# Internet of Things (IoT): technological indicators from patent analysis

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**Abstract.** The Internet of Things (IoT) is a computing concept that describes the idea of everyday physical objects being connected to the internet and being able to identify themselves to other devices. The connection of the various devices occurs over the internet for the exchange of information in the industry. Currently is one of the most important topics in the technology discussion. IoT is one of the cornerstone industry 4.0. In addition, IoT decentralize analysis and decision making, allowing responses to occur in real time. This study mapped the technological development on Internet of Things using patent indicators from documents indexed in the Derwent Innovations Index database between the years 2010 and 2017. We evaluate the patent activity, the role of countries and the main technological subdomains. Among the main results, the year 2016 stands out with 4647 patent documents. China stood out with 79.80% of patent documents linked to IoT and Approximately 50% of the patent documents analyzed are linked to the technological domain of electronic-electricity.

**Keywords:** Internet of Things, Industry 4.0, Patent analysis.

## 1 Introduction

Connecting various devices over the internet for the exchange of information in the industry is already possible through the Internet of Things (IoT). The term was first assigned to work developed by Auto-ID Labs on Massachusetts Institute of Technology – MIT on research about Radio Frequency Identification - RFID[1].

Another assignment for IoT is related to research of Gershenfeld [2], which a scenario is modelled as a set of objects able to process information.
IoT enables the intercommunication among physical and virtual process based on information exchange. Thus, IoT became a disruptive technology which can make possible the build of new product and new business models. As a result, a set of opportunities are emerging and allowing the value creation through IoT[3].
In the context of industry changes such as the introduction of automation systems, cyber-physical systems and the Internet, the industry 4.0 emerged. Industry 4.0 is a new industry revolution that succeeds three previous revolutions. In order to allow the realization of industry 4.0 is necessary to use of technological infrastructure composed of virtual and physical systems powered by information and connections from simulations, augmented reality, big data, IoT, and robots. Therefore, it is necessary a friendly environment for building and incorporating these new technologies.
The growth of devices connected to Internet increased over the last years. According to European Commission Information Society and Media there will be 50 to 100 billion of connected devices to the Internet [2]. All this, together with the ideology of smart homes, smart devices and intelligent transportation are the main core of an infrastructure that may connect our world more than we ever thought possible. In this context, the Internet of Things (IoT) emerged as an expected solution for building a world where things have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network [3].

Thus, IoT implies a very promising concept to build powerful industrial systems and user needs based applications. Furthermore, in an economic perspective, the value generated by IoT technologies are estimated in a value of 33 trillion of dollars [1]. In order to allow the IoT behave properly, IoT bundles different technologies together such as: sensors, semantic, data modelling, cloud computing, communication protocols, storing and hardware manufacturing.

The interconnection among objects and things enables many possible applications in many domains. Essentially, these application can be divides into three categories based on their focus [2]: industry, environment and society. Table 1 highlights some very promising applications under the IoT main categories.

**Table 1.** Promising applications under three IoT categories.

| Category | Applications |
|---|---|
| Industry | Transportation and logistics<br>Aviation<br>Autonomous driving |
| Environment | Agriculture and breeding<br>Environmental monitoring |
| Society | Healthcare |

IoT applications have different finished and can be adapted to a very large amount of areas such as smart industry, smart buildings, smart health and other applications to smart cities. Also, in smart industry there are systems of intelligent production discussed over industry 4.0, changing the means of acqcuire, processing and distribution of basic material and finished products. In smart buildings, we have the construction of buildings based on measurers, safety systems and apps to provide the monitoring of safety issues, electricity, water and even gas. Also, in smart mobility is possible to monitorate the vehicular route, ticketing emission and measure the user patterns to provide solutions for traffic in big cities. In smart health, it is possible to watch patients and chronical diseases follow-up. Finally, we can do real monitoring of smart cities projects such as parking space, illumination and the occupancy of streets and public areas (WORTMANN; FLUCHTER, 2015).

Future expectations about the use and apps for IoT are emerging. However, there is a set of challenges to be overcome which include technologies and operational issues, aside from strategical issues from emerging business models. Thus, it is necessary identify threats and opportunities. So, existing business models have to adapt to the new positioning of these products (WORTMANN; FLUCHTER, 2015).

It is possible to know how much a subject has been developed and also forecasts about future expectations. For that, you can monitor products on the market, scientific articles or patent documents. atents represent a valuable asset and a competitive resource at the disposal of companies. Patents allow the sole exploitation of the product, excluding third parties. In addition, patents can also be used as technological information. In this way, patents can be used as input for new research and development processes (FERREIRA; GUIMARÃES; CONTADOR, 2009). The technological monitoring through of patents related to IoT allows to dimension the technological scene on this subject. The objective of this article is to present the overview of patent documents related to the internet of things, in view of their importance for Industry 4.0, identifying the evolution and the main technological subdomains and the depositor countries.

## 2. IoT in the Industry 4.0: The future of connected industry

Factories have machines, process and devices that supplement operations. These industrial units can be connected to Internet, allowing interconnection between data and systems, so, industrial plants can be digital over industry 4.0.

As presented, the term industry 4.0 emerged to characterize a new industrial revolution that succeeded the previous three revolutions. The first industrial revolution occurred in the late eighteenth century and was characterized by the mechanization of production, favored by the emergence of the steam engine. The second industrial revolution occurred in the early twentieth century with the emergence of mass production, the division of labor, and the development of the Taylorist and Fordist Systems of production, including the use of electric power. The third industrial revolution began in the 1970s and was driven by the use of electronics, information technology, and greater automation of production processes (Kagnermann, Lukas and Wahlerster, 2011). Figure 1 summarizes the key development factors achieved in industrial revolutions over time.

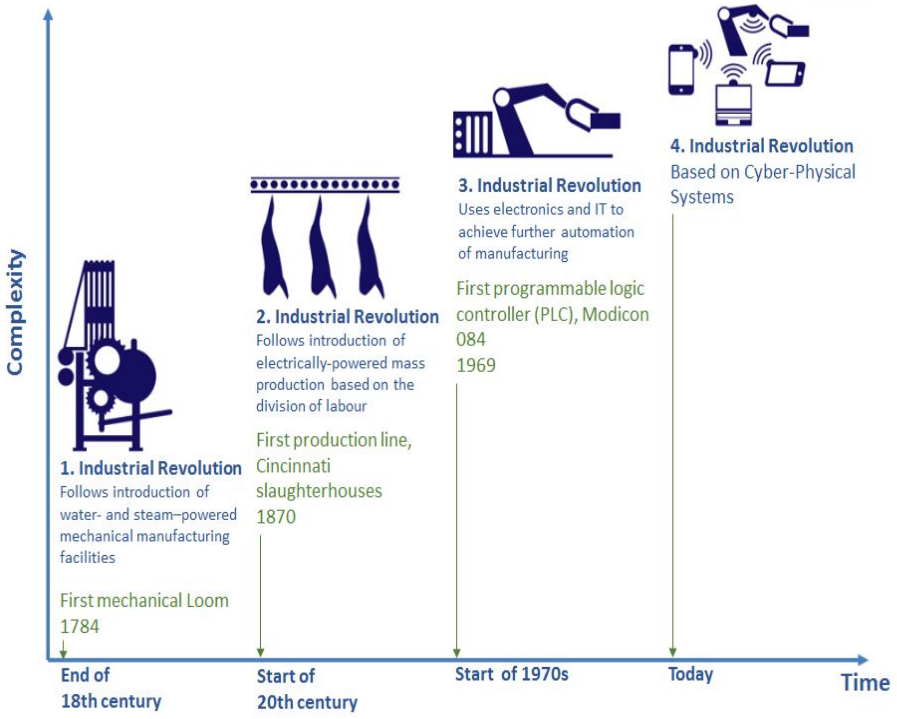



**Fig. 1.** The four stages of industrial revolutions (Kagermann et al., 2013)

Industry 4.0 is based on four main elements: Cyber-Physical Systems, Internet of Things (IoT), Internet of Services (IoS) and Smart Factory. Cyber-Physical Systems (CPS) are constituded by actuators and intelligent sensors which allows information systems do the physical control of production processes. IoT allows data sharing among devices that control production processes in real time using wireless networks. Internet of Services allows each service can be performed using machine to machine communication or supplier to factory to generate information data. Finally, on Smart Factory the cyber-physical communication using IoT helps machines and people in tasks execution (HERMANN, PENTEK, OTTO, 2015).

So IoT is one of the cornerstones of the 4.0 industry by allowing the connection between machines, vehicles and other physical objects through embedded electronic devices. IoT enables the exchange and collection of information, and also decentralizes analysis and decision making, allowing responses to occur in real time.

## 2 Sources and Methodology

A patent document contains, in a standardized form, a wealth of information about the state-of-the-art about cutting-edge technologies that is often not available in another document. Therefore, they are an important information source to disseminate science and technology information. But, as a first step, it is essential to grasp clearly the basic concepts of the patent system so as to appreciate better the practical usefulness of patent as a rich technological information source. In this sense the works elaborated by (Ardito; D'Adda; Petruzzeli, 2017; Wang, Hsieh, 2018) are highly recommended because contribute to understand the universe of research.

### 1. **Derwent Innovations Index**

In this study technological indicators were developed using patent documents data indexed in the Derwent Innovations Index (DII). Integrated to the Web of Science platform, it is a patent database that covers value-added patent records from Derwent World Patents Index with patent citation information from Patents Citation Index. It is updated weekly and contains over 16 million basic inventions, with coverage from 1963 to present. Patent information is drawn from 41 patent-issuing authorities around the world and is categorized into three categories, or sections; Chemical, Engineering, and Electrical and Electronic. This database allows for complex Boolean searches in

multiple bibliographic fields, such as the title, abstract, inventors, assignees and International Patent Classification (IPC).

### 1. Methodological procedures

Patent information is very important to the policymaker but it is necessary to collect and analyze a large number of patent documents through tools, such as, a data mining, in order to make a decision. Therefore, this study has been conducted following the next steps:

- Definition of search expression;
- Search of bibliographic records in database;
- Bibliometric analysis;
- Graphic representation; and
- Analysis and presentation of results.

The following set of bibliometric indicators was developed:

- Number of patents per year and annual growth rate from 2010 to 2017;
- Patents documents per country of origin;
- Distribution of patent documents according to technological subdomains.

## 3 Results

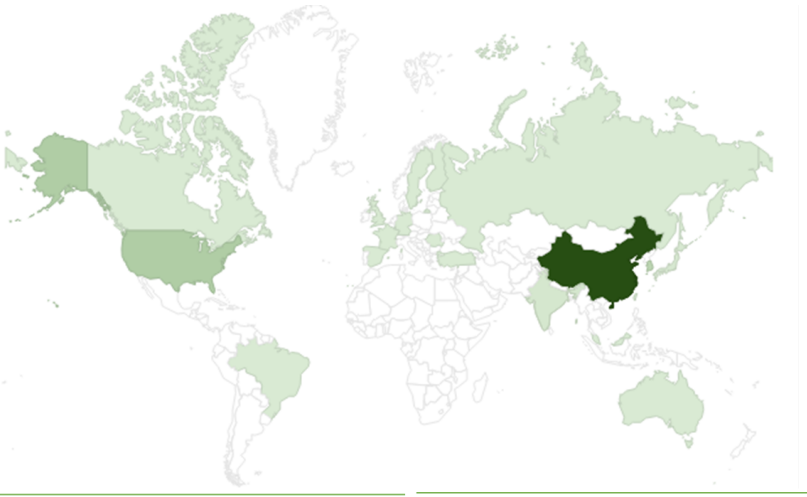
A total of 14.763 patent documents related to IoT in the period from 2005 to 2017 were identified. The term was introduced in 1999 by Kevin Ashton in the context of RFID-related supply chain management [1]. Therefore, in 2005, we have the first patent document indexed in the DII related to the subject and it approaches a method for the production of work products. From 2005 to 2009, it presents only 6 patent documents, of which four are from 2009. It was noted that only from 2009 to 2010 there was a growth rate of 2600% of patent documents.

The evolution of the number of patent documents between the years 2010 to 2017 is presented in Figure 1. The year 2016 stands out with 4647 patent documents, however, the year 2017 in future research may present a greater amount of documents, since not all patents referring to this year may have been indexed in the DII, having in view, that the data of this research were collected in early 2018 (see Fig. 2).


**Fig. 1.** Annual number and annual growth rate for patent documents about "internet of things" from Derwent Innovations index in the period between 2010 and 2017.

The databases normally depend on the availability of information from the intellectual property offices of each country and account should be taken of the confidentiality period of these documents, which may vary from country to country, and the processing time of such information for availability [ 2].

Thus, from the importance of the internet of things in the context of industry 4.0 and its promising implication for building industrial systems and application based on the user needs, it is possible to note the commitment of several actors to create favorable environments for new technologies to be created and incorporated in the coming years. Since the economic outlook for IoT technologies is estimated at $ 33 trillion [3]. Therefore, the main countries of origin of patent documents related to IoT in Figure 2 are presented.



| # | Record | Origin of country | % | # | Record | Origin of country | % |
|---|---|---|---|---|---|---|---|
| 1 | 11734 | China | 79,80 | 6 | 81 | Japan | 0,55 |
| 2 | 1486 | United States of America | 10,11 | 7 | 29 | United Kingdom | 0,20 |
| 3 | 1051 | South Korea | 7,15 | 8 | 17 | Germany | 0,12 |
| 4 | 148 | India | 1,01 | 9 | 10 | Singapore | 0,07 |
| 5 | 100 | Taiwan | 0,68 | 10 | 10 | Sweden | 0,07 |

**Fig 2.** Patent documents per country of origin .

China stands out with 79.80% of patent documents linked to IoT, this scenario may be related to the fact that the Chinese government adopts the development of IoT as a national strategy, supporting four aspects of IoT: RFID, M2M (machine to machine), merger of industrialization and informationization [4]. The promotion and growth of the Internet of Things in China is marked by competition between cities, in which each city or province is creating its own IoT-linked strategy, setting up research centers, and implementing projects. As well, in the expectation that IoT solves many social problems and brings economic growth from the implantation of companies in the different regions [5].

The United States, in turn, represents 10.11% of patent documents, which together with the European Union, despite presenting few patent documents in this study, attach great importance to IoT as a new engine of the economy [4].

Industria 4.0 is a strategic initiative of Germany, therefore the country has an important role in this context, which sought to create intelligent factories, using manufacturing technologies from cyber-physical systems (CPSs), Internet of Things (IoT) and cloud computing [6]. With regard to the IOT, Germany has 0.12% of examined patent documents.

Approximately 50% of the patent documents analyzed are linked to the technological domain of Electronic-electricity and 33% of Instrumentation. Figure 3, on the other hand, presents the main technological subdomains in the period from 2010 to 2017.

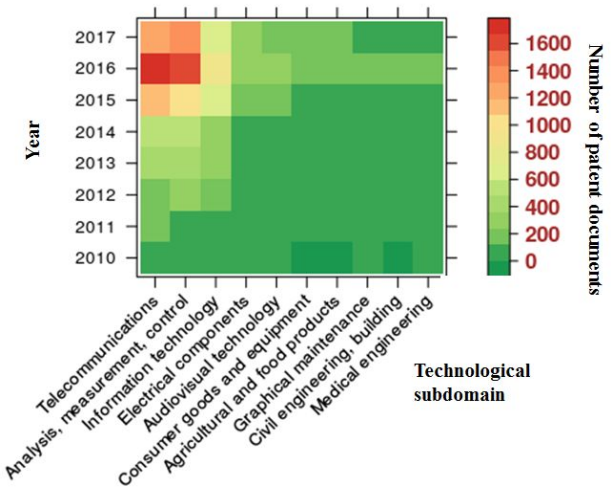



**Fig. 3.** Patent documents according to technological subdomains

The main technological subdomain is Telecommunication, with approximately 28% of patent documents. The subdomain of Analysis, measurement, control, corresponds to 27% and Information Technology subdomain, 16%.

As of 2015, there is a significant growth in Telecommunication and Analysis, measurement, control subdomains. However, with respect to the growth rate in the technological subdomains presented in Figure 3, growth in Consumer goods and equipment (8450%), followed by Analysis, measurement, control (7328% ).

IoT technology has been used in different areas, whether in smart cities, manufacturing or healthcare. Thus, the objectives and applications of IoT may be different, however, different countries work in collaboration to use IoT in projects, in order to improve the development of this technology [6].

## 4 Conclusion

Since the creation of the term Internet of Things in 1999, the term has been gaining more and more importance worldwide and has been applied in different areas such as health, transportation, smart cities and manufacturing. IoT, on the other hand, is also one of the bases for Industry 4.0.

This paper presented the overview of patent documents related to the Internet of Thin gs, in view, its importance for the Revolution 4.0. Thus, it was identified that the first patent document dates from 2005, however, the number of patents became more significant as of 2010 and in 2016 it reached 4647 documents. China stood out as the main country of origin of patents, which may be related to the strong incentive of the Chinese government to adopt IoT as a national strategy. However, research and development in the area of IoT also occurs in collaboration among countries. This would be interesting to analyze in future research.

The technological domain that has mostly developed is that of Electronic-electricity. Parallel to this, in subdomains, telecommunication was supported by further growth among all subdomains, particularly after 2015. Since than devices manufacturing and communication protocols among devices are one of the pillars in IoT, it is reasonable to realize why these are the main subject area of patents development. Furthermore, the highest growth rate in the period from 2010 to 2017 was the subdomain of Consumer good and equipment. Therefore, we can predict that consumer goods and equipment are one of the most promising sub-domains to be studied in the coming years.

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