IoT and the Autonomy of Communicating Objects Lead toward an Adapted Future

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ABSTRACT
Communicating objects have today become a truth and there is no doubt that they operate a prominent place in our lives. This bridge between the physical world and the virtual world corresponds to the natural evolution of the Internet. The Internet of Things (IoT) describes the network of physical terminals, "objects", which integrate sensors, software and other technologies in order to connect to other terminals and systems on the Internet and to exchange data with them. These terminals can range from simple domestic appliances to highly complex industrial tools. In this review, we consult on the representation of communicating objects, their autonomy, their purpose and their limits. We proceed to an overview of the communicating applications of the Internet of Things (IoT). We also explain how and for which applications, wireless sensors and other connected objects can take advantage of energy harvesting devices in order to gain autonomy.

Keywords
Autonomy of communicating objects, Internet of Things (IoT), Connected people, Sensors, Technologies of the future.

1. INTRODUCTION
Human, whatever the corner in which he is (in store, in his car, in town, in his habitat etc.), whatever his activity (work, sport, rest etc.), he uses more and more connected objects. Communicating objects are present in our environment. They talk to each other and especially to us. The objective of this review is to present the communicating objects; we are particularly interested in the challenges represented by the autonomy of this evolution integrated into the Internet of Things. For this, in a second part, we present the Communicating Objects. Third, the communicating autonomy of objects. For the fourth part, we present the Internet of Things and we end with the conclusion.

2. COMMUNICATING OBJECTS
2.1 Definition
A communicating object [2] is an object forming an integral part of the network of objects, reversing the whole of the real world towards a large digital virtual space. Ambient intelligence consists, not in communication between humans, but in communication between objects and between different networks. These objects, communicating with each other, constitute an infinite distributed scenario where each node of the network turns out to be the object itself. Communicating objects evolve, through the network, capable of mutual self-management, ensuring a new independence from humans. These electronic identification systems respond to the different solutions allowing to address, i.e. to uniquely identify an object, such as the IPv6 protocol, RFID technology [2] (Radio Frequency Identification), or again QR codes (two-dimensional barcodes).

2.2 Functioning
An object deposits its own identifier (ex: IP6), as well as the addresses of the objects it communicates with and the object instance variables [2]. The logic of object language makes it possible to reduce and improve the functioning of a complex system. The objects are at first connected to each other on a local scale to then be related to objects of a global order. This ordering of objects turns out to be the very core of the Internet of Things.

2.3 Concept
Ambient intelligence penetrates four essential concepts :

- **Ubiquity**: ability for a user to have access anywhere and at any time to assistance from interconnected objects. Entirely, we are talking about electronic systems buried in the real world (Embedded Software) [2].
- **Attentiveness**: listening, for the same object, to the nearby universe in order to detect and locate neighboring objects. Various sensors can provide emotional signs: cameras, microphones, radars or biometric sensors.
- **Natural interaction**: increased means of communication with the machine; we speak of a multimodal man-machine interface. Unlike the classic interface (WIMP interface) [4], natural interaction focuses on voice and gesture recognition and the manipulation of communicating objects.
- **Intelligence**: the Internet of Things can analyze the context and adapt the actions of objects according to the environment. We then speak of objects learning the behavior of users (artificial intelligence) [2].

2.4 Limits
Ethics and philosophy: Communicating objects through surrounding intelligence raises the ethical problem of respect for privacy [9]. The question is posed because the progressive computerization is carried out in an ever-wider shift, surprising both public and private spheres, and the appendix vis-à-vis IT is ever increasing. The boundary between the real and the virtual is becoming increasingly blurred. The computerization of objects carries a significant danger of dependence on the network. Then, the development of Cloud Computing [6] in information systems and collaborative solutions drastically reduces the control of information. Addressing all the objects of reality in the network will mechanically give an increasingly important judgment to the network, convincing a probable loss of control of material goods. The growth of communicating objects goes hand in hand with a

significant increase in the risks of intrusion into the user's information system as a whole.

Technical: The quantity of objects will not meet the limit of current IPv4 logical addressing [2]. However, saturation of the bandwidth by an explosion of traffic is to be feared, in the same way as the saturation of the 3G mobile network today. The local use of the bandwidth within a house or an apartment where home automation reigns will not establish problems from the moment the home is equipped with fiber optics; ADSL will remain a limiting factor on this point. [5] The centralization of media and networks is likely to persist as a problem since Internet users use the Internet today as they used the Minitel 20 years ago [4]. Indeed, most users access the content of other users through centralized servers, instead of accessing the content directly from the user or a trusted local third party. In the end, computer security will be absolutely essential knowing that anyone will be likely to break in.

System sustainability: The energy consumption of connected devices could pose a problem knowing that the peak of fossil fuel production has reached its limits. Pollution is a worrying fact since electronic waste will undergo exponential growth. In addition, pollution is both harmful for the planet but also for humans because of toxic residues.

2.5 Presentation of different protocols

The following summary table lists the main protocols subordinate to the communicating objects. The technological evolution of the Zigbee protocol [7] marks a considerable advance over current standard wireless protocols such as Bluetooth and wifi. Thus, Zigbee requires more than 30 times less memory than the Wifi standard. The Zigbee protocol [7] similarly solves the problem of autonomy by presenting an energy recharge independence for at least one year; autonomy can go up to 10 years with a simple 1.5V battery. The number of nodes supported by the Zigbee protocol is considerable. The only two black points of Zigbee technology remain the limited transfer speed (four times lower than that of Bluetooth) and the range lower than that of wifi.

Table 1: Comparative table of wireless protocols

Protocols	ZigBee	BlueTooth	Wifi
IEEE standard	802.15.4	802.15.1	802.11a-n
Memory	4-32 KB	250 KB +	1 Mb +
Autonomy	Years	Days	Hours
Nodes	65000+	7	32
Speed	20 -250 Kb/s	1 Mb/s	11-320 Mb/s
Range	100 m	10-100 m	300 m
Applications	Sensors	Wireless USB	Internet

3. THE AUTONOMY OF COMMUNICATING OBJECTS

3.1 Communicating sensors

Autonomous sensors are compact, miniaturized and multifunctional intelligent devices integrating micro-sensors connected to a processing unit. They are able to transform data and communicate with other microsystems or a remote control station, via a wireless transmitter. The operation of these nodes is ensured by an on-board energy source.

The applications of sensor networks exhibit very different characteristics from each other but are generally accessible on the energy constraint aspect [4]. Abandoning this observation, many researches have been initiated, presenting, for example, communication protocols adapted to the applications of micro-sensor networks, which would allow a better use of the energy available within the network.

This evaluation remains complex due to the heterogeneity of a node, combining mechanical, electronic and computer elements (fig 1).

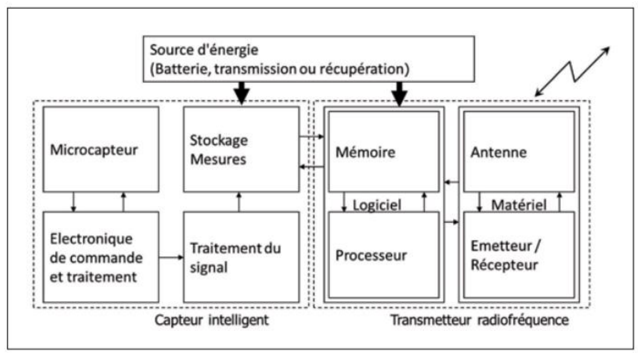

Figure 1: Architecture of an autonomous sensor

It could be an objective to propose a new simple energy model of a node. This model could allow us to consider the impact of the specifications of the application on the consumption and the impact of the energy cost due to the implementation of a particular operating strategy such as a communication protocol specific to the networks of micro sensors. [5].

3.2 Energy consumption

One of the most interesting criteria in the design of a sensor network node is its autonomy [2]. Indeed, due to the density of the network but also to the environment in which the sensor is placed, the switching of its battery is generally complex. It is therefore important to maximize the life of a node and therefore of its battery.

To guarantee a certain autonomy, it is necessary to sequence the activity of the node so as to replace operating modes with standby modes.

We will then speak of the duty cycle of the node's operation. We can split the operation of a node into several phases (fig 2). The awakening of each of the elements of the node is managed independently. The microcontroller will have the task of controlling the awakening of the different blocks. It will thus govern the different operating phases of the node.

The energy consumed during the different phases can be written as a first approximation: : $\mathbf{E_{cons}=P_{on}*T_{on}}$ [2] Where P_{on} represents the power consumed during the phase considered and ton represents the duration of this phase.

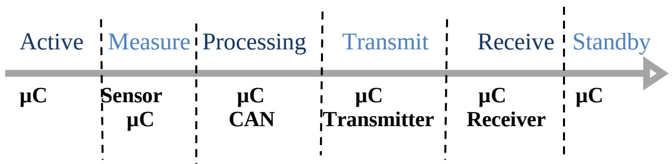

Figure 2: Different operating phases of the autonomous sensor

4. THE INTERNET OF THINGS

The Internet of Things [1] [3] (IoT) extends the domain of cyberspace to everyday objects: objects, places, trees or animals. In this, the next step will go through the Internet of humans (with physical addressing and no longer the interface offered by the terminal), which will allow the Internet to swallow up the entire planet.

4.1 Why the Internet of Things

Continuous progress in microelectronics technologies and sensor networks [8] now makes it possible to envisage the deployment of secure and optimized services distributed over networks of interconnected intelligent communicating objects: this is the vision of the Internet of Things. . The interconnection of objects with advanced processing capabilities will lead to a revolution in terms of service creation and availability and will greatly change the way we act on our environment. In short, the physical world is gradually merging with the virtual world.

This vision encompassing simple connected objects, such as sensor networks, up to sets of more complex and intelligent communicating objects, as envisaged by the Internet of Things. Do this challenge by involves putting an interdisciplinary approach to new technologies, concepts and models (integrated circuit development, energy management, communication systems and principles, embedded systems and packaging, data acquisition and processing, field experimentation) and involves meeting many scientific, technical and commercial challenges .

Scientific and technical challenges require different skills concerning: [5]

- **The integration of interconnected autonomous smart objects** (sensors, actuators, processors, etc.) with strong constraints in terms of energy consumption, durability and environment of use (physical and chemical environment);
- **The gigantic size** (billions of objects can be interconnected) of secure, dynamic and flexible communicating networks and the concept of the ubiquity of service delivery;
- **Fusion of sensor data**, network and service management, distributed data processing and ambient intelligence.

4.2 IoT network

The IoT network is used to provide an object with connectivity to the Internet to allow the feedback of information. Different communication protocols are available in the market to do this. Not all have the same characteristics. For companies embarking on the IoT, choosing the most suitable communication network for their uses can thus become a Chinese headache. They must take into account the coverage of the network, the lifespan of the objects on battery, the distance of communication or the cost of service.

Two main categories of networks exist on the market:

- **Long-range networks**: we distinguish low-power networks called LWPAN such as Sigfox, LoRa, cellular technologies (GSM, 2G, 3G, 4G, 5G). Both of these types of long-range networks are capable of moving data from one device to another over vast distances. They are used by companies that want to connect kilometers of infrastructure to the internet or in smart city projects.
- **Short-range network**s such as Wifi, Z-Wave, ZigBee, or Bluetooth low Energy, allow data to be transferred over short distances. They are used in home automation or in the consumer wearable market.

Before looking in detail at the technical features of each network, it is therefore necessary to determine whether or not its connected objects will be located far from the portal for receiving their data.

4.3 Future work

The initiative will support on the technological and architectural aspects of the apparent innovative systems which are key enablers of the “Real World Internet”. The work will be structured according to several application scenarios provided by the manufacturers which will make it possible to define the specifications and the scenarios for use and demonstration. The work will be carried out in specific projects of different natures: national projects, projects between Carnot institutes and Fraunhofer institutes, European projects (FP7, ITEA, etc.) [1], with an effort to integrate into large platforms applications around the following topics:

- Ubiquitous services and mobility;
- Industrial processes and logistics;
- Wholesale and retail trade;
- Transport and aeronautics;
- Smart buildings and homes;
- Personal, medical and recreational services.

The interface between the real and digital worlds requires the ability for the digital world to perceive the real world and act accordingly. The initiative will contribute to the design of smart objects that can be used at the network level. It correspond to a new generation of sensors and actuators making. It possible to meet the multiple requirements imposed by the great diversity of devices in which they will be integrated such as reduced capacities in terms of computing power, memory, size, exploitation and energy storage and finally specific integration in the environment taking into account the constraints specific to the targeted applications. A research effort [1] will also focus on the architectures of the devices which will integrate these functionalities and which, for example, will carry out on-board signal processing, distributed information processing and will offer possibilities for data aggregation

The table in the following page lists some representative applications of these themes and gives the main characteristics and challenges of the corresponding interconnected objects.

4.4 Objects connected to the IoT

The challenges around the intelligence needed to be integrated into these systems will be described and studied together with the analysis of the ability to communicate of the components that must interact. A particular effort will be focused on the exploration of network architectures (ad hoc, WSANs, swarms of robots, etc.) [4], as well as on the exploration of the corresponding protocols.

Self-organization and self-management are essential in this environment and the conceptual principles specific to these new networks, namely addressing, naming and identification of paradigms, adapted routing solutions, mobility solutions and location capability, are just some of the fundamental requirements of these new network paradigms.

The initiative will also build on the interworking of different heterogeneous systems, including merging with cellular networks and network and service stewardship.

Security solutions will be developed jointly with network solutions. This will result in a requirement for self-organized architectures and adaptable security.

The partners [8] will participate in the design of the model simulators that will be required, of the software, in particular the operating systems, and of the solutions for the dynamic updating of the software elements. This activity will include the design, formal verification and on-board testing of the real-time distributed systems studied. Specific Human-Machine Interfaces (HMI) will also be designed. Advanced service architectures, including software components (middleware) and specific solutions for identifying available elements and services, will also be proposed.

4.5 Architecture of Future

The Internet architecture of the future will therefore consist of a core and two rings (fig 3): the core will consist of the evolution of the current Internet infrastructure (fixed-mobile access and convergence). The first ring will consist of a new generation of terminals with networking capabilities and therefore the ability to participate in spontaneous and self-organized networks. The second ring, based not only on these intelligent, active and sensitive systems to their environment, but also on the underlying technologies [8], will allow the fusion of the real and digital worlds.

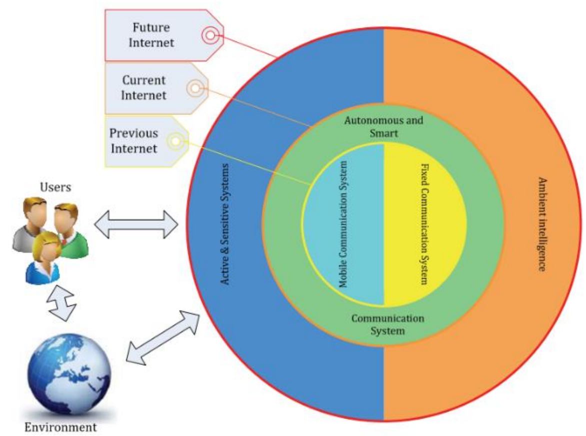

Figure 3: Future Internet

Table 2: Main characteristics of interconnected objects

Application	Energy source	Transmitter Receiver	Size	Quantity	Cost	Network characteristics	Remote interaction mode
Smart home	Sector	PLC / Debits : Tx: a few kbps Rx : a few kbps Distance : <50m	<20 cm3	>100 millions	< 1€	Auto-Configuration Service Discoveries Network Discoveries	Query Loading
Smart home	Sector or battery	PLC or Microonde Debits : Tx : a few kbps Rx : a few bps Distance < 100m	<10 cm3	>10 Milliards	<0.5 €	Auto-configuration Spontaneous network Network coding	Activation Query
Smart Cities - Clean Cities	Battery or Microwave photovoltaic	Microonde /Debits : Tx : 100 bps Rx : a few bps Distance < 1km	<10 cm3	> 10 Milliards	<0.5 €	Auto-configuration Spontaneous network Network coding	Activation Query
Smart Home / Surveillance	Sector or battery	Microonde/optique Debits : Tx : 100 kbps Rx : 1 kbps Distance < 500m	<20 cm3	> 100 millions	<10€	Spontaneous Network Centralized/Distributed Network Coding	Data Transfer Activation Command

Smart Cities - Clean Cities / Surveillance	Battery	Microonde / optique Debits: Tx : 100 kbps Rx : 1kbps Distance < 5km	<20 cm3	> 100 millions	<10€	Spontaneous Network Centralized/Distributed Network Coding	Data Transfer Activation Command

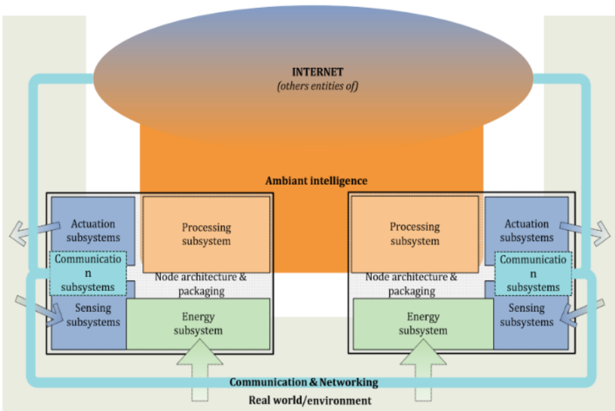

Figure 4: Description of objects connected to the Internet of Things and the three main corresponding challenges: Technologies - Communication - Intelligence.

4.6 Choose the right network

There are low-power networks that allow you to limit the use of the object and use it only when sending and receiving a message. In the industrial context, this takes on its full meaning. It is also useful for connected trackers that require little energy to transmit their position. For short-distance connections of less than 100 meters, RF transmission seems particularly suitable. For greater distances, it will be necessary to opt for the Sigfox network, already established in France, or LoRa, a similar technology. This type of transmission limits energy consumption. For example, an object connected to Sigfox will consume the equivalent of a gate remote control. LTE is following this same shift with the experimentation of low power 4G. These solutions are still less ideal for the autonomy of more complex connected objects, such as smartwatches and wearables in general.

4.7 Fast changing technologies, a significant contribution

In the meantime, the democratization of fast charging technologies is essential for all retail products. They speed up the amount of time a device is unavailable. There is no longer any need to wait half a day to launch your drone, activate your connected watch, etc. For example, the Huawei Watch and the Sony Smartwatch 3 have this technology reducing the waiting time by two. At Qualcomm, this technology is called Quickcharge. At Oppo, the VOOC [12]. If the usage time remains similar, you have to wait about 45 minutes maximum to restart it. This type of solution to improve the autonomy of connected objects is set to evolve, with the advent of wireless charging from the Qi consortium and laser charging technology for drones.

5. AUTONOMY

Faced with a very competitive market, the autonomy of the battery for your connected object is often a strong argument. Design offices have a new moral obligation towards their customers: to tell them as precisely as possible about the autonomy of their connected object. The best way to know the autonomy of your connected object is to measure it. The LTM measuring device is dedicated to this purpose, with two operating modes, firstly measurement of the energy required by your product and secondly stack emulation (accelerated mode or not)

5.1 The essential role of energy harvesting

In order to maintain a permanent link between the sensors and the network, another power supply must be found. Its role is to ensure minimal operation of the network in a hostile environment and in the context of a situation of energy starvation. Energy harvesters, also called “energy harvesting” systems, are then used to supply the battery[10]. These exploit natural phenomena, located in the immediate environment of the sensor, in order to generate a satisfactory electric current. Most often, this energy harvesting system is used to convert the illumination of a small solar panel (a few square centimeters), placed on the back of each of the sensors, into direct current through the photovoltaic effect.

In addition to natural sunshine, other phenomena can be used, such as mechanical vibrations, temperature differences or, more generally, a wide range of electromagnetic radiation. For this last type of energy harvest, specific equipment has been designed for each frequency band considered. A sensor adapted to the type of measurement performed (temperature, pressure, luminosity, etc.) is connected to a microprocessor via an analog/digital converter (ADC) [11].

This processor can, for example, calculate the average value of the measurements carried out over a given time range and send only this towards the sink node. A low-speed modem and an antenna allow each sensor to communicate with its immediate neighbors. In the case of sensor networks in the most isolated hostile environment, the distance separating the sink node from the nearest Internet access node can be several hundred kilometers or more. The measured data is then transferred by the sink node via a low orbit satellite. As an indication, a signal sent from the ground takes 13ms to reach a scrolling satellite of the Iridium constellation, with a power of 7W in transmission and 0.6W in reception. This operation requires solar panels of around one*m2, which deploy automatically when the sink node is removed.

5.2 Consumption and increase autonomy

Increasing autonomy and reducing consumption are a daily challenge for engineers who develop IoT or wearable products. The MAX14720 PMIC is ideal for non-rechargeable battery (button battery or alkaline [12] applications where space and energy efficiency are critical. Additionally, an electronic "seal" extends the battery's storage life by disconnecting it before initial power-up. Integrating the functionality of five discrete devices: power switch, linear regulator, buck regulator, buck-boost regulator, and monitor, the MAX14720 simplifies the bill of materials (BOM) and enables much smaller products.

In 2020, 190 million wearable electronic fitness and health devices will be sold, generating $14.4 billion in revenue1," according to Gartner. Designing systems for wearables is kept fairly simple, using basic Micro Controller Unit (MCU) processing, BT and Wi-Fi communications, and acceleration sensor chips and to gyroscope, combined with display drivers, opto-electronics, USB charging interfaces, small NOR memory and power regulators, which play a major role in many wearable projects2. Therefore, the main advantages are:

- **Reduced consumption**: While most PMICs must be supplied with 3V, the MAX14720 operates from a primary cell delivering 1.8V.
- **Extended autonomy**: The quiescent current management IP is essential for wearable applications, insofar as it allows the duration of use of the system to be extended significantly.
- **Extended Storage Life**: An electronic seal keeps the battery disconnected and extends storage life by providing a completely sealed battery compartment.
- **Flexible Operation and System Diagnostics**: Multiple value-added features such as push button supervision, power-up sequencing, or power rail supervision further reduce BOM costs and footprint.

5.3 Renewable energies: infinite autonomy of connected objects

Connected objects can very well be equipped with photovoltaic sensors. Solar energy is now well under control. In industry, open air installations can easily benefit from this technology. For users, we can think of the Helios music headset which has a solar panel on its headband. 1 hour in the sun equals 30 minutes of listening. Ideally, this gives it unlimited autonomy, when the user's living space is sunny enough. Other renewable technologies can achieve results without the need for the star of the day. By using piezoelectric energy, electricity created by pressure and friction, a device can be charged by using it normally. Stored electricity comes from moving, pressing a touch screen, for example.

Adapted to a watch, this solution seems ideal. Nokia has already patented such a battery. Samsung and LG have thus invented flexible batteries that react to the movement of the user. Unfortunately, these techniques for optimizing the autonomy of connected objects are still under development. They are at the miniaturization stage.

5.4 How IoT sensors can gain autonomy through energy harvesting

The concept of energy harvesting has been around for more than a decade. However, implementing systems powered by ambient power alone in the real world has proven to be tricky, complex, and expensive. Nevertheless, transport infrastructure, wireless medical devices, tire pressure detection, or building automation are all examples where the energy harvesting approach has been used successfully. More specifically, in the case of building automation systems, certain elements such as occupancy sensors, thermostats and even light switches today do without the power and control wiring usually associated with their installation, and now rely on a local energy harvesting mechanism.

A good example is how predictive maintenance will use sensors (IoT) and other hardware devices to monitor the condition of a commercial building and all the equipment it houses. This feedback will allow any necessary maintenance to be planned in a timely and efficient manner. Unforeseen events that typically occur as part of a preventive maintenance program can be overcome by using a predictive maintenance approach.

The IoT will allow commercial owners to have buildings with optimized energy consumption. This will influence the design of buildings and make it possible to better respect the environment and use resources more efficiently. What's more, these smart building management systems can be managed remotely from anywhere, replacing heavy and obsolete construction equipment with sensors that trigger on vibrations or temperature changes, example. It is clear that this saves a lot of energy and capital, while reducing maintenance costs.

One of the biggest impacts IoT can have on buildings is energy efficiency. Sensor networks provide information that enables managers to better manage their assets, while reducing environmentally harmful waste. Here are some examples :

- Use of sensors for temperature regulation
- Use of actuators for heating, ventilation and air conditioning (HVAC) system controls
- Certain complex applications such as the complete energy automation of a building
- Consideration of weather forecasts to save energy costs in real time

5.5 Wireless sensor nodes: key application for energy harvesting

A wireless network using an energy harvesting technique makes it possible to link an unlimited number of sensors within a building, in order to reduce the costs of air conditioning and electricity, by adjusting the temperature or turning off the lights in certain non-essential areas, when the building or certain rooms are unoccupied. Furthermore, the cost of energy harvesting electronics is often lower than that of power cables, or the periodic maintenance required to replace batteries, so there is clearly an economic advantage to using an energy harvesting technique.

However, many of the advantages of a wireless sensor network disappear if each node requires its own external power supply. Even if current developments in energy management allow electronic circuits to operate longer from a given energy reserve, there are limits to this, and energy harvesting is a complementary avenue. Thus, energy harvesting is a way to power wireless sensor nodes by converting local ambient energy into usable electrical energy.

Sources of ambient energy are light, temperature differences, mechanical vibrations, transmitted RF signals, or any source capable of producing an electrical charge through a transducer. These energy sources are all around us and they can be converted into electrical energy by using an appropriate transducer, such as a thermoelectric generator (TEG) for temperature differential, a piezoelectric element for vibrations, a photovoltaic cell for light daylight (or interior lighting), and even galvanic energy for moisture. These "free" energy sources can be used to autonomously power electronic components and systems.

Since all wireless sensor nodes are now able to operate with an average power of the order of microwatts, they can be powered from unconventional sources. This has led to energy harvesting, which provides the power to recharge, top up or replace batteries in systems where their use is impractical or impossible, costly or dangerous. Energy harvesting also allows the elimination of cables to transport energy and transmit data. A typical energy harvesting or Wireless Sensor Node (WSN) configuration consists of four blocks. They are:

- Sources of ambient energy
- A transducer element and an energy conversion circuit to power the downstream electronics
- A detection component that connects the node to the physical world, and a computer consisting of a microprocessor or a microcontroller that processes the measurements and saves them in memory
- A short-range radio communication component providing wireless communication with neighboring nodes and the outside world.

6. CONCLUSION AND FUTURE WORK

Communicating objects via the Internet will mark the major challenge of today and tomorrow. This evolution of computing will modify the economy as a whole, but also the relationship between people and objects. In this paper we presented the autonomy of communicating objects, their concept, their limits and their technique.

In a second part we talked about the Internet of Things and the main works of the future. The heterogeneity of the Internet of Things is pushed to its climax, whether from the point of view of information or services. The issues of energy consumption, security for the user and the risks that weigh on his private life, oblige researchers to carry out work on the management of privacy, trust and energy reputation.

We also explained how and for which applications, wireless sensors and other connected objects (IoT) can take advantage of energy harvesting devices in order to gain autonomy.

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