An overview of internet of things

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Article Info	ABSTRACT
	The internet of things is an emerging technology that is currently present in most processes and devices, allowing to improve the quality of life of people and facilitating the access to specific information and services. The main purpose of the present article is to offer a general overview of internet of things, based on the analysis of recently published work. The added value of this article lies in the analysis of the main recent publications and the diversity of applications of internet of things technology. As a result of the analysis of the current literature, internet of things technology stands out as a facilitator in business and industrial performance but above all in improving the quality of life. As a conclusion to this document, the internet of things is a technology that can overcome the challenges in terms of security, processing capacity and data mobility, as long as the development related to other technologies follows its expected course. *This is an open access article under the [CC BY-SA](#) license.*

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1. INTRODUCTION

The internet of things (IoT) can be considered as a service that can cover different types of demand based on the use of some of its faculties. Hence, the authors in [1] define IoT as: "a system that performs various types of functions, such as services involved in device modelling, device control, data publishing, data analysis and device detection". IoT has managed to push back other adjacent technologies, due to their promising future [2] and capacity to enable the analysis and study of different elements. According to this statement, it is noteworthy to assess some neuralgic aspects of the continuous rise of IoT, so this technology can cement itself on a medium term.

Different authors have defined IoT from their own point of view. According to [2], it can be described as "an interconnection of machines and devices through the internet, allowing the creation of data that can shed light on analytic performance and support new technologies". The work in [3] argues that "IoT is a group of interconnected static and/or mobile objects such as devices equipped with communication, sensors, and actuator modules connected through the internet". In [4] states that "IoT can be used to describe a system of physical objects having independent communication among them". In [5] defines IoT as "internet-connected embedded systems can be upgraded and adapted to changing needs on demand, useful information can be immediately collected from remote geographic areas, and fault diagnosis and system restarts can be made more efficient and cost-effective by not having to send out technicians to remote places". In [6] mentions that "IoT connects sensing devices to the Internet for the purpose of exchanging information". Meanwhile, [7] says that "the IoT is a global ecosystem of information and communication technologies aimed at connecting any type

of object (thing), at any time, and in any place, to each other and to the Internet". In [8] indicates that "the IoT comprises a large number of sensor nodes with limited processing, storage, and battery abilities".

Smart city is a concept that has been driven by different sectors of human development. In fact, the idea of a city that understands the pace of its citizens is quite refreshing for humanity. "It can contain intelligent things which can intelligently automatically and collaboratively enhance life quality, save people's lives, and act a sustainable resource ecosystem" [9]. Smart cities will become the technological nudge that made devices more efficient and useful. According to [10], "the constant miniaturization of hardware and an increase in power efficiency, have made possible the integration of intelligence into ordinary devices". This implies that some definitions may arise regarding smart environments, which in turn, may be a part of smart cities. In [11] encompasses IoT in Smart cities by stating that "in the industrial environments of the future, robots, sensors, and other industrial devices will have to communicate autonomously and in a robust and efficient manner with each other, relying on a large extent on wireless communication links, which will expand and supplement the existing wired/Ethernet connections"; [12] shares the idea of civil comfort by arguing that "the ultimate benefit of the IoT is to improve quality of life by supporting the automation and interconnection of various services; this interconnection includes public facilities in platforms such as smart cities". In [13] mentions that "IoT is in charge of the construction of a network of devices enabled for Internet to promote a smart environment". However, the definition given in this article will be: a network with great extent that connects devices that emit information, with support stations and analysis of data gathered by said devices to offer an informative product that is completely useful for its own use in human evolution in terms of monitoring and control of a certain object. It is important to keep in mind the derived use of IoT, given that a citizen-centered economic purpose is crucial for this technology to take off. The authors in [14] argue that "while IoT technologies are widely available today, its adoption needs to be justified by business purpose. The fact that IoT grows with the economy on its sight may represent a wide support for this development process and that it is necessary to involve this technology to different settings. For instance, [15] states that "the IoT could become an important aspect of urban life in the next decade".

In [16] a platform is proposed for efficiently managing healthcare data, by taking advantage of the latest techniques in data acquisition, 5G network slicing and data interoperability. In this platform, IoMT devices' data and network specifications can be acquired and segmented in different 5G network slices according to the severity and the computation requirements of different medical scenarios. Concerning the Data Interoperability mechanism, the specific IoMT device dataset was translated manually in HL7 FHIR, in order to compare the results of the developed mechanism, with the actual outcomes. This was the main reason that a small data sample was chosen for the platform's evaluation. Through that, we resulted that the developed mechanism provided results of 100% accuracy. In [17] explore the influence of weather on ridership of urban rail transit lines, taking Chengdu rail transit line 1 and line 2 as examples. Linear regression method was used to develop models for estimating the daily passenger flow of different rail transit lines under different weather conditions, with the help of IoT. The results show that for Chengdu rail transit line 1, the daily ridership rate of rail transit increases with increasing temperature. While, for Chengdu rail transit line 2, the daily ridership rate of rail transit decreases with increasing wind power. The research findings can provide effective strategies to rail transit operators to deal with the fluctuation in daily passenger flow. In [18] investigate level of sense of loneliness, identity styles and Internet problematic use among students. This descriptive survey study whose statistical population is all of the students of Technical-Engineering Faculties of Islamic Azad University in 1394-95 (2015-2016) in Tehran, using Multistage Cluster sampling method. 3 questionnaires, sense of loneliness, identity styles and internet addiction, have been selected for gathering data. Data analysis have been carried out by SPSS software and the results indicate that sense of loneliness is higher than two other variances which in turn end in internet addiction and identity disorders. In [19] using proper laboratory equipment, run-up and run-down processes were investigated under irregular waves and also granular and geotextile filters' conditions. In this study, wave run-up and run-down estimation relations in ACB Mat revetment with the open area were explored for the first time. As the obtained results showed, relative maximum wave run-up and rundown are desirable for all conditions. Using a geotextile layer under ABC Mat caused a 14% increase in relative wave run-up values compared to granular filter. Further, in the run-down process, geotextile filter caused a 40% decrease in relative wave run-down values. In [20] addresses the examination of design theory and evaluation of research methodology. It shows how participatory research methods may contribute to answering research questions and lead to the next research stage.

The present article has the purpose to describe the current state of IoT technology, offering a glimpse of its projection over the following years, as well as its challenges. Thus, it becomes a starting point for future research in the IoT area, that leads to new research approaches. The synthesis of the current state of IoT requires the recompilation and analysis of recent work from different sources of scientific knowledge, that were synthesized to shape a concept of technology merger that seems highly promising. The added value of this article lies in the analysis of the main recent publications and the diversity of applications of internet of things

technology. This study seeks to determine the impact of IoT technology on the economy and development of a country through the performance of industrial processes supported by IoT and on the quality of life of society through the inclusion of IoT in daily and domestic activities. The fact that IoT technology automates a large part of the processes and activities in the various fields of action of society, allows it to optimize the time used in these activities and redirect it towards family and recreation, improving the quality of life of people.

The application or ultimate destination is an important aspect in IoT. In addition, this document will also focus on the devices, networks, security, cloud-based features and challenges of this technology. IoT applications allow users to visualize and analyze the status of the system in action [1]. Although the platform used is crucial, it is noteworthy to mention that the application layer would be pointless without the other aspects that were previously mentioned. Furthermore, the application layer is quite more homogeneous than the processes carried out in the remaining blocks and layers that are seen as novelties in the technological sector [21].

It is expected that IoT applications increase rapidly and expand to many sectors. In addition to other applications, IoT has a promising future in daily activities, medical needs and prevention of harmful eventualities [21]. There is room for two technologies in IoT which are cognitive radio and Blockchain. Cognitive radio is a system that allows the use of primary channels of information to its users, making spectral mobility much faster and efficient. In [22], the combination of cognitive radio and IoT is forecast given that "the demands for smart devices that can manage and configure its transmission parameters based on the spectrum availability in spatio-temporal dimensions are remarkably increased. Cognitive radio (CR) is the best candidate technology". Therefore, cognitive radio and IoT may become the best allies in the evolution of future communications that will keep people connected to optimal and safe data networks. On another note, Blockchain is a technology that gained momentum with bitcoin, a virtual coin whose transportation is based on encryption blocks that modify their own information settings and disable access in case of alteration. This technology will also be an ideal ally for IoT since [23] makes a similar statement by arguing that "Blockchain and IoT, two of the top disruptive technologies, are already on their way of reshaping our future of the digital world, characterized by a drastic change in the current network architecture."

In this article, each aspect mentioned will be studied, as well as the security, a vital feature of any technology. Said aspects are known as IoT blocks and, although there are three main aspects (cloud, transportation and devices) there are intermediate layers that represent a significant part of the technology such as middleware. Figure 1 shows a simple representation of the operation of IoT, the relationship between these blocks is vertical given that each block is in charge of passing the data from element 1 to element 3 in Figure 1, through the network element 2 as shown in Figure 1. The third element, also known as the cloud, is the interim entity in charge of cleaning, storing and processing the data to deliver the results to the fourth element which is the end user (service contracting party).
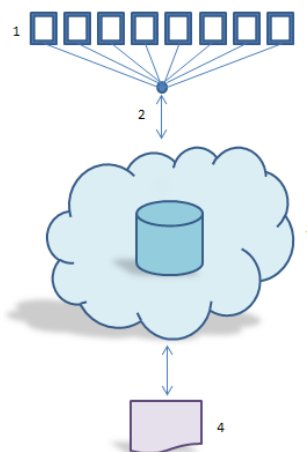

Figure 1. Simple diagram of the operation of IoT

2. INTERNET OF THINGS
2.1. Devices
An IoT device (also known as endpoint) may be understood as a gadget that captures information when it monitors a specific target. This is carried out by using sensors that allow to gather data on the variables

of interest such as location and other multimedia-related data [24]. The device simply emits information to connect itself to the internet and transmits the information headed to the cloud. Each device has its own identity within the system, known as unique identifier (UID) which can help determine the origin of any specific data, as mentioned by authors in [25] "Rapid advancements in emerging technologies and the smooth convergence of wireless communication, sensors and radio frequency identification (RFID) have resulted in the birth of the internet of things (IoT)". Hence, IoT not only caters to the comfort of citizens but to the industrial needs of the city [26].

Most of the architectures designed for IoT have been built over wireless networks since they offer an effective data transportation with low resource consumption [27]. Specific architectures have been designed for large surfaces or large-sized devices through radiofrequency. This seeks to diversify the transportation methods of IoT data. A significant challenge for device developers is to create devices that can be coupled with different branches of the internet of things [21]. Some are related to the seafloor and the prevention of meteorological disasters such as tsunamis or hurricanes based on the changes in temperature between the water and the exterior [13].

The crossing of various technologies to strengthen the advance of the internet of things is possible if the layers are established correctly and without fail. An example of using technology crossing is the project discussed in [28], which is based on two different lines of research, the prediction of energy demands in buildings and the implementation of an IoT-based big data analysis platform. This study aims to establish predictions of energy consumption adding environmental and electrical factors which are monitored to know the electric balance of air conditioning according to the weather of each day. Although devices are the cornerstone of this technology, the adjacent blocks are equally important. The network block has the purpose of carrying the information obtained by the devices to analyze it and take it to the end user.

2.2. Network

The network is the solution to the need of transporting information through large areas with little effort, and, in the modern world, the internet fulfills that important role according to [29] "Nowadays, the internet has become available everywhere and has spread significantly faster than any other technology". An article that has been written in another part of the world can be read with relative ease due to this breakthrough. Given the significant increase in demand, several techniques have been developed to carry information.

5G is a tool that may prove useful to the communication development in terms of the technology for IoT. This technology can satisfy large traffic demands in network information. "5G is on the purview where IoT will seize the stage spotlight, as IoT devices would form a notable segment of the 5G network" [30]. This is a vision for the use of these two technologies with the purpose of supplying the need of optimal, safe and swift communication [31]. Spectrum scarcity is another restriction of designing massive IoT implementations [32]. The most plausible solution for this issue is cognitive radio, a tool required for a formidable, constant and secure information system. Cognitive radio is a technology aware of its surroundings and knows which channels are available in real time to carry information.

2.3. Security

One of the most relevant components in any technology is security. The rise of any technology depends on it, given that the gathered data is important and private. The security of this technology is comparable to the security of any financial transaction. Hence, the implementation of Blockchain is an interesting idea that can assure the authentication, authorization, privacy, message integrity, content integrity and data safety. Currently, one of the potential threats of IoT devices is the safety and privacy of the gathered/transported data that is directly related to the users' lives [33].

Blockchain is a cryptography technique that consists in an information chain of blocks enclosed with a key that is only known by the final node. It contributes to the certification of the devices and information transfer. In the same train of thought, the combination of IoT and Blockchain allows to have certainty that the information incoming from any machine within a company is truthful and confirmed. This is executed by placing a physical additory to the device and the latter is set to contain the corresponding signatures of the company and the machine, making information unique. Blockchain allows to have an immutable record of transactions related to industrial assets. If any block is modified, the information is not sent to the record book since it does not match with the other blocks of the chain.

The fact that the security is stricter is in line with the increase in confidence from different companies and organizations to commercialize with IoT products. In fact, the main obstacle for IoT to become a part of countless applications is none other than the few advances in security that have been made regarding this technology. When discussing economic construction, the authors agree with [34], which states that reducing the need for third parties to guarantee the confidence of the commercial transactions is a significant value

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for entrepreneurial innovation in many areas, such as the digital supply chain, the vehicle systems, security systems and the creation of new businesses such as economic trades, commercialization of local energy, smart cities, just to name a few [34, 35].

2.4. Cloud

The cloud is another added value of this technology. It is in charge of storing the data, direct it and maintain security in the data blocks that it receives with each wave of information coming from the devices. The cloud transfers the information to the analysis centers and these are in charge of delivering the balances or conclusions corresponding to the data that comes from the devices to the cloud, to be then handled by the user. The cloud is also the most commercial component of the technology since it carries important data from different subjects of study. This allows third-party companies to see a complete overview of how the remittent characteristics of the study subjects can be useful. This can be further explained with an example: let us suppose that an embedded sensor can determine how many times, at what speed and in which places do cars put the brakes in the city of Bogotá. If the government were to have access to these data, they could know the places where most unexpected brakes happen and then take countermeasures such as the positioning of traffic lights or pedestrian bridges. However, if a mobile application company gets hold of these data then it could notify users on the areas where most people cross roads without further notice and thus prevent accidents in smart cities.

There are currently several organizations that intend to extract data from devices, that will come from the internet of things. In fact, the growing dependence of modern society on data has paved the way for big data, which can be understood as a large volume of information coming from various sources. For the information to be labelled as big data it must come from different sources and at large speeds and volumes. This requires a significant processing capability which in most cases can be solved through cloud computing or the on-premise system which refers to systems with equally large computing capabilities that manage to organize, solve and analyze the information coming from internet of things, currently gathered and used by different companies.

The Cloud Computing and On-Premise services are differentiated by the storage unit. The former keeps its data in the cloud and the latter does the same but in physical media with resources that could represent a high opportunity cost by involving spaces and money in said resources. Hence, the technologies have been migrating to cloud services where higher capabilities are available at lower prices [36]. Once the data is stored in the cloud, it can be processed and analyzed in the search for patterns through algorithms dedicated to specific search tasks or through autonomous learning which is able to find patterns that were not previously considered. The final part of this process is submitted to big data which makes the resulting data visible and understandable to keep the data for their use in economic instances. Why should the data be so understandable? Simply put, this allows the decision-makers within companies to take action based on a priori knowledge of where can a product be more successful.

3. APPLICATIONS

The authors in [37] confirm that several IoT applications focus on automating different tasks and are trying to empower the inanimate physical objects to act without any human intervention". According to this statement, Table 1 describes some of the IoT applications that meet the requirements in [37].

Table 1. IoT applications

Reference	Main feature	Advantage	Disadvantage	Bibliography
Biopatch	The Biopatch is a patch inserted in the patient that determines the oscillations in vital signs.	It allows for a swift care in case of a medical abnormalities.	Possible coverage failure.	[13]
Virus control	Controls the access to air and light in certain rooms to put them in quarantine.	Higher control over a virus in given area.	The risk that a mechanism failure may represent for the people in charge of maintenance	[38]
Packet Delivery Ratio	It monitors the temperature and humidity in a hospital.	The device is non-invasive for any agent in the hospital.	Low computing capability within certain hospitals.	[38]
Robots for monitoring crops	This group of robots armed with artificial intelligence can obtain data when they navigate through crops.	It can cover large areas of crops and generate safer information.	The recollection of data depends on the range of the sensors and the transmission	[38]
SWAT robot	This robot is sent to dangerous areas to monitor the terrains and not expose lives.	The use of these devices will save many human lives by creating plans based on data.	Military investment leads to an unbalance in other social areas.	[38]

Table 1. IoT applications (continue)

Reference	Main feature	Advantage	Disadvantage	Bibliography
Monitoring the temperature and humidity of crops	It is a series of sensors in charge of monitoring the humidity and temperature of the ground.	It leads to the technological diversification of the agricultural space.	This system has a single traffic data line. If it were to collapse, the monitoring process would be affected.	[39]
Connection of home appliances	It interconnects home appliances to monitor and control them.	Optimal use of the electric energy and appliances connected to them.	The additional cost of continuous monitoring of appliances.	[40]
Monitoring people with disabilities	This model monitors the location of people with disabilities.	It gives useful information to the entities responsible for the welfare of this social group.	Lack of privacy by exposing location at all times.	[40]
Harvest time	It is a network of sensors placed on the ground that can predict the proper times to put seeds and use insecticides.	It helps the agricultural sector to grow by optimizing watering times, the application of insecticides and harvesting.	Maintenance that can affect the entire harvesting process.	[40]
Prevention of disasters	It rapidly predicts and attends natural calamities thanks to the nodes installed in Ships, or in the seafloor.	It offers useful information for contingency plans in the case of calamities.	Monitoring bodies of water implies high computing	[40]
Monitoring of mountain areas	Medical monitoring in hard-to-reach areas	Rapid care in hard-to-reach areas	It is still hard to access some areas due to geographical constraints.	[40]
Prediction of patient demand in hospitals	It monitors the number of patients in the hospital to work around the flexibility of the medical team.	Easy adaptation to medical situations that can risk lives.	In an oversaturation situation, the system could fail.	[41]
Water purification	It is a purifier that cleans water through electric processes.	It is a response to water contamination.	The investment required for the purifier and the additional expenses.	[42]
Remote /virtual laboratories	It can take data from simulations in a virtual lab based on physical tests in remote labs.	The implementation of new skills for the scientific operators and the reduction of costs from facilities.	The migration to these labs can mean significant investment.	[43]
Medical application for patient monitoring	It monitors the signs and shifts of patients and medical staff through handles connected to the hospital control station.	It can determine the number of patients treated in a single day, their vital signs, and the instruments available at all times.	The medical overrun in costs of a budget hole in regional hospitals where this would be useful but less affordable.	[44]
Monitoring tardive mold in potato	Continuous monitoring of the status of the soil to tackle tardive mold in potatoes.	It helps prevent losses in crops.	The cost that this technique may represent for farmers.	[45]

4. CHALLENGES
The most notable challenges for IoT are security, costs and connectivity;

4.1. Security
The security of IoT must guarantee that all parts of the system are safe, which is a complex challenge for the developers. The privacy of users is at stake and the security measures must evolve at the same pace as the development of devices. The confidential data cannot become a vulnerable element and must instead be beneficial to harnessing the capabilities of IoT. Harnessing this technology and making it safer go in hand with the trust rate that is reflected in the market. If IoT corresponds to the proper behavior of data and its expected efficiency, it will close the gap of mistrust that new technologies may face when they are launched in the market.

4.1. Costs
Turning technology into an adaptable system that can face modern security issues implies that developers must implement updates which translates into maintenance costs for the system. Costs are a relevant part of any technology and would also include the costs related to installation, electric infrastructure and labor during the implementation phase. These could represent an obstacle on the way for the growth of IoT.

4.2. Connectivity
Lastly, the issues of the connectivity component must be tackled by IoT to be on par with the technological world people live in, since the connectivity component not only involves the transportation of information but also connecting to inherited assets. These devices were not designed for the mentioned

technology but can give data of vital importance for the intellectual harnessing of said devices. This seeks to build specific standards, handle time delays, high transportation speeds and low energy consumption.

5. CONCLUSIONS

In conclusion, the internet of things can be consolidated among the most essential technologies developed by mankind. IoT is a tool that is lacking in economy, mobility, health and all components of imperative need within any city that aims to provide care and comfort of its citizens. The internet of things is a new technology that comes to revolutionize the world through the connection of several devices to the Internet making a smarter and intelligent planet. As future work it is proposed to develop and strengthen the internet of things, through the integration of this technology with cognitive radio, Blockchain and big data, to carry all the information with efficiency and security and then apply deep learning techniques and obtain results from different sources.

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