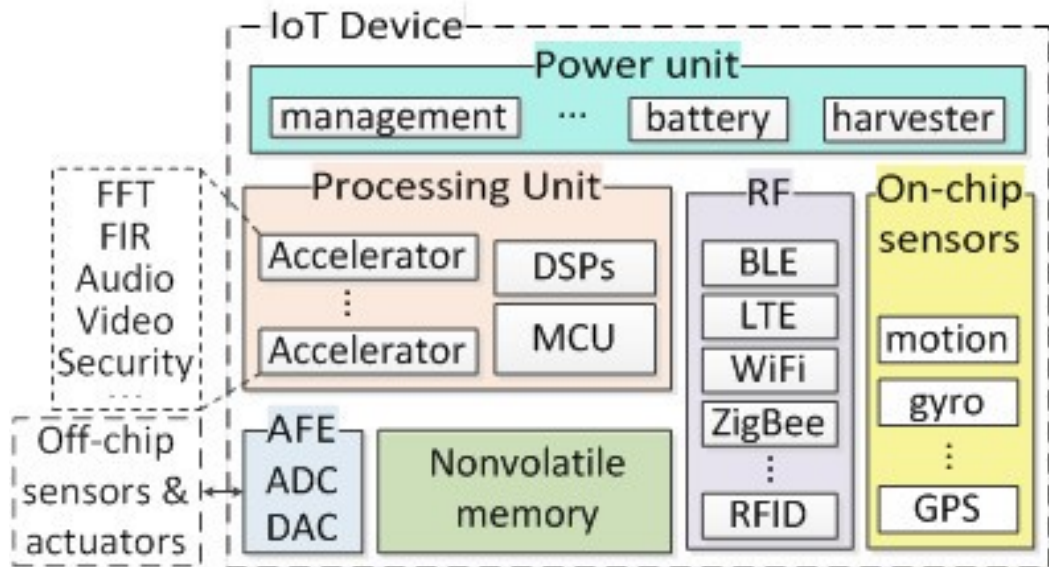
Fig. 2. IoT device block diagram [8]

In fact, these blocks are common to many of the devices that exist today in the market. However, IoT devices must include, particularly remote ones, other features such as [9]:

- **Energy-efficiency**: Many IoT devices may be difficult, costly, or dangerous to access for charging or battery replacement. Therefore, they may need to be able to operate for quite long periods of time or unattended or be able to wake up only periodically to transmit data.

- **Cost-effectiveness**: Objects that contain IoT devices may need to be distributed broadly, as in the case of IoT devices in food products in supermarkets that would indicate if the item has spoiled. They need to be relatively inexpensive to purchase and deploy.

- **Quality and reliability**: IoT devices may need to operate in harsh environments outdoors and for long periods of time.

- **Security**: IoT devices may need to transmit sensitive or regulated information and protect them from unauthorized access.

5 Applications and Study Cases

It is practically impossible to imagine the full potential of IoT applications. Potential applications are numerous and diverse and they go beyond of just connecting standard devices such as desktops, laptops, tablets and smartphones to a network. Some applications will mature much faster than others.

Currently, there is a wide range of IoT applications covering many fields, such as smart cities, smart buildings, agriculture, car communication, transportation and mobility, smart industry, and smart health, environmental and social aspects.
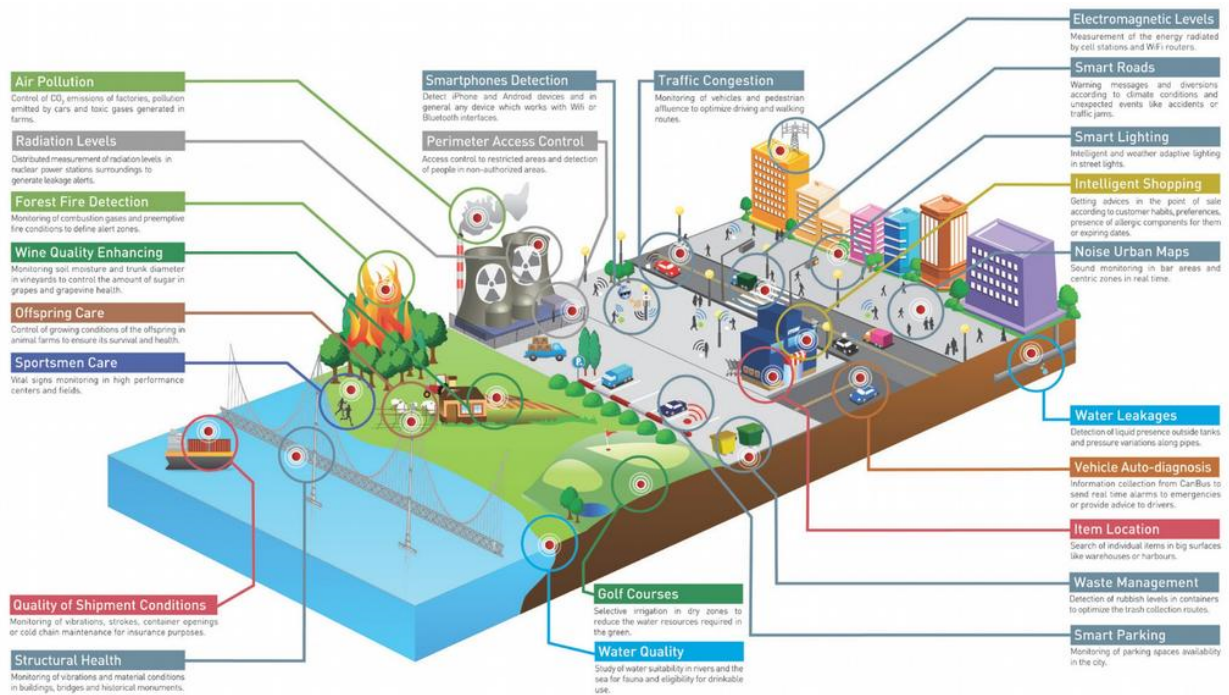

Fig. 3. IoT applications [10]

The potential of IoT applications promises to transform many aspects of our lives [11]. New IoT devices like smart appliances, home automation components, and energy management devices are moving us toward a vision of the "smart home'', offering more security and energy efficiency. Other personal IoT devices like wearable fitness and health monitoring devices and network enabled medical devices are transforming the way healthcare services are delivered. This technology promises to be beneficial for people with disabilities and the elderly, enabling improved levels of independence and quality of life at a reasonable cost. IoT systems like networked vehicles, intelligent traffic systems, and sensors embedded in roads and bridges move us closer to the idea of "smart cities'', which help minimize congestion and energy consumption. IoT technology offers the possibility to transform agriculture, industry, and energy production and distribution by increasing the availability of information along the value chain of production using networked sensors.

A number of companies and research organizations have offered different projections about the potential impact of IoT on the Internet and the economy during the next years. Cisco, for example, projects more than 24 billion IoT objects by 2019; Morgan Stanley, however, projects 75 billion networked devices by 2020. Huawei forecasts 100 billion IoT connections by 2025. McKinsey Global Institute suggests that the financial impact of IoT on the global economy may be as much as $3.9 to $11.1 trillion by 2025. To estimate the potential economic impact of IoT across economies, McKinsey Global Institute took into account a range of IoT adoption rates, economic and demographic trends, and the likely evolution of technology over the next 10 years [12].

In the following subsections we present some of these applications which can have a great impact in our lives in a near future. This is just a limited description in order to imagine all possible new applications and services that IoT could provide.

5.1 Smart cities

Up to day, we can find different definitions of a smart city but there is still no a unique accepted definition. The idea of a smart city varies from country to country and even from city to city. It means different things to different people depending on their own needs to make a better city with a high quality of life.

In the near future, it is expected a rapid expansion of city borders due to an increase in population and infrastructure development. Big cities will absorb the surrounding small ones to form mega cities with a population of more than 10 million people. This fact will cause the mega cities to evolve towards smart cities. It is expected about 40 smart cities in the world by 2025 [13].

Cities will be improved in many levels, they will be more secure, more productive, and more sustainable, all thanks to the IoT technology. Smart cities demand requires support of agreement from governments. In fact, the role of the cities governments will be crucial for IoT deployment. The next table shows some examples of smart city applications.

Table 4 - Smart city applications

Application	Description
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.
Smart Roads	Intelligent Highways with warning messages and diversions according to climate conditions and unexpected events like accidents or traffic jams.
Traffic Congestion	Monitoring of vehicles and pedestrian levels to optimize driving and walking routes
Smart Lighting	Intelligent and weather adaptive lighting in street lights.
Waste Management	Detection of rubbish levels in containers to optimize the trash collection routes
Potable Water Monitoring	Monitor the quality of tap water in cities

5.2 Smart home (and buildings)

A smart home does not mean a home plenty of new and crazy gadgets or robots but a home with "connected" appliances and accessories, so it seems that they are appliances that can act autonomously as if they had some intelligence. Thus, we can talk about smart light bulbs, smart thermostats, smart washing machine, smart security systems, etc.

Until recently, the Wi-Fi network has been used primarily to interconnect electronic devices such as smartphones, tablets, TV, etc. However, the Wi-Fi network will take on great importance in the concept of smart home [14]. By connecting home appliances to the Wi-Fi network we can obtain great benefits.

Any device in our home that uses electricity can be connected to our home network.

Firstly, we could control everything in real time either from an app on our smartphone or tablet, or from our voice.

Secondly, we can have access to all data and information stored in home appliances. Thus, smart home appliances can give us easily accessible data on security by accessing to smart security camera records or on energy by monitoring electricity and gas consumption.

Thirdly, we have got home automation. Instead of manually controlling our home gadgets all the time we can go one further and set up routines and rules. The idea is that our home gets to know us and our family and automatically works based on what is happening, without the need of our control commands.

Finally, and probably in a near future, we can imagine completely autonomous gadgets and robots that operate themselves at home such as lawn mowers robots or laundry folding robots.

Entertainment, energy efficiency and security are expected to be the three big categories for smart home devices in the near future.

Table 5 - Smart home and building applications

Application	Description
Real Time Alerts	Starting time for washing machine and dish washer scheduled to save energy.
Security and Surveillance	To increase safety, protect our family and monitor activity on our property.
Perimeter access control	In buildings, access control to restricted areas and detection of people in non-authorized areas.
Air Control and Central Heating	House/room temperature is automatically adjusted to our preferences.
Smart Lighting	Intelligent and weather adaptive lighting in home and building lights.
Smart Enterteiment	Automatic selection and in a in a personalized way of a tv program or movie according to the user's tastes
Energy and Water Use	Energy and water supply consumption monitoring to obtain advice on how to save cost and resources
Keep your plants alive	To keep plants fed based on their actual growing needs and conditions.

5.3 Smart environment

The environment needs smart ways and new technologies for monitoring and management. Monitoring the environment is important in order to assess the current condition of the environment to take the correct life decision according to collected data from monitoring systems, and management is needed to have an efficient consumption of resources and use in addition to decrease waste from factories and vehicles [14].

All collected data from monitoring systems are essential to force municipalities and public institutions to protect people and environment, and to mitigate or to avoid natural disasters that might occur.

Smart environment sensors provide many facilities and solutions for many environmental applications such as water and air pollution, weather and radiation monitoring, waste management, natural disasters, and many other environment indicators as shown in Table 6. Smart environment sensors integration with IoT technology is developed for tracking, sensing and monitoring objects of environment which provide potential benefits to achieve a green world and sustainable life [14].

Applications in smart environment can be divided into two main categories: environmental resources management and environmental quality and protection management. Environmental resources management relates to all natural resources such as forests, animals, coal, petroleum, water, air, sunlight, wind, gold, silver, iron and many others. These resources can be seriously affected by pollution, waste and abuse. IoT technologies provide an effective means of communicating among resources sensors and monitoring centers to take appropriate decisions in the consumption of these resources. Thus, for example, air quality can be monitored by using a set of remote sensors across the city, and as a result, we can get a full-time map with pollution levels and better manage the urban traffic of the city. Also, decisions on water usage and treatment can be taken if levels of pollution are known.

There are many other applications that can be implemented by using smart sensors wirelessly connected to a management center. To cite just two more examples, an IoT sensor network can continuous monitor radiation levels around nuclear power plants for prevention, or provide a high resolution and accurate weather forecast map of the region.

Table 6 - Smart environment applications

Application	Description
Forest fire detection	Monitoring of combustion gases and preemptive fire conditions to define alert zones.
Air pollution	Control of toxic gases (CO_2, O_3, NO_2, CO, CH_4, …) emitted by factories, farms and cars.
Snow level monitoring	Snow level measurement to know in real time the quality of ski tracks and allow security corps avalanche prevention.
River floods	Monitoring of water level variations in rivers, dams and reservois.
Landslide and avalanche prevention	Monitoring of soil moisture, vibrations and earth density to detect dangerous patterns in land conditions.
Natural disaster early detection	Distributed control in specific places of tremors, earthquakes, hurricanes, volcanic eruptions, floods, … to reduce the impact of natural disasters.
Ultraviolet radiation	Measurement of UV sun rays to warm people not to be exposed in certain hours.
Waste Management	Real time detection and control of industrial pollution (waste chemicals and others) to improve environment
Pollution levels in the sea	Control realtime leakages and wastes in the sea
Chemical leakage detection in rivers	Detection of leakages and wastes of factories in rivers.
Help Protect Wildlife	To use GPS tracking collars to locate and track wild animals and communicate their coordinates to researches.

5.4 Smart energy and the smart grid

The energy model based exclusively on sources of fossil energy will not be able to meet the world's energy needs in a not too far future. All solutions involve incorporating renewable and green energy sources into the energy model. However, the intrinsic nature of this type of energy requires a very high control of the consumption of energy by consumers [13].

Normally the energy consumption is not uniform and there are time slots with very high energy demands as well. This forces the electrical grid to be intelligent and flexible to withstand electricity fluctuations by controlling electrical energy sources and loads. In order to achieve this goal, the electrical grid will have to incorporate networked intelligent devices and grid infrastructure elements such as sensing and monitoring devices for monitoring energy flows, digital communications infrastructure to transmit data across the grid, smart meters with in home display to know about the energy usage or control and automation system to process all data and make a smart management of the grid. Ideally, it would require to know the instantaneous energy consumption of individual loads but a knowledge about energy usage per customer is enough in first approximation [13].

A smart grid integrates the information and communication technologies to the electricity network in order to have a smart energy management.

Instead of main power plants outside cities, future smart grids will be characterized by small and medium energy sources and power plants distributed across the smart city trying to emulate the structure of an internet network.

Smart grid solutions aim to optimize the production, distribution and consumption of energy, facilitating the entry of new suppliers and consumers in the electrical network, with significant improvements in monitoring, management, automation and quality of electric power supplied.

Table 7 - Smart energy and the smart grid applications

Application	Description
Photovoltaic installations	Monitoring and optimization of performance in solar energy plants
Smart grid	Energy consumption monitoring and management
Narrowband PLC	Narrowband power line Communication (N-PLC) allows communications over power lines.

5.5 Smart agriculture and farming

In 2005, predictions from the Food and Agricultural Organization (FAO) of the United Nations suggest that by 2050 the global population will move beyond the 9.6 billion. In order to feed this much population, agricultural production needs to increase 70% by 2050. In 2017, a study published by BioScience, they conclude that an increase of approximately 25% to 70% above current production levels may be sufficient to meet 2050 crop demand [15]. Anyway, to do this, the farming industry must embrace IoT. In addition, change in climate conditions and drawbacks of intensive farming over land and water resources makes important to devise new methods to face future challenges in the agricultural sector.

By smart agriculture and farming we understand the application of modern information and communication technologies into agriculture and farming. From the point of view of the farmer, smart farming provides the farmer with opportunities for better decision-making and more efficient management.

Farmers can manage their farming practices remotely. Thus, data can be collected from satellites or drones. Sensors in the fields, on animals, in the soil can transmit real time data. This is a cost effective method and an accurate means to predict and protect the growth of agricultural crops.

Table 8 - Smart Agriculture domain applications

Application	Description
Increased Quality Production	Analyzing production quality and results in correlation to treatment can teach farmers to adjust processes to increase quality of the product.
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.
Hydroponics	Control the exact conditions of plants grown in water to get the highest efficiency crops.
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.
Remote monitoring	Local and commercial farmers can monitor multiple fields in multiple locations around the globe from an internet connection. Decision can be made in real time and from anywhere.

5.6 Smart industry and smart manufacturing

The smart industry is the fourth industrial revolution. For this reason, the term smart industry is also known as Industry 4.0. The first industrial revolution was characterized by mechanization based on water and steam power. The steam engine was one of the most important technologic developments of the first industrial revolution. During the second industrial revolution, the existing manufacturing and production methods were improved. The second industrial revolution happened through the introduction of mass production, assembly lines and electricity. The third industrial revolution happened with the introduction of electronics and computers for a further automation of production. Finally, Industry 4.0 is based on cypher physical production systems which can be able to connect to internet. The IoT will connect the industry to a new range of applications around production such as connecting the industry to the smart grid.

The smart industry will fundamentally change the way how products are invented, manufactured and shipped. In addition, worker safety is increased and the environment is protected by generating zero-emissions and zero-incident manufacturing as possible. In the smart manufacturing products, transport options, and tools will communicate with each other and will be organized with the goal of improving the overall production.

Table 9 - Smart industry and manufacturing applications

Application	Description
M2M applications	Machine auto-diagnosis and assets control
Indoor air quality	Monitoring of toxic gas and oxygen levels inside chemicals plants to ensure workers and goods safety.
Temperature monitoring	Control of temperature inside industrial and medical fridges with sensitive merchandise
Maintain Quality and Consistency	Using networked sensors, cameras, and lasers to analyze manufacturing processes
Fleet tracking	To optimize performance, reduce costs and improve productivity.
Supply chain control	Use of RFID sensors, QR codes, … for better operational efficiencies (asset tracking, vendor relations, forecasting and inventory,…) and revenue opportunities (to know about customers, buying habits, ..)

5.7 Smart health

There are many people in the world who suffer from poor health because they do not have access to effective health monitoring. However, this problem could be easily solved by means of small monitoring devices connected through the IoT. The main task of these small health devices will be to collect health data and physiological information of the patient, apply complex algorithms to analyze data and afterwards send them wirelessly to medical professionals who will make appropriate health recommendations. In addition, we can replace the process of checking the vital signs of patients at regular intervals by means of a health professional.

The main objective of IoT applications in the health field is to enhance life quality for people who need permanent support or monitoring, to decrease barriers for monitoring important health parameters, to avoid unnecessary healthcare costs and efforts, and to provide the right medical support at the right time and at a reasonable cost.

One of the main challenges to solve is that medical devices and equipment have not been designed for interoperation with other medical devices or devices connected to a network. Security is also an important and critical issue to solve as patients' data and information must be transmitted through the network [13].

IoT applications have a great future market potential for electronic devices and services. Just to cite a small sample of this great potential is the success of smart bracelets and watches together the health applications for android that one can download and run in your smartphone.

Table 10 - Smart health applications

Application	Description
Fall detection	Assistance for elderly or disabled people living independent
Monitoring of 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 warm people not to be exposed in crtain hours