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Internet of Things and Heterogeneous Networks Technologies: Concepts, Challenges and Perspectives

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ABSTRACT

The IoT network is used to provide an object with connectivity to the Internet to allow the feedback of information. The IoT has the ambition to make objects interact with each other and with people. It promises to be the engine of great transformations in the lives of individuals by democratizing new uses and services in the mobility sector. This is why it is compared to the internet of the future. The global size of the IoT, the huge number of Things in the IoT, the changing topology of the IoT, and the resource constraints make routing in the IoT difficult. Routing is a necessary process in the Internet of Things because it enables the interchange of data between Things by quickly guiding and reliably delivering data through the network from its origins to its destinations. The Internet of Things is enabled by key pillars: radio frequency identification (RFID) and wireless sensor networks (WSNs) (IoT), NFC (Near Field Communication), BLE (Bluetooth Low-Energy technology), LoRa and Sigfox. This paper examines these different technologies as well as the barriers and challenges that must be solved.

1. INTRODUCTION

The Internet in general and the web in particular have been constantly evolving: from the web ofinformation to the web of individualized objects2, passing through various connected objects thanks to miniaturization and technological development, which allows a dual aspect: to be connected and to communicate continuously without space and time constraints in order to meet the requirements and needs of the user at the level of services, communication and information. The Internet is gradually transforming into a HyperNetwork, as a network formed by multitudes of connectionsbetween Artifacts (physical, documentary), actors (biological, algorithmic), writings and concepts (linked data, metadata, ontologies, folksonomy), called. "Internet of Things (IoT)", connecting billions of human beings but also billions of objects [1, 2]. It becomes the most powerful tool ever invented by man to create, modify and share information. This transformation shows the evolution of the Internet from a network ofcomputers to a network of personal computers to a nomadic network incorporating communication technologies. Recently, the demands of the Internet of Things (IoT) have been steadily growing. The main idea of the Internet of Things (IoT) is to revolutionize the current Internet by enriching it with a large number of intelligent objects that communicate with each other. Heterogeneous communication technologies are integrated into the Internet to achieve the IoT application. The function of these objects is to collect data fromsensors, process it, and communicate it. Therefore, sensors are main features of IoT. The Heterogeneous Wireless sensor network (HWSN) isa key technology element of the Internet of Things (IoT) (Figure 1), which is considered as the future evolution of the Internet The integration of HWSNs into IoT makes communication with any type of object possible and opens the gates to a multitude of application areas.

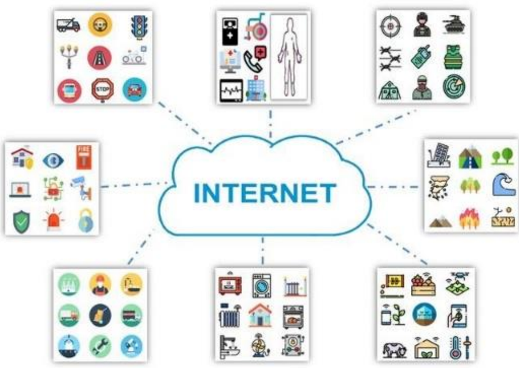

Figure 1. The IoT applications

2. THE FUNCTIONING OF THE IoT

The Internet of Things works mainly with sensors and connected objects placed in / on physical infrastructures [3]. These sensors will then emit data that will be sent to IoT platforms via a wireless network. The data can then be analyzed and enriched to get the most out of it [4]. These data management and data visualization platforms are the new IoT solutions allowing territories, companies or even users to analyze data and draw conclusions to adapt practices and behaviors. As you can see, IoT is closely linked to connected objects because they have the ability to capture data and send it via the Internet or other technologies. Connected objects interact with their environment through sensors: temperature, speed, humidity, vibration. In the Internet of Things, an object can be a vehicle, an industrial machine or a parking space.

3. RELATED WORK

CoLaNet [5] is the first proposal in the MACapproaches, without content, cross-layer based on TDMA using routing protocol information. Its operation is as follows: Each node transmits information about its neighborhood to the BS. After receiving all local information from each node. CoLaNet builds a MinDegree routing tree by choosing the BS as the root of the tree, and then each node chooses as its parent, the neighbor closer to the BS than itself, which has the least number of children in the tree. The BS takes care of the assignment of slots to the different nodes by applying the coloring algorithm proposed by Chou and Chuang [5] on the MinDegree tree. It starts by coloring the node that has the most neighbors in the routing tree. Then, the coloring is applied to the nodes that have an already colored neighbor. This algorithm tries to keep using the colors already assigned, if not, a newcolor is added. At the end of the coloring, the number of colors obtained represents the number ofTDMA slots and each color represents a transmission slot of the node to which the color is assigned. The authors [6] proposed a distributed algorithm in heterogeneous networks called Weight Based Clustering for Heterogeneous sensor Networks in which the clusteringis based on three factors: residual energy, number of live neighbors and distance to BS. The proposed protocol enhances the stability period of the network by electing sensor nodes with the highest residual energy as CH. A major advantage of this algorithm is the fact that the probability of low-energy sensor nodes elected as CH is decreased. This improves the stability and the lifetime of the sensor network. On the other side, the inconvenient of the algorithm [6] is that a higher number of sensor nodes can be elected as CH. Therefore, the CHs send the data directly to the base station (does not indicate any communication protocol between CH and BS). This election method can cause high energy consumption for these CHs. A seaport terminal scenario is used to present a convergence network platform incorporating WSN sensor theory [7]. The results of the simulation of the proposed network confirms the suitability of WSN to be used in the transmission of data traffic associated to meter readings which is required for effective energy consumption and management policies in industrial environments comprising equipment with high energy demands. The authors [8] have proposed a new (Distributed Energy efficient Adaptive Clustering Protocol): hierarchical approach for sensor networks with energy consumption. This approach is designed to reachthe following objectives: Reduce the overall energy consumption by balancing the energy dissipation between nodes. This has the direct consequence of extending the life of the network. The load balancing of the clusters must be well done by using of two contributions: The temporary cluster-head and the final cluster-head. A major advantage of this approach is ensuring a better distribution of leaders and is providing a quality of service that adequately reflects network reliability and latency. The protocol has some disadvantages: if the cluster head fails, the process of choosing a final cluster-head stops, also it generates several control messages. With all cases, conditions, and problems to be rectified, certain safety surveillance system examinations have been undertaken. This may be observed in the system design research [9], which examines and defines responsibilities in the campussecurity planning process, as well as users' security needs and awareness of campus public areas. Inaddition, research was conducted in the context of the IoT platform, which was built as modules for the integration of temperature sensors, humidity sensors, and CO_2 sensors [3]. The design and implementation of tools using a mix of RFID tag- chip technology, GSM communication technology, keyboard input, and an LCD screen will be the focus of future study [10]. To the designated handset, the GSM module sends a confirmation message. For campus security, the module isutilized. Other research projects create and implement an intelligent Campus Security Tracking(iCST) system that uses RFID and ZigBee networks. Through FRID and ZigBee nodes, iCST takes data from RFID tags and sends it to PC nodes via ZigBee. The optimal topology for communication between sensors utilizing LoRa, especially in high-building contexts, such as the campus environment, is being assessed as part of the research into the usage of LoRA technology [11].

4. CONNECTED OBJECT (CO)

Before defining the concepts of IoT, it is important to define the connected object which is a device whose primary purpose is not to be a computersystem or an interface to the web, for example, an object such as a coffee machine or a lock was designed without integration of computer systems or Internet connection [12]. The integration of an Internet connection to a CO allows it to be enriched in terms of functionality, interaction with its environment, it becomes an Enriched CO (COE), for example, the integration of an Internet connection to the coffee machine making it remotely accessible. An CO can interact with the physical world independently without human intervention. It has several constraints such as memory, bandwidth or power consumption, etc. It must be adopted to a use, it has some form of intelligence, ability to receive, transmit data with software through embedded sensors [13]. A connected object has value when it is connected to other objects and software bricks, for example: a connected watch is only of interest within a health/wellness-oriented ecosystem, which goes far beyond knowing the time. An CO with three key elements: The data produced or received, stored or transmitted, the algorithms to process this data, the ecosystem in which it will react and integrate. The usage properties of a CO: Ergonomics(usability, handiness) [14]. Meta-Morphism (adaptability, personalization, modulation).

5. INTERNET OF THINGS (IoT) WIRELESS DRIVING TECHNOLOGIES

5.1 RFID (Radio Frequency Identification)

The abbreviation RFID means "Radio Frequency IDentification", it is a technology which allows to identify an object, to follow its path or to know its characteristics at a distance reflecting radio waves, attached or incorporated to the object. The RFID technology allows the reading of tags even withouta direct line of sight and can penetrate thin layers of material (paint, snow, etc...). Although the first paper on modulated retroreflection (the basic principle of the passive RFID tag) was published in 1948, this technology has known many developments before it many developments beforeit reached the current level of maturity and performance [15]. Today, RFID technology has many applications in many fields isbased on several standards and regulations acceptedand used at the international level (ISO, class 0, class 1 and Gen 2 are examples) (See Table 1).

RFID (Radio Frequency IDentification) technology is one of the automatic identification technologies, just like optical character recognition or barcoderecognition. The aim of these technologies is to allow the identification of objects or individuals by machines [15]. The RFID technology has the particularity to work remotely, on the following principle: a reader emits a radio signal and receives in return the answers of the labels - or tags- that are within its range. There is an almost infinite variety of RFID systems; different types of memory, different frequencies, different ranges, different power supplies, etc. RFID technology has been used for a long time and on a large scale, especially in logistics, theft protection and animal identification.

Table 1. The fields of RFID sensing application

Health	Agriculture
Continuous patient monitoring inter-departmental communications patient's mobility Efficient emergency dispatching.	Sensor innovations smart irrigation, smart tractors. Monitoring key parameters.
Industry	
Smart maintenance, environment-aware objects, real-time monitoring, real-time monitoring of the platforms	

a) The RFID sensor tag

The sensor enabled RFID tag is an RFID tag that contains a sensor to monitor a certain physical parameter (e.g. temperature) but also contains the same identification function as a "normal" RFID tag. This kind of sensor tag can be class 2, class 3 or class 4 in the EPCglobal tag classification [15]. As fully passive, a class 2 tag can measure physical parameters only once powered up by theinterrogator. Since Class 3 tags have a battery, the sensors can work independently. Therefore, they can contain logging devices to maintain measurement results over time or they can record predefined events. The advantage of class 4 is the increased reading reliability.

b) RFID sensors

Sensors are "devices that transform physical quantities such as pressure or acceleration into output signals (usually electrical) to serve as inputs to control the system" [16]. The rapid development of RFID technology presents a fresh opportunity to evolve the application of sensors. RFID tags that carry sensors that can be used in areas such as project tracking, environmental monitoring, motor vehicle electronics, telemedicine and process control, etc., are multiplying as a result. The primary sensors in use today can be classified according to their functions as: Temperature sensors, pressure, acceleration, inclination, humidity, light, Gas sensors, Chemical sensors.

c) RFID and WSN integration

WSNs are utilized for sensing the environment and placing objects or persons, whereas RFID networks are focused on detecting the presence of taggedthings. On the one hand, RFID has various capabilities that can help a WSN overcome some ofits shortcomings, such as the ability to identify and track things and the ability to harvest energy from radio frequency signals. The integration of RFID with WSN allows RFID technology to extendits read range and become part of a highly interconnected network using a more widely used protocol, such as IP [16]. This protocol is difficult to implement in extremely simple nodes like RFID tags; as a result, the combination of RFID and WSN makes it easier for tags to connect to the internet by giving them the ability to integrate their IDs intothe IP protocol. This is accomplished by adding a routing capability to the RFID reader, allowing it to send and receive data from other readers and increasing the reading distance from a few meters to 100–200 meters [17]. A coordinator microcontroller, an RFID reader, and an RF transceiver make up an integrated WSN node. This microcontroller is in charge of the reader and the rest of the node's components. A microcontroller, a sensor, and an RF front-end to connect with other nodes or tags make up an integrated RFID tag with WSN capabilities. These tags broadcast not onlytheir ID, but also data from the sensor they arelinked to. In the realm of neuro-engineering, RFID sensing is becoming more popular (see Figure 2). Because of the immense promise that RFID's wireless power and data transfer capabilities bring to this industry, implantable biomedical devices are undoubtedly one of the hottest application areas for RFID. As a result, the RFID physical layer is appropriate for applications like neural recording, in which implanted sensors do notrequire any energy source other than an external RFfield [18]. Table 1 provides an overview of the primary areas of RFID sensing application.

5.2 NFC (Near Field Communication)

NFC (Near Field Communication) [19] is a technology that enables simple and secure bidirectional interactions between two electronic devices (smartphones in particular, allowing consumers to in particular), to allow consumers to make contactless payment transactions, access digital content and connect to electronic devices. Standard: ISO/IEC18000-3, Frequency: 13.56MHz (ISM), Range: 10 cm, Transmission speed: 100-420 Kbit/s. Depending on the measurement environment, the transmission medium of the sensor network must be chosen with care. For example, communications can be based on infrared, radio or optical transmissions. The transmission channel will be different according to this choice. Similarly, if sensors are mobile, their retransmission can be done for example by near field communication (NFC) when they pass near a when they pass near a fixed NFC receiver. Naturally, the development of protocols such as ZigBee or 6LoWPAN based on the IEEE 802.15.4 standard tend to transmission media to radio waves and their frequency bands.

6. FAULT TOLERANCE OF RFID SYSTEMS IN WSN

Fault tolerance is one of the critical issues in the RFID world, due to the uncertain nature of Radio Frequency (RF) communication [20] (Figure 2). RFID tags are attached to items, they can be found at any time via RFID readers and the networked database system, and they can be monitored throughout their lifecycle. RFID tags are silicon chips with IDs, radio frequency functions, some additional logic and memory. Most RFID tags come with the ability to communicate via radio frequency with external readers. The RFID infrastructure can span multiple sites, which leads to the need for remote configuration and monitoring tools. In addition, for a robust infrastructure, redundancy must be built in at each layer, with backup capabilities. A wireless sensor network is an ad hoc network with small communicating wireless nodes where each node is equipped with multiple components. In particular, each node has a computational engine, communication and storage subsystems, a battery in reserve, sensors, and in some cases components in action [21]. The micro-sensors are capable of harvesting and transmitting environmental data in an autonomous manner. The position of these nodesis not necessarily predetermined. They can be randomly dispersed in a geographical area, called "sensing field" corresponding to the terrain of interest for the sensed phenomenon. The data captured by the nodes are routed through a multi- hop routing to a node considered as a "collection point", called sink node. This sink can be connectedto the network user (via the Internet, a satellite or another system). The user can send requests to the other nodes in the network, specifying the type of data required, and harvest theenvironmental data captured through the sink node. The diagram in Figure 2 shows the great similarity in infrastructure between a complex RFID system and a sensor network, both of which are embedded systems.

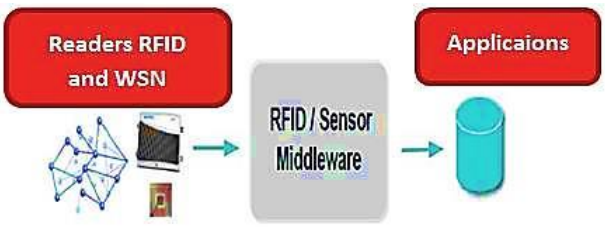

Figure 2. RFID/Sensor network infrastructure

- **Bluetooth Low-Energy (BLE) technology**

BLE is a variant of the Bluetooth standard designed to consume little energy, but with a lower distance (50m vs 100m for the classic Bluetooth) and a lower speed. BLE works only in point-to-point mode [22]. Listening or intercepting a BLE communication is more delicate, theoretically. There are many other technologies such as Nike+, which also relied on the 2.4Ghz frequency for interconnection with sports equipment such as pedometers. This solution was finally abandoned bymanufacturers. WIFI is an alternative to the protocols mentioned above, but its consumption becomes a brake in this case of use. WIFI is very energy consuming. BLE adds mesh networking capabilities to BT Smart. Highly secure and robust, it uses authentication and encryption, sends dataover three channels and coexists well with Wi-Fi, enabling plug-and-play operation without the need for a router or access point. It reduces costs and simplifies networking to make the Internet of Things (IoT) a reality.

- **ZIGBee**

ZigBee allows to circulate more data than Z-Wave (up to 250 kbps, against 100 maximum). It is also cheaper and easier to implement for manufacturers of connected objects than Z-Wave or Bluetooth (in its version 4, called Low Energy as in its version 5, which has just been standardized) [23]. But this network only has an average range of 10 meters, which is 20 meters less than Z-Wave and 50meters less than Bluetooth Low Energy.

- **Sigfox**

Sigfox is a proprietary network. In the city, it has a range of more than 10 kilometers, which can reach 30 or even 50 kilometers in the countryside. The devices consume very little energy to send theirdata on this network, even if it is difficult to compare it to other technologies, because of thelack of comparative tests carried out by an independent organization. Sigfox, which costs on average only 2 euros per year and per object, covered 91% of the French population at the end of 2015. This network was deployed in July 2020 in 71 countries [24].

In return for its low energy consumption, Sigfox can only carry very small amounts of data, between 10 and 100 bits per second maximum (bps). Monodirectional at the beginning, it now allows to send information to its connected objects, even if it is impossible to make important updates quickly.

- **LoRa**

The very low power LoRa protocol [25] is deployedby various companies, such as Orange or Bouygues Telecom via its Objenious brand. Bidirectional and low cost (from 1 euro per year and per object to 12 euros for Bouygues Telecom), it can transmit data at distances of 2 to 5 kilometers in urban areas and up to 45 kilometers in rural areas. This protocolalso has the advantage of being developed as a private network so that a company can manage it itself. Only 0.3 to 50 kilobits per second (kbps) canbe transmitted on this network, which is (like Sigfox) ideal for sensors that periodically transmit small amounts of temperature, geolocation or pressure data, for example. Internationally, Bouygues Telecom plans to weave roaming agreements. A first agreement with Switzerland was signed in January 2019, with more to come, but coverage outside the border is still limited.

7. EXAMPLE OF "E-APPLICATION" IN HETEROGENEOUS WSNS

We explain an example of "e-application" in heterogeneous WSNs, which corresponds to our proposal. The farming profession is becoming more specialized, but the areas to be managed, the constraints, the regulations and the daily tasks are increasing [26]. Measurement sensors and digital technology help farmers to reduce the drudgery and the time spent on the job. The birth of companies to meet the demand of farmers, the objective of these companies is the development of simple sensorswith interactive web interfaces.

7.1 The platform

This work needs two basic processes: software installation and hardware installation. The software installation step needs to start with the installationof an operating system for RCSFs like TinyOs under Ubuntu 10.10 for example, then a web application needs to be installed to create the management interface, we propose PhpMyAdmin, telosb sensors, MicaZ and NesC language. In thesecond hardware installation step, we need to use a telosb sensor as Receiver and resource-rich MicaZ sensors as Sender, each of which represents a very specific role, and soil moisture sensors as EC-5 (sensor heterogeneity). The MicaZ communicates with the base station via a wireless link and the basestation communicates with the computer via USB cable (communication heterogeneity) [27, 28]. The farmer can use Internet technology to monitor the process remotely via communication with thecomputer in order to improve the service orintervene in case of emergency.

8. CHALLENGES & PERSPECTIVE

Due to their disparate requirements, integrating wireless communications into many types of applications can be problematic. This finding has animpact on IoT applications because they connect things in various surroundings. *Scalability:* IoT solutions will entail tens of thousands of smart devices, with that number expected to skyrocket in the coming years. *Communication mechanisms and protocols*: Fixed, On-demand, Random, and Hybridassignment are the four types of MAC communication systems. *Energy usage*, including harvesting, conservation, and utilization. Nodes must be energy efficient and capable of low-power connectivity and on-node computation at areasonable cost (See Table 2) [29].

An interesting perspective is first to study the feasibility of setting up a global and common distributed hash table common to all services, firstly within the network and then in the network itself. of an RFID system and then to extend it to all the concepts of the Internet of Things. These studies go in the direction of a homogenization of the systems of the Internet of things, be it sensor networks, passive RFID, but also mobile phones or barcodes cell phones or barcodes, etc.

Table 2. RFID and WSN technologies challenges

Technology	Challenges
RFID	Energy harvesting Inflexibility Platform Cost Communication protocols Coverage/ReadRang
WSN	Latency Reliability Data rate Energy consumption Scalability Communication protocols Security and privacy
RFID-WSN	Coordination Communication protocols Energy management and accuracy of sensors

9. CONCLUSION

The Internet of Things connects billions of objects and billions of people. It can now be considered as one of the most powerful tools to create, modify and share an incalculable amount of information. Indeed, the IoT has the ambition to make objects interact with each other and with people. It promises to be the engine of great transformationsin the lives of individuals by democratizing new uses and services in the mobility sector. And yet, IoT experts estimate that only 1% of its potential is exploited today. This is why it is compared to the internet of the future. Different communication protocols are available on the market to do this. Notall of them have the same characteristics. For companies that are getting into IoT, the battery life of the objects, the communication distance or the service cost.

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