RECENT ADVANCES IN SECURITY, PRIVACY, AND TRUST FOR INTERNET OF THINGS (IoT) AND CYBER-PHYSICAL SYSTEMS (CPS)

Edited by
Kuan-Ching Li
Brij B. Gupta
Dharma P. Agrawal

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Dedicated to my family and friends for their constant support during the course on the preparation of this book.

— Kuan-Ching Li
— Brij B. Gupta
— Dharma P. Agrawal

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Preface

The Internet of Things (IoT) and Cyber-Physical Systems (CPS) provide mechanisms that are monitored and controlled by computing algorithms that are tightly coupled among users and the Internet. That is, the hardware and the software entities are intertwined, and they typically function on different time- and location-based scales. Security, privacy, and trust in IoT and CPS are different from conventional security. Different security concerns revolve around the collection, aggregation, or transmission of data over the network. Analysis of cyber-attack vectors and the provision of appropriate mitigation techniques are important research areas for these systems. Adoption of best practices and maintaining a balance between ease of use and security are again crucial for the effective performance of these systems.

This book will discuss present techniques and methodologies, as well as a wide range of examples and illustrations, to effectively show the principles, algorithms, challenges, and applications of security, privacy, and trust for IoT and CPS. It will be full of valuable insights into security, privacy, and trust in IoT and CPS and will cover most of the essential security aspects and current trends that are missed in other books. The material will prepare readers for exercising better protection/defense in terms of understanding the motivation of attackers and how to deal with it, as well to mitigate the situation in a better manner. The proposed book will guide readers to follow their paths of learning yet structured in distinctive modules that permit flexible reading. It will be a well-informed, revised, and comprehensible educational and informational book that addresses not only professionals but also students or any public interested in security, privacy, and trust of IoT and CPS. Specifically, this book contains discussions on the following topics:

- An Overview of the Integration between Cloud Computing and Internet of Things (IoT) Technologies
- Cyber-Physical Systems in Healthcare: Review of Architecture, Security Issues, Intrusion Detection, and Defenses
- The Future of Privacy and Trust on the Internet of Things (IoT) for Healthcare: Concepts, Challenges, and Security Threat Mitigations
- Toward the Detection and Mitigation of Ransomware Attacks in Medical Cyber-Physical Systems (MCPSs)

- Security Challenges and Requirements for Industrial IoT Systems
- Network Intrusion Detection with XGBoost
- Anomaly Detection on Encrypted and High-Performance Data Networks by Means of Machine Learning Techniques
- Deep Learning for Network Intrusion Detection: An Empirical Assessment
- SPATIO: end-uSer Protection Against ioT IntrusiOns
- Low Power Physical Layer Security Solutions for IoT Devices
- Some Research Issues of Harmful and Violent Content Filtering for Social Networks in the Context of Large-Scale and Streaming Data with Apache Spark

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An Overview of the Integration between Cloud Computing and Internet of Things (IoT) Technologies

Reinaldo Padilha França, Ana Carolina Borges Monteiro, Rangel Arthur and Yuzo Iano

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1.1 INTRODUCTION

The high level of connectivity between the most varied devices in society has caused an explosion in data volume. The ability to analyze and manage this large flow of information currently generated has allowed companies to make more assertive decisions and improve their relationship with their customers. Coupled with the massive increase in the number of devices and the amount of data transmitted requires changes in the architecture and implementation of technologies, making data management and balancing the biggest challenge for companies. In order to control these demands of infrastructure and data traffic and storage, corporations have been betting on the cloud, which will, therefore, have more and more direct influence on the increase of quality and safety level (Hashem et al. 2015).

When it comes to cloud computing, it refers to the sharing of information, data, images, and services over the Internet anytime and anywhere, where cloud storage and data processing services are provided over the cloud. Cloud technology has gained importance in every possible scenario. Whereas in the past, almost every investment focused on infrastructure to be able to store virtual documents and execute different software options, today information technology has a more strategic role. In addition, cloud computing allows storage terms and bandwidth to be tailored to seasonal business needs, where planning becomes more flexible and easier to execute (Rittinghouse and Ransome 2017).

Thus, Cloud computing is the way to use programs and documents that, instead of being located on a physical computer, are in the cloud, that is, on an external server, accessed over the Internet. One reason for its rapid expansion was the ability of this technology to lower infrastructure costs. Since unlike maintaining a physical server, where the user pays for the entire space, even if it is empty, in cloud computing the user pays only for what is used. The more space he needs, the more he would pay, bringing simplicity, having a greater economic character for the company or certain application projects (Rittinghouse and Ransome 2017).

The concept of the Internet of Things (IoT) refers to common electronic devices in our daily lives. Its highlight is the way it connects and interacts with other smart electronics using the Internet, being a technological revolution that has been a big bet on big companies. It seeks to connect electronic devices, which we use in our daily lives, to the Internet. Examples of such electronics are appliances, industrial machines, small appliances, and means of transportation. In addition, other objects are part of this technology, such as clothes, shoes, lamps, and pens. Its main focus is to establish the communication of the virtual world with the physical world, giving objects the ability to see and hear through sensors. That is, it tends to meet the communication networks with the real world of things, besides being able to detect problems in advance without the dependence on the human factor, proposing to revolutionize our daily lives and make our lives simpler, quickly and efficiently (Wortmann and Flüchter 2015).

In the age of artificial intelligence (AI) or IoT where the Internet is not only present in computers, phones, and tablets, but also in vehicles, shoes, clothes, pens, among many other objects that we could not even imagine a while ago, the cloud computing has become a solution with an increasingly crucial role with all this virtualization. Today, innovation can be found in a variety of ways, from industrial machinery, appliances, small appliances, and transportation to mixing with accessories, since that what sets these technological products apart from normal objects lies in their ability to exchange information through sensors; in this sense, the user relies on smart devices to automate their tasks (Russell and Norvig 2016).

The concept of cloud computing aims to facilitate data access and program execution using the Internet, gives the ability to use services and applications without the need for an installation as everything, or almost everything, will run on servers, where data access is possible from any devices as long as they are connected to the Internet and have the permission of the person responsible. The devices need to be connected to the network and exchange information with each other, especially the most complex devices. Taking as an example the case of a surveillance camera that requires a strong database to warn the owner of something suspicious, something quite complicated for a data center of its own, as the cost of maintaining this base becomes high. In this sense, cloud computing has the function of replacing the infrastructure of large companies, where there is no concern about high energy costs, since depending on the object, such as security cameras, should be kept on all day, or maintenance (Rittinghouse and Ransome 2017).

The smart device is responsible for capturing and processing the information, and cloud technology, on the other hand, allows collected information to be stored and transferred to another device—complementing each other's actions. However, the operation of smart objects requires full performance, such as a camera that broadcasts to smartphones and can detect when something unusual is happening, this object is capable of receiving and transmitting information in real time, so it must have 100% availability for its good performance. This technology has as its basic principle, connect devices to the World Wide Web to make their use easier and even expand the possibilities of resource delivery to users. To better understand the concept, other examples such as sensors that can be installed on trucks for speed control and fleet tracking, smart locks that only open with a smartphone, or wristbands that record users' activities as distance traveled, speed, pulse rate, among others. In addition, doing everything "indoors" requires more time and high investment value, because maintaining an internal data center is not cheap since there is constant maintenance, cooling needs, upgrades, among other conditions (Lom et al. 2016).

Cloud computing has a robust, high-performance infrastructure in qualified data centers that are prepared to handle a large amount of data and applications, with high-speed processing, being the best option for the IoT data that will be processed in the cloud. Therefore, the greater the number of interconnected objects communicating with each other, the number of data increases simultaneously and the need for storage will also be greater (Lom et al. 2016).

Unfortunately, smart devices are still not immune when it comes to their own security. For both loss and intrusion, devices often have little or no protection for compromised data, so for this reason, the cloud serves as a great addition to storing the information collected, having your infrastructure more robust for both security and backup itself. Thus, in case of loss, cloud technology has the ability to retrieve what has been lost and encrypt it if data is stolen, meaning any malicious person is unlikely to have access to data (Hossain et al. 2015).

In the IoT, there are devices that do data collection, and in the cloud, this data is stored, that is, it completes each other. With all this data traffic, security is paramount, it is totally out of the question to put this volume of information at risks, such as virus attacks or malicious attacks, for example, since these innovations need the guarantee of security and privacy, and the cloud computing service ensures security with its continuity, backup, disaster recovery capability, and privacy by encrypting data. Another important point is that these devices IoT must have flexibility, as there are some objects that are practical and can be moved from one place to another, is another condition that the cloud can handle, its mobility allows the user to have the continuity of their device anytime, anywhere, and from any device (Bokefode et al. 2016).

Considering the highlights, it can be seen that the age of the IoT is fully associated with Cloud services, as the cloud facilitates the entire process with its automated tools, keeping devices up-to-date and service fast, affordable, and flexible. On the other hand, the cloud allows this data to be synchronized in real time to generate smart reports and make them available later. One of the factors that catch the eye of companies in this combination is its cost-effectiveness, both devices and the Internet, if properly configured, can be a low cost to the enterprise (Hsu and Lin 2016).

A practical example of where both technologies work together is enterprise data collection using web services from companies, such as AWS (Amazon Web Services), which relies on IoT technology on a cloud platform that enables smart devices to securely interact with other applications and devices connected to the enterprise to cloud. This practice allows to measure, for example, how much is spent on electricity in equipment, this way, the company can use tools, that are also available on the platform as a SaaS (Software-as–a-Service), IaaS (Infrastructure as a Service), or even PaaS (Platform as a Service) to analyze all the results obtained, improve its decision-making and thus reduce company costs (Hsu and Lin 2016).

If cloud computing is a consolidated trend today, IoT's greatest influence on IT is to reinforce this return less path toward a virtualized IT architecture. It is no longer possible to imagine the world without technology. This is why IT is indispensable in the management of the IoT, because that cannot put information and applications in the cloud without thinking about how to keep it safe. As the IoT trend grows, IoT security challenges increase. Increasingly, the world becomes mobile and automated, since, with each passing day, more devices become connected by sensors, communicating with each other. But while this technology has been very favorable for people and businesses, on the other hand, it is amazing how much data needs to be stored for everything to work as planned. In this way, the use of cloud resources becomes necessary as the IoT becomes more and more present in people's reality, being the Cloud proves to be the ideal resource for storing and making available a large amount of data that needs to be handled in real time (Hossain et al. 2015).

Another important point regarding Cloud computing's partnership with IoT is data security, which means that from the moment that having a universal smart device connectivity environment, it is necessary to create a secure environment through which information must be trafficked. So, there is no denying that both Cloud computing and the IoT have become prevalent technologies today and represent trends for the future. Therefore, this chapter aims to provide an updated review and overview of IoT and Cloud computing, showing its relationship and integrations approaching its success relation, with a concise bibliographic background, categorizing and synthesizing the potential of both technologies (Singh et al. 2016).

1.2 CLOUD COMPUTING BACKGROUND

It is used to store files and data of all kinds as well as to use applications on-premise, that is, installed on our own computers or devices. However, in modern corporate environments, this scenario is different as long as applications available on servers that can be accessed by any authorized terminal are used. The main advantage of on-premise is that it is possible, at least most of the time, to use applications even without access to the Internet or the local network. In other words, there is a possibility of using these resources offline. On the other hand, in the on-premise model, all data generated is restricted to a single device, except when there is network sharing, which is not very common in the home environment. Even in the corporate environment, this practice can have some limitations, such as the need to have a certain software license for each computer (Bassi and Chaudhary 2015).

The constant evolution of computer technology and telecommunications is making Internet access ever wider and faster. This scenario creates the perfect condition for the popularization of cloud computing, as it spreads the concept around the world. The concept for what cloud computing is the possibility of offering content or service through online pages, being tied exactly to the need to be tied to something, needing only the Internet to perform the operations. Since it is possible to access files, edit and view photos and videos from anywhere in the world as if a person was at home or in the office, or even just with a mobile device, having a browser like Mozilla Firefox, Google Chrome, or Opera and an Internet connection for access to all cloud computing. Thus, with cloud computing, many applications, as well as files and other related data, no longer need to be installed or stored on a user's computer or a nearby server. This content becomes available in the clouds, that is, on the Internet facilities (Changchit 2015).

Cloud computing brings a huge paradigm shift, since no longer is it necessary or has to install proprietary offline file editing software. Instead, it is possible to connect to large business services and use their applications like Google Docs and do it online without even writing a file to your hard drive. Most of the time the hiring is done through rent and in the same way the user can have access to the service through a monthly payment, that is, he pays for what he uses. This also characterizes as a constant circulation of capital since the user not only makes a payment for the purchase of the service, but a smaller and constant payment according to the use (Rafaels 2015).

The functioning of the cloud uses concepts of distributed computing, and it is because of this feature that this technology has been named. It is unknown where your files and services are stored. It can be either on a server next to your home or in a data center in China. But there is no need to worry about security or privacy, as access to files and services will only be allowed to those who have their login and password. A good example of cloud computing is websites and applications for photo and video editing, because nowadays there is a vast diversity of applications and software of this type and for this purpose and in online versions, that is, they do not need to be downloaded for use (Sen 2015).

Another example is that applications that exist in desktop, mobile (Android and/or IOS) versions, can also be accessed directly by the browser, and in all three options meet basic tasks of photo and video editing without change from one platform to the other. So, summarizing the concept of what cloud computing is, it is access and management of data through a network connection without the need for a download. Within the idea of what cloud computing is, there are still some divisions to separate different types that can be offered through cloud storage. They are primarily divided between deployment and services, followed by subdivision into these first two (Sen 2015).

The deployment of cloud computing needs special attention because as it is online access, various companies and customer information will be saved in clouds, that is, on the Internet. In addition, charges may vary for each storage cloud service deployment license. Private cloud is suitable for larger companies that need a large amount of storage in the cloud, that is, constantly generating a lot of data, it is the best option for only the company to have access to that network and server as a share could disrupt the connection of company and/or customer. From the user's point of view, the private cloud offers virtually the same benefits as the public cloud, but the difference is essentially behind the scenes, since the equipment and systems used to build the cloud are within the corporation's own infrastructure (Chang 2015).

1.2.1 Cloud Computing Models

The need for security and privacy is one of the reasons why an organization adopts a private cloud. In third party services, contractual clauses and protection systems are the features offered to prevent unauthorized access or improper sharing of data. A private cloud can also offer the advantage of being precisely shaped to company needs, especially for large companies. In other words, the company makes use of a private cloud built and maintained within its domains. But the concept goes further: the private cloud also considers corporate culture, so that policies, goals, and other aspects inherent in the company's activities are respected (Rittinghouse and Ransome 2017, Chang 2015).

The public cloud is suitable for smaller, less data-intensive businesses that need to invest less in the storage cloud service, where while it is smaller and requires a lower investment when infrastructure is installed, it is still a good fit for businesses that need to make apps and some functions of your business off-site (Almorsy et al. 2016).

Hybrid cloud is when a single company makes use of the other two storage cloud options at the same time, that is, when the company hosts, produces, and manages the heaviest and most sensitive materials through a private cloud, and uses the public cloud for everyday data and transfers. Being the best choice for the business that needs more advanced data security without losing the quality of service for lighter access to the simplest business tasks. In them, certain applications are directed to public clouds, while others, usually more critical, remain under the responsibility of your private cloud. There may also be features that work on local systems (on-premise), complementing what is in the clouds. Hybrid cloud deployment can be done to meet continuous demand as well as to meet a temporary need (Diaby and Rad 2017).

1.2.2 Cloud Computing Infrastructure

IaaS is the infrastructure of the Internet-managed computing network, more simply, it is like your online server, it is only avoided to hire a more expensive service and have access to identical functions. It will be your storage cloud data center. The focus is on the structure of hardware or virtual machines, with the user even having access to operating system resources (Malawski 2015)

PaaS serves to serve the services the company intends to offer, being a platform that receives, manages, and spreads content through this online server that supports the application and access to it. This is a broader type of solution for certain applications, including all (or nearly all) of the features required for the operation, such as storage, database, scalability (automatic storage or processing capacity increase), language support programming, security, and so on. Who hires this mode avoids server costs for the distribution of your app and also avoids the maintenance headache and access licenses. A modern example can be seen on Netflix, which has the platform to receive all its content and allow users to access it online without downloading the app (Van Eyk et al. 2018).

SaaS is aimed at companies that need to make software hosted on an online server allowing users access. In essence, it is a way of working in which software is offered as a service, so, there is no need to purchase installation licenses or even purchase computers or servers to run it. As modern examples of SaaS can be seen as Google Apps like Google Docs, which provides access to a tool made entirely online and allows the user to create and store their documents. In this mode, at most, one pays a periodic amount—as if it were a subscription—only for the resources used and/or the time of use (Safari et al. 2015).

In today's market, there are also concepts derived from SaaS that are used by some companies to differentiate their services. Database as a Service (DaaS), this modality is aimed at providing services for storage and access of data volumes. The advantage here is that the application holder has more flexibility to expand the database, share information with other systems, and facilitate remote access by authorized users, among others. Testing as a Service (TaaS) provides an appropriate environment for the user to remotely test applications and systems, simulating their behavior at run level (Sousa et al. 2016, Villanes et al. 2015).

1.2.3 Benefits of Cloud Computing

One of the advantages of cloud computing is access to applications from the Internet, without having them installed on specific computers or devices. But there are other significant benefits such as the user being able to access applications regardless of their operating system or equipment used; not having to worry about the structure to run the application—hardware, backup procedures, security control, maintenance, and more. Information sharing and collaborative work become easier as all users access applications and data from the same place, the cloud. In a cloud structure, the user can count on high availability, that is, if one server stops working, the others that are a part of the structure continue to offer the service (Hashem 2015, Rittinghouse and Ransome 2017).

Many cloud applications are free, and when a person needs to pay, it's just paid for the features to be used or for the precise time required. It is not necessary to have to pay for a full usage license as it is done in the traditional model of software; depending on the application that a person is using, all or most of the processing (and even data storage) is up to the clouds. It is worth mentioning that regardless of the application, with cloud computing the user does not need to know the entire structure behind it, that is, he/she does not need to know how many servers run a particular tool, which hardware configurations are used, how the scheduling is done, and where is the physical location of the data center, anyway. What matters is knowing that the app is available in the clouds. There is still a lot of work to be done, since the very idea of certain information being stored on third-party computers (in this case, service providers), even with documents ensuring privacy and confidentiality, worries people and, especially, companies, why this aspect needs to be better studied (Tarhini et al. 2018).

But storage cloud computing is not always going to be the best option, since as it is an Internet-dependent service it can be compromised depending on the business and user connection. In addition, of course, the ease of access and encounter with your company through browsers that are such a constant use in most people's lives today. The constant expansion of Internet access services and the advent of mobile devices (smartphones, tablets, smartwatches, and the like) increasingly open space for cloud applications (Jain and Mahajan 2017).

1.3 IoT BACKGROUND

IoT is the way physical objects are connected and communicating with each other and the user, through intelligent sensors and software that transmit data to a network, an interpretation would be like a large nervous system enabling the exchange of information between two or more points, resulting in a smarter and more responsive planet. The IoT cannot be seen as a single, massive technology, but rather a set of factors that determine how the concept is constituted, since essentially three components that need to be combined to get an IoT application are devices, networks communication, and control systems (Olson 2016).

From a clock or a refrigerator to cars, machines, computers, and smartphones, which are devices ranging from large items to small objects such as light bulbs and watches, the important thing being that these devices are equipped with the items certain to provide communication such as chips, sensors, antennas, among others. Allowing a person to talk to each other via technology over communication networks such as Wi-Fi, Bluetooth, and Near Field Communication (NFC), which is a new wireless communication technology compared to Wi-Fi, both of which can being and having use for IoT; however, since these networks have a limited range, certain applications depend on mobile networks like 3G and 4G/LTE (Olson 2016).

Also considering that today's mobile networks (with regard to 2G, 3G, and 4G) are targeted at devices such as smartphones, tablets, and laptops, with a focus on the text, voice, image, and video applications, but this aspect is not preventing these networks from being used for IoT. As a consequence, it generates more comfort, productivity, information, and practicality, and its uses may include health monitoring, providing real-time information about city traffic or the number of parking spaces available and in which direction they are, even recommending activities, reminders, or content on your connected devices, that is, any tool that can theoretically and in practice be connected and transmitting information, thus entering the world of the IoT (Pan and McElhannon 2017, Olson 2016).

1.3.1 IoT Devices and Connectivity

Connectivity serves to make objects more efficient or receive complementary attributes. In this sense, the Internet refrigerator could warn a person when food is about to run out and at the same time search the web which markets offer the best prices for that item. The fridge could also search and display recipes for that person. As it turns out, creativity can bring really interesting applications. A simple thermostat can check on the Internet what the weather conditions are in your neighborhood to make the air conditioner at the ideal temperature for when a person gets home, the device can still send information to the user's smartphone through a specific application so that have reports showing how air conditioners are being used or apply custom settings for energy savings (Lee and Lee 2015).

Still considering smartphone usage, users can know the location of a particular bus, since sensors can also help the company discover that a vehicle has mechanical defects, as well as know-how, is meeting schedules, which indicates the need or not to strengthen the fleet. And when it comes to the fleet, sensor data installed on trucks, containers, and even individual boxes combined with traffic information gives the information for a company to define the best routes and logic, choosing the most suitable trucks for a given area, which orders to distribute between the active fleet (Greengard 2015).

In this sense, everyday things become intelligent and have their functions expanded by data crossing, in this context enter the virtual assistants crossing data from connected devices in order to inform, even without request or request, a simple example in this regard is about the time it will take a person to get to work when he sits in his car to leave home. In this scenario, wearable devices such as smartwatches, sensor accessories, and exercise monitoring headsets are only recently being widely adopted and used by people, and classic objects are examples of connected devices that integrate the IoT (Greengard 2015).

Security cameras that, online, allow a person to monitor your home remotely or watch your store when the property is closed. Practical applications of the IoT in the organization of traffic, the speeding up of medical treatments, and also the preservation of the environment, always conditioned on the human capacity to analyze the data that the connected devices generate. However, there are a number of other possibilities that are often overlooked, such as aircraft parts or oil and gas rig platform structures that can be connected to the Internet for accident prevention and real-time problem detection with regard to in general, if an object is electronic, it has the potential to be integrated into the IoT (Greengard 2015, Olson 2016).

Cities that suffer a lot from pollution have been directing efforts to improve air and water qualities. Modern cities are distributing small air pollution measuring devices to citizens, which can be plugged into cars and bicycles, circulating with vehicles around the city, working on actions to reduce air pollution. The sensors transmit the information to the company application. The app, in turn, consolidates information on a single server, allowing Londoners to check a digital air quality map at every point in the city (Weber et al. 2017).

The IoT can help a person to measure machine productivity in real time or indicate which sectors of the plant need the most equipment or supplies. And in the sales market, using smart shelves can tell a person in real time when a particular item is starting to run out, which product is having the least output where the manager can make promotions or at what times certain items sell the most, aiding in crafting sales strategies. From agricultural technology to air cleaning, smart devices act as important allies in solving humanity's problems (Caputo et al. 2016).

1.3.2 IoT Benefits and Applicability

The field also benefits from the IoT, as in environments plagued by drought that harms local farmers, using aerial imagery drones and soil quality sensors have helped growers identify the best places to plant new crops. Also taking into account that scattered sensors can give very accurate information on temperature, soil moisture, rainfall probability, wind speed, and other information essential for good crop yield. Similarly, sensors connected to animals can help control cattle through a chip placed in the bull's ear can track the animal, report its vaccine history, and so on (Sharma et al. 2018).

Still considering that millions of people still suffer from hunger and malnutrition in the poorest countries, and one-third of food produced annually for human consumption is lost or spoiled somewhere in the supply chain, using the IoT can be reduced. The extent of the problem, acting directly in the rural environment, since it is possible to monitor processes such as irrigation, pollination, and soil fertilization, and to provide reports to farmers, also enabling management for producers to manage their sales and prevent losses in the transportation of goods (Greengard 2015).

Connected sensors are also already being used in medicine, since wearable devices that measure patients' heart rate, pulse, and blood pressure are already used in many countries, leaving physicians informed all the time. This is not only in hospitals but also in patients' own homes for those who are at constant risk. Still considering the possibility of controlling epidemics of contagious diseases, where there are devices that measure risk indicators in people with the virus. With data transmitted via Bluetooth, physicians' need for physical interaction with infected patients has been reduced, helping to control disease transmission (Greengard 2015, Olson 2016).

It is not enough for the device to connect to the Internet or exchange information with other objects. This data needs to be processed, that is, it must be sent to a system that handles it. Data from cameras, fire alarms, air conditioners, lamps, and other items are sent to a system that controls every aspect. This system can be a cloud service, ensuring access from anywhere, as well as relieving the homeowner of the task of upgrading it. However, a problem faced by many companies is the amount of information that all these devices produce, where they will have to find ways to store, track, analyze, and make use of this large amount of data. And to make sense of all this data, big data analytics play a critical role, regardless of the size and size of the business, the IoT has the ability to accelerate business processes (Hassanien et al. 2015).

If the IoT describes a scenario where almost everything is connected, however, there are risks associated with it. IoT has a greater concern about the security and privacy of the sensors used and the data they store, yet the integration of devices to transfer all critical data also presents problems, since there are billions of devices connected to each other, and with there must be guarantees that the information will remain secure. The risks are not just an individual, there may be problems of collective order wherein a city that has all the traffic lights connected. The traffic management system intelligently controls each to reduce traffic jams, provide detours on accident-blocked roads, and create alternate routes when major events occur. If this system gets attacked or crashes, city traffic will become chaos in minutes (Wortmann and Flüchter 2015).

Industry must, therefore, define and follow criteria to ensure service availability (including rapid recovery from failure or attacks here), communications protection (which, in enterprise applications, must include strict protocols and audit processes), definition privacy, data confidentiality (no one can access data without proper authorization), integrity (ensuring that data will not be improperly modified), among others. Many industry segments are already dealing with such issues, but this is a work in constant development. Objects, people, and even nature emitted a lot of data, we just couldn't see, hear, or make sense of them. It is common for us to think about how, throughout the history of humanity, our technology has advanced far enough that we could perceive smaller and smaller things: atoms, protons, electrons, quarks, among others (Gilchrist 2016).

However, the IoT and the data we generate is one of the examples of the giant things we come to see, understand, and use to our advantage as technology advances. This is what IoT has come to change in our reality, because now everything around us has intelligence, and is interconnected, so that we now have access to data, or rather a piece of information. Deep down, we had a sea of data, which we are now able to put intelligence into and transform it into information, knowledge, and ultimately wisdom (Soldatos et al. 2015).

Once we can understand the patterns of all this data, society will become more efficient, increasing productivity, improving the quality of life of people and our planet itself. With that, we can generate new insights, new activities, and of course further fuel innovation. The bridge between data collection and appropriate sharing of data, with security and protection for all parties, remains a key challenge in the evolution of this industry. Nonetheless, it is an exciting segment and one that we must follow closely (Soldatos et al. 2015).

1.4 CLOUD COMPUTING AND IoT INTEGRATION

IoT is the future of devices since this technology has as its core principle, connecting devices to the worldwide computer network to make their use easier and even expanding the possibilities of delivering resources to users, ranging from smart locks that they only open with a smartphone, sensors installed on trucks to control the speed and location of a fleet, or even wristbands that record users activities such as distance traveled, speed, heart rate, among many others. Like IoT, Cloud computing technology is also expanding worldwide due to its many advantages that have taken companies to another technological level, being currently a cost reduction engine, the ease and agility in scalability, and security of data are hallmarks that have made cloud computing expand worldwide (Botta et al. 2016).

Thus, the Cloud and the IoT are inseparable due to the rapid technological development in which IoT is responsible, since every day more devices become connected by sensors, communicating with each other, generating an astronomical volume of data that must be captured, stored, and turned into knowledge for mankind. So, cloud computing comes into play as a facilitator of this process related to this amazing amount of data that needs to be stored for everything to work as scheduled. In this way, the use of cloud resources becomes necessary as the IoT becomes more and more present in people's reality. Thus, Cloud is the ideal resource for storing and making available a large amount of data that needs to be handled in real time (Díaz et al. 2016).

Cloud is the fuel of the IoT because it is through the cloud that it is possible to realize all the potential benefits of IoT, since the cloud offers not only storage to maintain this data volume but also efficient to manage it. In addition, scaling analysis is possible, which helps to decongest local infrastructure. Another important point regarding Cloud computing's partnership with IoT is data security. This means that from the moment we have a universal smart device connectivity environment, it is necessary to create a secure environment through which information must be transported. If there is an environment where a person has invested in high-end security, this environment is cloud computing. With cloud computing, organizations do not have to deploy extensive hardware, let alone configure and manage networks and infrastructure in IoT deployments. The cloud enables companies to extend their storage and processing capabilities to their needs, all without setting up additional hardware and infrastructure. These factors help accelerate the process of deploying IoT solutions, as well as reduce costs, as companies do not have to invest in purchasing or provisioning servers or infrastructures as they pay only for resources consumed (Aazam et al. 2016).

A business example of the interaction between technologies is in the area of people management, with electronic time registration systems simplifying the routine of the human resources and personnel departments, but with some unique IoT advantages, such as time communication between the devices on which time recording is made, through marking software such as a mobile phone, notebook, or even a clock, among other devices. Registering this point in the company or outside, and he/she receives this information at the same time, a possibility that facilitates the control of scales and overtime. With IoT it is possible to easily access time card information from anywhere in the world, a valuable resource for companies that have branches in various regions of the country or abroad. All done online (Sajid et al. 2016).

Since this information is stored in the cloud, since it is possible to do analysis anywhere, there is no need to be on a specific computer that has a certain software installed, providing more flexibility and independence to the personal department, just an Internet connection. Another advantage in the business environment is that of advertising and marketing, exploring the union of IoT and Cloud, in terms of knowledge extracted from information in the physical world, especially regarding people's behavior and their interactions with things. And are essential in determining advertising campaigns, product definition, customer segmentation, and affirmative and brand value actions. Just as several business modalities receive real-time insights from devices around the world through cloud technology, coupled with IoT services, allowing specific analysis of this easily collected device data to be performed using advanced analytics technologies and applying technologies like Machine Learning (Cai et al. 2016).

The combination of both technologies enables the construction of smart cities and buildings, creating a comprehensive solution that encompasses billions of sensors and devices that bring a new level of intelligence and automation to homes, buildings, or entire cities. Since there may be ground sensors that use an advanced combination of infrared and magnetic technologies to safely record a vehicle's arrival and communicate with a gate or gate barrier, allowing operators to obtain real-time information about the use of the environment and managing their capacity by allowing parking operators to identify whether vehicles parked for limited periods of time have exceeded the limits, photographing license plates to identify such vehicles, notifying and taking actions such as issuing infringement notices, or even provide automated guidance and signage to customers and users about the number of parking spaces available at each level of a parking structure or even the street area of a city. Everything is managed by a cloud—primarily due to support for sophisticated big data management and machine learning in serverless architecture, all processing at an incredible rate, providing real-time messaging, enabling a serverless environment to enable data delivery streaming, and connecting managing parking device data, yet with the ability to identify trends at all customer parking locations and make recommendations to operators (Alioto 2017).

Also taking into account that IoT systems are based on resource-constrained networks and devices, that is, there is a lack of computational resources to leverage and leverage the information generated, which leads to applications with high capacity reduction and not are enabled to perform large processing such as the use of data analytics and/or big data. Since IoT-associated devices have various storage, network, and processing limitations that combine the need for complex analysis, scalability, and data access, IoT needs Cloud computing technology as the most widely used alternative, where IoT system sends data for cloud processing, storage, and analysis. Noting that this combination of both technologies follows a trend related to the evolution of processing power with the ability to transmit information (Amadeo et al. 2016).

However, one of the main issues related to IoT platforms is the interoperability issue, as it relates to a single platform connection centralizing all types of protocols, devices, and applications that can use these services. A major challenge in technology synergy is related to the wide heterogeneity of devices, operating systems, platforms, and services available and possibly used for new or improved applications. Cloud services typically come with proprietary interfaces, so feature integration tends to be properly customized based on specific providers. So, the difficulty is that for each possible application/service, they have to examine target scenarios, analyze requirements, select hardware and software environments, integrate heterogeneous subsystems, develop, provide computing infrastructure, and provide service maintenance (Lucero. 2016).

Cloud IoT applications often ensure specific performance and Quality of Service (QoS) requirements at various levels for communication, computing, and storage aspects. When these applications are deployed in resource-limited environments, there are a number of challenges related to device failure or inability to reach this device; however, cloud capabilities outweigh some of these challenges as it increases device reliability because of lets to the device discharge heavy processing tasks by extending battery life. These applications allow being created innovative applications that target the integration and embedded analysis of real-world information. However, deploying IoT devices sometimes makes monitoring tasks more difficult as they have to deal with dynamic latency and connectivity issues (Khodkari et al. 2016).

Coupled with the ubiquity of mobile devices and sensor diffusion, it directly reaches scalable computing platforms, with huge volumes of data bytes being created, their handling naturally being a key challenge, highly dependent on the properties of data management technologies such as big data. Relating that it is in developing countries that there are the highest growth rates in IoT investment, and of course this is where there is the most room for creating and implementing these new systems. Since most IoT and Cloud applications are in developed countries, and since traditional systems are fully deployed, the cost of moving it to a new IoT paradigm is exorbitant. In short, IoT and the growing number of devices, technologies, and platforms in this area have made it a global and extended technology in many other areas; however, it has limitations and the need for complex resources to meet the many existing demands. Cloud computing is appropriate as an integrative add-on (Formisano et al. 2015).

Since the adoption of this aggregator, the paradigm has made possible several new applications, which derives from the success in the main challenges faced by each one of them. The main conclusion is that when considering the concept of IoT, not as island systems or as large silos, but as something that connects to the Internet and talks to each other, as in a large network, it is impossible to imagine them without the use of resources a cloud (Olson 2016).

1.5 DISCUSSION

At first, computers began to think later, talking to each other, nowadays with IoT being the connection between several devices, it is possible to collect information, share different databases, and generate significant advances in the production system, logistics, and customer experience to name just a few fields.

Numerous technological resources have been employed to provide devices and artifacts that go beyond Bluetooth, proximity field communication (CPP) is also a feature used in IoT. However, the increasingly innovative features of Radio Frequency IDentification (RFID) are the technical and functional basis for IoT.

However, the most interesting thing is not only to connect objects to the Internet, but also to realize the main potential of IoT that is to realize the communication between objects and people. This concept, of a practical nature, can also be understood as transmission of data and information. Thus, via the Internet, things (artifacts, devices, among others) exchange signals with each other, that is, mobile and fixed objects gain autonomy to interact with each other.

In agriculture, sensors scattered across crops can feed a system with data on temperature, humidity, wind speed, and direction, as well as soil conditions. Parameters can automatically trigger the irrigation system, pest control, and other aspects of farm management. Already in the herd, chips in the animals' ear send their location, history of vaccines, and treatment protocols.

In factories, the reasoning is the same. Combining monitoring and automation increases efficiency, reduces waste, reduces costs, and minimizes errors. But we can already see the IoT on the daily commute to work using public transportation. Sensors on buses inform the location if there is any mechanical breakdown or any other unforeseen event. Thus, through an application, we can know if the collective will reach the point on time and what is the best combination of modes to reach a certain destination.

In the corporate universe, it is possible to identify the same movement, as understanding about IoT is focused on generating insights through the sea of data that is collected. Attached to cloud computing that enables the storage and processing of so much of data. And if data is being generated exponentially, then it takes devices to process it. And it is not just state-of-the-art AI advanced computers that can do it, but also devices with intelligent software that have the function of connecting to the Internet, accessing specific databases, learning, and improving their performance or user experience.

In healthcare, IoT applications with AI are innumerable from the information continuously generated in the modules of a hospital management system; administrators and physicians can make much more assertive decisions, thus contributing to diagnostic processes, identifying predispositions to diseases and treatment prescriptions. Using AI to assist physicians in the diagnostic process, based on data obtained from standard medical devices when connected to the Internet, broadens their ability to collect data and broadens insight into symptoms and trends such as data capture multiparameter monitors such as heart rate, respiratory rate, blood pressure, and temperature of patients, wherefrom this information, intelligence tools will, for example, classify risk to patients, aiming to optimize care and shorten the long waits that can be today very common in the public health network, integrating IoT using information collected by hospital equipment for AI learning, promoting greater integration between systems and equipment, and feeding the AI database. As a result, better services will be provided to patients by recording and tracking data by regularly monitoring health status.

Two other technologies are driving IoT growth, AI is ensuring more autonomy and learning for objects connected to the Internet, and the blockchain promotes more security, so that objects connected to networks are not hacked. Like the big booster of IoT, it is Big Data, since the more objects connected, the more data produced and extracted for use. As a result, the accumulation, analysis, and use of Big Data will be more significant, especially for companies, where they have the most expressive data production with IoT, because they have a large number of objects that can be connected or already connected.

In short, digital transformation is shaping new behavioral patterns, along with IoT, coupled with other technologies such as Cloud, and AI derivations such as machine learning and Big Data, is an important part of this process, as through it other technologies in devices that connect to each other, modifying and simplifying the way they perform routine tasks.

1.5.1 Challenges, Issues, and Implications

Cloud computing and IoT appear to be two completely distant technologies. However, they are complementary, even more than you might think. The spread of cloud computing and