Smart Cities Ecosystem in the Modern Digital Age: An Introduction

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

Abstract Smart cities are those that use science, engineering, artificial intelligence, digital knowledge, and other technologies to progress the well-being of residents, boost economic development, and at the same time, promote and favor sustainability, as also to improve infrastructure, optimize urban mobility, and engender solutions sustainable, to generate efficiency in urban operations, this is, improving the population's quality of life. Smart cities are automated and more sustainable cities, considering that technology is fundamental, but it is only a means to resolve a set of urban issues and attain purpose and goals that are increasingly essentials for large urban centers. This is achieved through the employment of advanced ICT (Information and Communications Technology) to stimulate sustainable development, and improvement in the quality of life, in which everything becomes connected. Through this, for example, it is possible to count on the fastest free public WiFi, i.e., high-speed internet for all residents and visitors and the interconnected functioning of traffic, lighting, public transport systems, among others. There are also discussions on reducing public spending and transparency in the relationship between government and citizens. It is evident, especially in large cities, that something must be done to increase the quality of life, public services, and sustainability. In addition to urban planning, it is necessary to invest in technological solutions that can be accepted and used by the residents of each smart city. Therefore, this chapter aims to provide a scientific major contribution related to the current overview of Smart City, approaching its essential concepts

R. P. França (✉) · A. C. B. Monteiro · Y. Iano
School of Electrical and Computer Engineering (FEEC), University of Campinas (UNICAMP), Av. Albert Einstein, 400 Campinas, Barão Geraldo, SP, Brazil
e-mail: padilha@decom.fee.unicamp.br; reinaldopadilha@live.com

A. C. B. Monteiro
e-mail: monteiro@decom.fee.unicamp.br

Y. Iano
e-mail: yuzo@decom.fee.unicamp.br

R. Arthur
School of Technology (FT), University of Campinas (UNICAMP), Paschoal Marmo Street, 1888 Garden Nova Italia, Limeira, SP, Brazil
e-mail: rangel@ft.unicamp.br

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and fundamentals, with a concise bibliographic background, addressing its evolution and relationship with other technologies, as also categorizing and synthesizing the potential of technology.

Keywords Smart Cities · Smart home · Smart transportation · Smart grid · Smart government · Smart industrial environments · Data · Artificial intelligence · IoT · Data analytics · Ecosystem · Intelligent infrastructure · Sustainable development

1 Introduction

Increasingly common worldwide, the Smart City concept is transforming entire cities by using technology and intelligence in public management. Smart Cities are ecosystems of people interacting with urban services and employing digital services, energy, materials, and funding to promote economic growth and provide a better quality of life. These streams of interaction (user + technology) are considered intelligent for making strategic application of digital infrastructure and services related to ICT with urban management and planning to meet the economic and social requirements of society. For definition in this context 10 dimensions are considered to points to the degree of intelligence of a metropolis: governance, public management; urban organization, planning, delineation, and design; technological aspect, environmental aspect; international relations; human capital; social cohesion; and the economic factor [1, 2].

Smart City is a relatively recent concept, which established itself as a key factor in the global debate on sustainable growth and drives a global market for technology tools and solutions since smart cities are those that use connected devices to monitor and manage their businesses streets, and public spaces. In its broadest sense, Smart Cities are urban centers that have been incorporating IT technologies and solutions to integrate and optimize municipal operations, decreasing costs and increasing the quality of life of its inhabitants [2, 3].

A city that reaches this level, therefore, is not only connected but a living and sustainable region that can use intelligence in favor of administration and resource management, as well as ensuring more safety and practicality in the use of roads and other devices public. One of the first things attacked in a Smart City is related to one of the problems of any major urban center today: chaotic traffic. In this sense, systems integration acts as a catalyst for transformation. Where intelligent traffic lights are considered receiving satellite information, being able to automatically adjust timing to give more traffic senses [4, 5].

With smartphone mobility and the support of IoT technologies, traffic agents can also work more efficiently and quickly by being directed to the most troublesome points or requesting signage maintenance within seconds. Another major point of concern in large urban centers is the safety of its inhabitants, where however efficient the police force is, it is often impossible to maintain the optimal proportion of agents to promptly respond to all occurrences. Soon in Smart Cities, more and more artificial intelligence monitoring is being used, considering security camera technology, security guards no longer need to be available 24 h a day, as face recognition technologies can identify potential hazards and automatically trigger police [3, 5, 6].

Sustainability is related to the bigger the city, the greater is also the concern with the management of resources, especially the natural ones, wherewith the implementation of technology in the public administration, significantly increases the energy and water saving, besides enabling a most effective distribution to the inhabitants. A recent aspect used is the issue of entertainment that can be transformed through an integrated IT structure, where infrared sensors on the lampposts capture and record pedestrian shadows, which are projected by images to accompany who comes walking later [7–9].

This type of artistic insertion in the city's streets and squares improves the inhabitants' quality of life and encourages the better use of public space. With regard to tourism, this same kind of thinking can be explored with a focus on attracting people from other cities and countries, since information and tour guides integrated with Smart City's system can be used in mobile apps to create custom roadmaps for each enriching the experience and driving the local economy [8, 9].

This chapter has motivation focused to concede a scientific major contribution concerning the discussion on the transformation in the governmental structure that Smart City has generated, which is a complex and heterogeneous concept that involves the use of innovation based on ICT to increase the quality of life in urban space [10]. Since, in addition to being a process rather than a specific technical solution, it tends to be truly "a new way of governing" with a focus on sustainability and development. Also discussing topics such as the aggregation of intelligence in microgrids, therefore, has a fundamental role in the proper manipulation of these energy resources, along a grid, making these units contribute to a predetermined global good. Along with the electric car that is associated with high technology by the automotive industry and which has been constantly exhibiting as 'the finest achievement of modern engineering'.

Therefore, this chapter aims to provide a scientific major contribution related to the current overview of Smart City, approaching its essential concepts and fundamentals, with a concise bibliographic background, addressing its evolution and relationship with other technologies, as also categorizing and synthesizing the potential of technology.

It is worth mentioning that this manuscript differs from the existing surveys since a "survey" is often used in science to describe and explains the theory involved, it documents how each discovery added to the store of knowledge, it talks about the theoretical aspects, how the academics piece fits into a theoretical model. While the overview is a scientific collection around the topic addressed, whose intent is from the topic offers a new perspective on an element missing in the literature, dealing with an updated discussion of technological approaches, techniques, and tools focused on the thematic, summarizing the main applications today. Still relating that this type of study is scarce in the literature, even more, so it is updated, exemplifying with the most recent research, applications, and technological developments.

In Sect. 2 of this chapter, will be presented the Smart Cities concepts for understanding the research. In Sect. 3, the Smart Cities Applications will be presented. In Sect. 4 the Importance of Big Data for the context of Smart Cities is explained. In Sect. 5 the Blockchain technology for Smart Cities relationship is discussed. In Sect. 6, Machine Learning applications for Smart Cities are highlighted. In Sect. 7, the Discussion is made around the thematic addressed in the manuscript. In Sect. 8, technology trends are argued. Just like the chapter ends in Sect. 9 with the relevant conclusions.

2 Smart Cities Concepts

Increasingly common in the world, the concept of Smart City is transforming entire cities by using technology and intelligence in public management, since the idea involves sustainability, improvements in traffic, integration between public systems, energy, waste management, public and civil services, and among others. Related to the conception of a "smart city" is to fosters and drives the evolution of the use of accessible resources, collecting and interpreting data and at the same time transforming it into useful information for use and application in a city [9, 11].

Smart Cities are considered intelligent because it makes strategic use of infrastructure and digital services which interact with people, performing communication and taking advantage of digital information related with urban management to respond to the economic and social needs of society. Involving information flows encompassing aspects related to the use of energy, materials, and natural resources, to drive and catalyze better economic growth, generating sustainability as a whole, improving the quality of life of its inhabitants [11, 12].

However, it is essential to emphasize that in Smart City, in which the citizen is the focus, it is complicated to develop all useful functionalities at once, in this sense the most important thing is to think big, but start small and quickly scale the results, to achieve the goal. Since there are several aspects related to the use and administration of a city that can define a Smart City, this concept goes far beyond the simplest and most direct way of considering that smart cities are those that use connected devices to monitor and manage the streets and public spaces [5, 6, 12]. So, 10 dimensions demonstrate the degree of intelligence present in a city: governance, public management; urban organization, planning, delineation, and design; technological aspect, environmental aspect; international relations; human capital; social cohesion; and the economic factor [13].

"Smart City" means that innovative urban space that uses ICT and other technological means respective to urban centers that have been incorporating technologies and IT solutions to integrate and optimize operations municipal, together with the efficiency of urban operations and digital services, meeting the needs of current and future generations related to environmental, economic, social and aspects; it should be attractive to entrepreneurs, citizens, and workers, generating jobs and reducing inequalities, and even decreasing costs related to a better quality of life [1, 2, 10, 13].

Valuing green spaces, optimizing electricity networks, and keeping greenhouse gas emissions low, in addition to concern with the proper use of natural resources, the elimination of garbage collection, and the improvement of traffic through the use of technology result in sustainable development serving as support for achieving a balance in the progress of smart cities. However, environmental concern not only raises awareness about consumption, but also seeks to reduce pollution and contamination of natural resources, as long as water and waste management, pollutant gas emission rates, CO_2 emissions, and energy consumption electricity, appear more comprehensively in the evaluation of urban sustainability, encompassing actions that imply not only in the saving of operating expenses but in the reduction of everything that interferes negatively in the environment [7, 8, 14].

Smart Cities are urban centers planned with effective digital processes and implemented to favor the places where it is applied, focusing on the fields of urban development related to mobility, safety and health, education, economy, environment, and government, which are the main axes that must be observed in a Smart City [2, 4, 14].

Smart Cities includes underground sensors acting in the detection of urban traffic conditions, and even possible to reprogram traffic lights whenever necessary; hydraulic networks controlled by remote plants; or yet applied in a pneumatic waste management system eliminating the requirement for waste and garbage collection; or even micro purification system reusing practically 100% of the potable water, as well as several other useful systems for the local society [4, 5, 14].

A city that reaches this level, therefore, is not just connected, but a living and sustainable region that manages to use intelligence in favor of administration and resource management, in addition to ensuring more safety and practicality in the use of roads and other devices public. Through sustainability considering the green areas of the city, combined with the preservation of the environment in terms of the reduction in the consumption of fossil fuels and the utilization of renewable energy, the reuse of waste, and the permanent monitoring of air quality, which are essential characteristics of a smart city, has a positive impact on the economic aspect of electricity, for economic growth coupled with sustainable development. Each Smart Cities has its specificities, but all have the common goal of providing its residents with a more fluid, cheap, sustainable, and intelligent relationship [5, 6, 14].

The concept of a Smart City is consolidated as an essential topic in the global discussion regarding social sustainability, considering that it is constructive to consider those activities and factors that can make a city smarter, which respectively drives a global market for new developments and research in search of solutions and tools technological [6, 9, 14].

Traffic is one of the first aspects attacked in a Smart City is also one of the biggest problems of any major urban center today: chaotic traffic. In this sense, systems integration works as a catalyst for transformation, since with intelligent traffic lights it receives satellite information, being able to automatically adjust the timing to give fluidity to the directions with more traffic.

And in this sense, with the mobility of smartphones and the support of Internet of Things technologies, traffic agents can also work more efficiently and quickly by being directed to more problematic points or requesting the maintenance of signs in a matter of seconds [9, 11, 14].

Sustainability is related to the bigger the size of a city, the greater is also the interest in natural resource management, given that the employment of technology in public management can significantly enhance saving these resources (mainly energy and water), enabling a better efficient resource distribution to the residents [11, 12, 14].

Security is another major point of concern in large urban centers, where, however efficient the police force may be, it is usually impossible to maintain the ideal proportion of agents to respond promptly to all occurrences, so in this sense, Smart Cities have been betting increasingly more in monitoring by artificial intelligence, through security cameras, the guards no longer need to be available 24 h a day, since facial recognition technologies identify possible risks and automatically trigger the police [6, 14].

Automated monitoring systems can be even more useful for personnel control not only to ensure security and to identify strangers within a certain location in the city, but the technology speeds up credential verification, making access and editing more reliable confidential information, in addition to providing relevant information on the use of space so that the entire internal operation of a given location can be redesigned [9, 12, 14].

Entertainment is also an important point, which can be transformed through an integrated IT structure, in cities on the level of Smart City use infrared sensors on lampposts to record pedestrian shadows and project images to accompany them whoever walks afterward, as long as this type of artistic insertion in the streets and squares of the municipality improves the quality of life and encouraging the best use of public space [9, 14].

With regard to tourism, it can be exploited to attract people from other cities or even from other countries, even considering that information and tourism guides integrated into the city system can be used in mobile applications creating personalized itineraries for each visitor, enriching the experience and driving the local economy [2, 4, 14].

As in smart cities, automation in the management of these systems leads to significant savings, where technology can be used to control energy consumption, mainly by shutting down systems when in disuse, also identifying the biggest resource spenders, developing plans for readjustment and redesign of processes to spend less without affecting productivity [1, 5, 14].

The philosophy of systems and processes integration performs automated traffic control as a reference for the management of a city, without productive bottlenecks and people trapped in a slow system, as well as the employment of the IoT (Internet of Things) and mobile applications that agents and maintenance workers use to solve problems around the city so that all departments perform the most urgent duties immediately and are always where the company needs them to be [1, 2, 14].

The benefits brought by a Smart City to the public agent are related to the reduction in the cost of sending letters to notify the citizen about the request made; reducing costs with the volume of paper stored; creating a dashboard to find out how many orders are requested, granted and rejected; agility in obtaining and disseminating information; the possibility of digitally tracking all stages of the process to improve performance; as well as making it possible to reduce the number of employees serving the public, allocating them to more critical tasks [5, 6, 14].

In the same sense that benefits are seen in relation to the citizen in the agility in obtaining information; the possibility of performing the procedure digitally, at any time or place; sending material inside the portal in a simple way; the single access point to interact with various services of the city hall; and the increase in the transparency of the process steps [6, 11, 14].

Converting conventional cities into smart cities is a relevant requirement for development in some cities focused on this concept, which should also be based on the international references identified, it is understood that cities transformed into Smart Cities should be used as benchmarks, not those already built on that concept. Since the perspective of a smart city is to offer more quality in well-being to citizens through technology and the advantages it provides, therefore, there is a wide range of possibilities to start the smart city project, having with the objective of making the citizen able to carry out activities that in fact require his presence, as a result, thus generating savings for public coffers [9, 12, 14].

3 Smart Cities Applications

A smart city is a concept that classifies technology as responsible for offering social improvements by mitigating problems triggered by the disproportionate growth of cities, which according to this thought, a smart city is able to manage its resources by handling smart devices in order to ensure efficiency It is important to highlight that a smart city is not a unique technology alone, but a concept, which unites several areas of human knowledge, which technologies are applied to improve the living conditions of people in urban environments, considering the most varied aspects of life within modern societies can be seen within this concept [2, 4, 15].

Cloud computing is a computing model that allows these ideas to be realized due to the gigantic processing capacity that cloud providers have, even considering that the cloud allows data to be obtained anywhere, due to the mobility that this technology allows [15, 16].

Another important technology involved is the Internet of Things (IoT), in relation to obtaining large amounts of data that this technology has to increase this type of data efficiency, related to sensors that are close to people, such as those of wearable technologies, help to verify health problems of an entire community, as well as other initiatives, involves the construction of devices with sensors dedicated to a specific application [14, 17, 18].

Bearing in mind that mobility is one of the urban factors most affected by population growth, an example of what occurs in most cities, where constant congestion generates losses in the most varied ways, be it financial, public health, among others, chaotic traffic is one of the biggest problems of any urban center [19–22].

In this context, intelligent traffic lights receive satellite information and are able to automatically adjust the timing to give more fluidity to high traffic locations, in the same vein as traffic lights and intelligent parking based on computer vision, presence sensors, and others. There is also the use of smart fleets to minimize traffic. In the same sense that traffic agents, in turn, through smartphones, can work much more efficiently and quickly when detecting points with heavy traffic [23, 24].

Concerning security, the cameras spread over a city guarantee greater security, as well as in the management of agglomerations at events and other movements; and about the population, each inhabitant has an easier time to find and activate public services through applications, QR codes spread throughout the city and other devices [25–28].

Reflecting on energy-related aspects, scattered and connected sensors ensure energy savings with efficient lighting, generating better use of waste for energy generation and identification of waste points, such as possible water leakage, lighting failures, among others [29, 30].

In public health, a better understanding of the regions and their characteristics can be made, fleets of connected electric cars can be triggered for emergencies when there is an energy infrastructure that allows their use. In public administration, Smart Cities do not just use technology, but seek innovation and development through environmental preservation and better use and distribution of natural resources [19, 31, 32].

In the same sense directed towards the focus on sustainable cities, we can mention cities with an efficient infrastructure for the use of bicycles, or having programs aimed at the rational use of motor vehicles and an efficient system aimed at saving water. Still taking into account that sensors connected to the garbage can be used, the collection, as well as recycling and reuse, being optimized, including being used in the generation of local energy [24, 33, 34].

As well as cities that have sensors in public places that avoid the time lost looking for a place, and the reduction in lighting expenses, making the global market for smart cities to be in the billions of dollars, for the development of solutions that collect and analyze data from the most varied sectors of the city, allowing security agents, civil defense and others to check and take action more quickly, thus increasing safety aspects. In the same sense that sensors and videos provide data, organizing a map in real-time, facilitating the visualization of problems, which is related in certain situations, the intelligence and analysis algorithms help to predict emergencies, and agents can take action before it even occurs [35, 36].

Smart cities have boosted the industry as a whole, due to their broad spectrum of solutions, since this demand for these solutions continues to grow, in addition to reflecting on the cultural changes caused by the information age that demand new approaches for solving problems. And of course, the expectation of generating business, estimated at the scale of billions of dollars, increasing the importance of this concept [1, 35, 36].

4 Importance of Big Data for Smart Cities

The large flow of data generated by society is essential for modern digital solutions to optimize their technologies and improve the daily lives of the population. Related to this factor, are Smart Cities based on the latest technologies of communication and information, promoting sustainable development. Considering the increase in the number of people connected and the consequent increase in information generated, it became necessary to have technologies capable of monitoring and interpreting this great flow of information that travels through computerized environments. In this context, Big Data Analytics are the main agents of smart cities, as allow the analysis and interpretation of the collected data, identifying new consumer behaviors and social trends, in addition to helping decision-making to be more assertive [37, 38].

The benefits that Big Data Analytics brings, however, are speed and efficiency, combined with a data culture that allows data to be compiled in one place so that all sectors of the Smart City have access to them. Thus, it is possible to carry out more comprehensive analyzes, monitor indicator reports, and use them in day-to-day activities. Therefore, a digital data culture requires all employees to be part of this strategy, understanding the importance that data has which contributes to rapid extraction of insights that contribute to the direction of smart cities, through consolidated and available data for that all employees and inhabitants can make better decisions in their daily routines [39].

Smart Cities make optimum use of Big Data in relation to interconnected digital information to improve the control of their processes, operations, activities, and resources, favoring the life of the population. Considering that Big Data techniques are a key factor for the success of these cities, which use various technologies investing in services such as health, urban mobility, energy, education, tourism, environment, among others [40].

This technology targeted at Smart Cities assists emergency professionals, including police and firefighters, by analyzing larger data sets to more accurately identify risks and events, as well as being able to identify the exact location of an emergency using advanced sensors and tracking systems that are common in smart cities. From the citizens' point of view, Big Data Analytics operates as an important role in public security, processing and analyzing messages, texts on social media, increasing the reporting process beyond simple phone calls, as well as through videos, location data, and other information in time to better inform rescuers and police [41].

From a data point of view, and even considering that data is an essential factor, and even its collection, devices connected to each other that are strategically installed in cities are needed to make readings that translate reality into numbers. Data sources are everywhere in cities, such as smartphones, computers, environmental sensors, cameras, websites, social networks, GPS, among many others. As well as considering the benefit of being able to use cloud computing to connect this data in order to organize, store, analyze and have insights helping decision-making concerning plan technological expansion in digital services, technological resources or area coverage [42].

Making the best use of Big Data Analytics, considering that the teams of emergency medical services through digital systems are collecting and analyzing larger volumes of data, considering the constant digital transformation driven by the generation and analysis of data every day, also considering an amplitude in the number of parameters, including even analysis of telephone calls (emergency services) and their response times. This new level of digital intelligence, through Big Data Analytics, improves operational efficiency, which allows knowing more about the location of the occurrence and the type of emergency, as well as the best teams and equipment available. In this sense, it is possible to send the necessary resources for each emergency more accurately and quickly, improving the efficiency of the care teams and doctors in favor of saving lives [43].

Big Data technology is capable of transforming large urban centers into smart cities, improving the lives of citizens, managing to cross all the data generated by the smartphones of the population of a region, and thus, identifying the new needs and problems faced by them. In this way, it is possible to arrive at powerful insights, obtained with the information generated by the users, and to create new solutions that can help in the daily lives of the people of each location.

This technology allows the stored information to be processed in real-time and collected continuously, considering that this data is obtained through various technologies that perform the constant monitoring of numerous urban elements, such as buildings, streets, electricity, traffic, logistics, people, among others. Thus, this information about the interactions between all urban activities is used so that it is possible to understand the functioning of the city and still help in its development, thus structuring a really smart city [39, 41, 43].

In this sense, the search for efficiency and a better quality of life has been the main objective behind the technologies used in Smart Cities and, through Big Data, it has been possible to improve processes and offer a more practical and intelligent daily rhythm, aligned with new lifestyles of the inhabitants. Since smart cities have allowed the creation of new business models and even a new reality with a renewed vision of the future, in which analyzes of the large data flows produced today become essential for the creation of smart solutions, understanding the importance of connectivity in people's lives and implementing it in their products and services, and thus not only offering this but intelligent solutions that promote user interaction with the city itself [44].

The insights obtained in Big Data analysis can reshape cities and help with structuring projects, dealing with the huge flow of data generated, it can develop solutions focused on specific problems and needs of the group of citizens of a given location, in which individuals technologies and even companies to create interconnected systems, with an intelligent and systemic functioning [41, 44].

5 Blockchain for Smart Cities

Considering that smartcities need adequate and consistent and even compatible technological ecosystems to be dynamic and functional and expand successfully. Otherwise, these cities will grow up secluded, with digital systems without properties and characteristics to communicate with other smart cities when "speaking" different digital languages. With this, the need arises to create platforms of greater transparency and connectivity, allowing the interconnection of services in an accessible and secure manner [45]

Blockchain is a disruptive technology, relative to a set of digital records able to track digital transactions in a way chronological and publicly. These decentralized registries are not linked to a specific government or global authority and favor the transaction of digital currencies. Basically, this is a combination of technologies that allows support for digital transactions, and the properties of this system allow more digital security and data inviolability, which allows more and more complex transactions to happen [46, 47].

Blockchain is a technological model of distributed database that keeps a lasting, permanent, and tamper-proof transaction digital record, eliminating the intermediary and lack of trust in digital transactions. That is, users can trust that their digital transactions will be fulfilled exactly as the digital operating protocol determines, removing the requirement for a third party. Still considering that public Blockchains give transparency to changes, which are visible to all parties, and all transactions are immutable, that is, cannot be changed or deleted [46, 47].

This technology aimed at a smart city is a model with an infrastructure that allows all interactions to be made by blockchain, in addition to guaranteeing inhabitants greater control over the privacy of their personal information, that is, residents will be able to carry out banking transactions and even vote without having to involve intermediary companies or the government in the process. Multiple technologies will alter and modify the way its inhabitants (users/people) interact daily and blockchain will be the central technology of it all, considering that the technology is responsible for keeping systems honest, fair, and democratic [48].

The benefits of blockchain for smart cities are directed in the sense that technology is combined with the IoT and Artificial Intelligence (AI) to pave a path that is able to end up in intelligence for cities and can encompass situations such as preserving the environment. environment, increased security, ease of public services, energy, and financial services. Using blockchain, it is possible to scale this up with high-tech smart systems interconnected through equipment generating information and automating tasks [46, 48].

A possible example is the construction of buildings with solar panels on the roof, generating thousands of kWh, considering the surplus of this energy can be directed to cars, buses, and neighboring buildings, given that all accounting for such a project can be done by blockchain [3].

Considering the advantages of Blockchain technology in smart cities, it includes greater connectivity and digital transparency as cities have conditions to perform interconnection to vertical services, such as energy, mobility, or even security, through cross-cutting system capable of exchanging data with their residents in real-time. Or even by Blockchain, it allows public administrations and citizens to interact digitally and without the requirement for digital intermediaries, providing direct communication, streamlining bureaucratic procedures in notaries, city halls, among others [3].

With Blockchain it performs encryption of a file whole or in part to share only what interests in a private, safe, and risk-free way by a third party, maintaining the integrity of the information. The blockchain also allows citizens and government to know the origin (source) and destination of each available resource, as well as allowing government officials to know how urban digital services are employed without compromising resident's digital privacy, providing efficient management [3, 46].

Blockchain technology can be exemplified concerning urban administration including digital security improving the cyber-protection of compiled data. Energy through smart contracts that are based on the blockchain allowing households supplied with solar panels to exchange surplus electricity generated with others associated with the electricity grid. Or even in relation to mobility considering that public administrations can know which residents use the car daily and encourage them with advantages to using public transport, or even encourage the use of bicycles, guiding an environmental awareness [3, 48].

Blockchain can provide information about garbage containers in real time to citizens and the waste collection service so, these citizens know if garbage containers are empty or full. Besides, Blockchain can generate advantages to other public services such as water management, park care services and gardening services, or even air quality control. Just as Blockchain platforms also guarantee digital cybersecurity and digital reliability, or even digital transparency and anonymity in search with the population, such as elections, opinion polls, among others [3, 47].

With this, blockchain emerges as a tool that allows better communication between government officials and citizens, through a digital interaction that facilitates processes allowing citizens to have access to the destination of public resources, promoting greater transparency in urban planning. Still considering that the need to provide transparent management, based on technologies that bring government closer to the citizen, has never been more latent [3].

Thus, among other factors, Blockchain allows securely track data packets with all your transaction history between two pairs, and in this case specific to Smart Cities, between devices. The advantages of using blockchain to control this network of devices are the fact that the database is not changeable, or even contains future risks that may arise, in this sense the technology enables an architecture that offers a self-management measure for the devices isolated, in case central control is unavailable [3, 45].

6 Machine Learning for Smart Cities

The union of Machine Learning (ML) through digital intelligence that allows an unprecedented level of coverage, automation, and agility in relation to cybersecurity is revolutionizing how data and digital systems of organizations have cyber-protection. With the application of machine learning algorithms, it is possible to perform the identification and detection of many digital threats that before it was difficult to recognize and deal with. In addition to making it able to act proactively and preventively in containing threats, unlike traditional systems, by subscription, which can only act when it directly identifies a malware or network virus [49].

Cyber-attacks are becoming more complex as government agencies become more dependent on technological processes, given the greater the digital impact caused by cyber-attacks. It was from the requirement to strengthen data cybersecurity, that forms of application of machine learning in cybersecurity began to be considered to protect against cyber-attacks still unknown, discovering flaws and vulnerabilities before cybercriminals [48, 49].

Machine learning employs various algorithms to recognize, classify, or even identify patterns in cyber-threat, developing immediate responses based on them. Contextualizing, establishing, and determining the chance (i.e., probability) of a data being malicious (supported on coefficient as digital domain, country (local), origin (source), among others) and performing from there, the grouping data and information from of this content assessed malicious in classes and status of threats (botnet, virus, malware, phishing, rootkit, ransomware, among others). Making ML algorithms capable of learning how malware works and considering possibilities before digital invention [50].

There are several techniques behind machine learning that allow systems to identify suspicious patterns and adopt appropriate behaviors for each one. Prediction, Clustering, Recommendation, among others, are some of these techniques, which bring different options of action for each scenario to be faced. Allowing intelligent systems to learn from examples and situations, responding to situations without the need for specific programming for each reaction. This technology capability is a huge advantage in combating digital threats, as it makes the cybersecurity solution able to identify suspicious patterns of behavior by users and programs, allowing it to react to a threat even if it is not immediately identified as a virus or malware [51].

Besides, it is also possible to employs ML algorithms to ascertain and explore cyber-attacks, by identifying the type of cybersecurity breach in a digital system, analyzing the traces left by the attacker, and formulating hypotheses about what happened. By following these clues, technology is able to get to the root of the problem and from there work on ways to correct and prevent similar attacks. Considering the support of machine learning algorithms, which learn from data about these threats, being able to explore thousands of possibilities without the same effort as a human professional who would spend to analyze just one hypothesis [50, 51].

Or even considering that the more these algorithms are fed with data, the better it gets with regards to understanding cyber-attacks and the way that these attacks are perpetrated. Considering that also is possible to apply ML to recognize and classify multi-vector cyber-attacks, performing a detailed forensic digital analysis, and responding to digital events and incidents from a single platform only. It also encompasses a more digitally secure defense to face cyber-threats-based social engineering, which is considered digital cyber-attacks that benefiting from human flaws to obtain access to exclusive and private digital systems and data [48, 51].

In addition to cybersecurity, another technological example is the employment of ML in cyber-protection outside the digital environment, considering the analysis of images of residents in the smart city and being able to recognize, classify, identify, supported on standards, given the occurrence of some type of crime in progress, such as a kidnapping or even theft [52].

In this context, digital risks are many and it is not possible to eliminate them all, but it is possible to manage them, finding the balance to mitigate risks to an acceptable level. For that, machine learning techniques are employed, creating algorithms that identify digital threats and that immediately reconfigure devices to defend themselves quickly, correcting vulnerabilities before it is exploited and, thus, mitigating complex cyber-attacks [48, 52].

7 Discussion

The impulse of large urban centers made planning cities more detailed, considering the scarcity of natural resources, including the collapse of essential services, such as health, transport, and security, until the lack of physical structures to house and serve so many people. In this context Smart Cities favor economic development combined with the quality of life of the residents, generating efficiency in daily operations through digitalization, becoming an integral part of daily life, evidently, the result is the accumulation of huge amounts of data.

As it is possible to notice the use of sensors to avoid traffic jams in Smart Cities, acting in urban planning, possible through the installation of underground sensors that detect the level of traffic on the roads in real-time. The data generated by these sensors are read by a center that is able to automatically reprogram traffic signals whenever necessary, giving flow to the flow of vehicles.

Or even through the use of electronic medical records integrated into intelligent systems at the Service of Health, since, through this, patient data are unified in a system shared between the health units of the municipality, and doctors and employees from any post can be accessed or hospital. Thus, when performing a service, any professional can have access to previous consultations, tests performed, pathological history, hospitalizations, and medications administered.

Environmental awareness is also an important factor in Smart Cities, through the use of bicycles against carbon emissions, as one of the best examples in reducing the consumption of fossil fuels, contributing to the concept of "zero-carbon" by half of the population. Population to get to work or other desired locations. Through technology to support users, Smart Cities need to have a digital system with GPS, and even through sensors installed on bicycles, it is possible to analyze and detect the volume of air pollution (quality) and provide residents with real-time traffic information.

Among several other examples of innovation, technology and infrastructure are the bases of digital urban mapping systems to map the municipality and assist the city in decision making. Considering the collection of structured and unstructured data from different sources, such as public data, maps, statistics, and images, and through Big Data Analytics technology and the crossing of these data enabling the realization of an urban, socio-economic and strategic x-ray of the city.

Or even the importance of extensive digital monitoring, collecting data, and analyzing it in real-time, it is possible to detect and identify regions that need some kind of support and to displace the necessary teams. In addition, there is also the possibility of integration with a weather map to help prevent the occurrence of risks caused by excessive rain or other climatic adversities for residents of certain regions.

In this sense, smart cities are already becoming a reality, and data technology, through a digital culture guided by data is essential for making intelligent decisions, using qualified information to decide which paths to follow. This makes it possible for cities to move towards becoming more interconnected, healthy, and intelligent, employing smart technologies, as well as Big Data to increases the level of intelligence of cities and or even improving the places (neighborhoods, villages, among others) where residents live.

7.1 Challenges on the Implementation of Smart City

As the pace of implementation of smart cities accelerates, it also struggles to prevent, identify and respond to cyber-attacks and privacy risks due to the lack of a centralized security approach, any initiative that leaves a gap in politics or digital security control in a smart city implementation increases cyber risk. And in this sense, it can also be added that these cities do not have the capacity to prove that the data and algorithms on which the city's functions depend for decision-making have not been violated.

Or even relating that cities that start adding technological aspects are overwhelmed with high volumes of new data being collected, and without the appropriate technologies, such as those described and discussed in this manuscript, these cities do not gain digital maturity in the IT environment for data inventory, classification and flow mapping, and even operational technology.

Still highlighting the political aspect, since governments generally need to understand the benefits that technological solutions can offer, improving the quality of life of citizens through the use of technology, collecting information to understand how society operates and how people interact with space where life can significantly improve transport services, public security, basic sanitation, mobility, housing, and others.

Including a strategic plan with transparent guidelines for the development of a "Smart City" taking into account, for example, a long-term vision, a dedicated budget, an ecosystem of qualified companies, for monitoring strategic points in cities, bringing important information to planning, event prediction and coordinated actions between administrative bodies.

Still relating the geographic aspect related to long distances in which distant neighborhoods are located in urban centers where technology is more concentrated inherent to energy transmission systems, pipelines and public services leave these remote locations and exposed without technological intelligence.

8 Trends and Future Directions

The idea of the city of the future is anchored in a new generation of technologies with respect to sensors, databases, computerized interfaces, tracking, and algorithms that integrate and provide information in real-time, making it possible to carry out analyzes of these data, helping people to make decisions that optimize their lives in cities [1, 52].

In the context of Smart Cities based on available technological resources, such as the use of QR Code (Quick Response Code), which is a two-dimensional barcode model used to transmit data to a technological device, such as a smartphone, for the transmission of information and services in different points of a city, it is possible to share website links, texts, location, images, phone numbers, among others, and can be attached to different points of a city providing information and services to citizens [25–27, 52].

With regard to infrastructure, the predominance of wooden structures and lower carbon emissions, using natural and renewable resources, from reforestation and the modular nature of the buildings, is adaptable to various needs [53, 54].

In the same way that more and more the control of parking lots through applications that detect and alert the existence of available spaces, or even the monitoring of public transport and the sharing of rides, are initiatives focused on ensuring the flow of activities in the urban environment through data available on the network [55–57].

As well as the capture of energy from the heat inside the earth and the expectation that part of the garbage will be recycled and used, where a network of underground tunnels must be used to carry out deliveries and transport of materials [58, 59].

With respect to connection and communication, the increasingly powerful optical fibers and Wi-Fi at 5G speed are other realities that may provide an even greater and better quality of life for the place [60–62].

Smart grids can optimize energy distribution, through smart electronic meters and communication systems, enabling the provision of more efficient and sustainable services, concerning data control regarding energy consumption, making it possible to instantly identify drops in the supply of the network, allowing remote programming of commands on household appliances [63, 64].

The city's intelligence can also rely on drainage systems and rainwater harvesting for water reuse and automated irrigation that changes depending on the climate. Sanitation, on the other hand, can be improved with technological devices, either by using bins connected to IoT-enabled waste collection and removal management systems or with sensors to measure treated water distribution parameters [65, 66].

Given the proliferation of ICT during the last few decades, especially in the use of various smart applications such as smart farming, supply-chain & logistics, smart healthcare, business, tourism and hospitality, energy management that need disruptive technologies in relation to digital security and privacy because of the employment of the open channel (Internet for data transfer) In this sense it is worth considering the importance of blockchain-based solutions Industry 4.0-based applications. Since the advancements in ICT and Deep Learning used on the data generated sensors IoT made the concept of Smart Cities into reality, which are deployed across several locations collecting the data about traffic, drainage, mobility of citizens among other aspects, gaining insights from these data to manage resources and even assets effectively [67–72].

Or even relating digital attacks by existing and emerging threat agents, in this context Big Data technology manages to manage the sheer volume of vulnerabilities discovered through rigorous statistical models, simulating anticipated volume, complex historical vulnerability data, and even dependence of vulnerability disclosures. Providing important insights become more proactive in the management of cyber risks, handling persistent volatilities in the data as well as unveiling multivariate dependence structure amongst different vulnerability risks, building more accurate measures digital for better cyber risk management as a whole [67–72].

Big data and Blockchain can be tackled for a better quality of service, e.g., big data analytics, big data management, and big data privacy and security with its decentralization and security nature, including blockchain for secure big data acquisition, data storage, data analytics, and data privacy preservation, has the great potential to improve big data services and applications in different vertical domains such as smart healthcare, smart city, smart transportation, and even smart grid [67–72].

Still relating the potential applicability of blockchain in Smart contracts ensuring transaction processes are effective, facilitating the trustless process, time efficiency, secure, efficient, cost-effectiveness and transparency without any intervention by third-party intermediaries as compared to conventional contacts, or the question that technology can counter traditional cybersecurity attacks on smart contract applications [72–75].

Related challenges for better performance and energy optimization and even energy sustainability in IoT in a smart city, wireless sensor networks (WSNs), are typically grouped as clusters, leading to forming Cluster Head (CH) collecting data from all other nodes, considering variables such as distance, delay, and energy used in IoT devices, and explicitly communicates with Base Station. In this sense, a valid approach for CH selection is to employ the modified Rider Optimization Algorithm (ROA) using the averaged value of bypass and follower riders through the averaged value of attacker and over taker riders, which is called as Fitness Averaged-ROA (FA-ROA) using various state-of-the-arts optimization models by concerning the number of alive nodes and normalized energy [72–75].

Considering also that the electric grid consisting of communication lines, transformers, control stations, and distributors aiding in supplying power from the electrical plant to the consumers, however, there is a need to efficiently manage this power supplied to the consumer domains such as smart cities, industries, household, and other organizations. In this regard, the Cyber-Physical Systems (CPS) model, aggregating IT infrastructure embedded Machine Learning (ML) on aspect and the power dissipation units, making it possible to employ Multidirectional Long Short-Term Memory (MLSTM) technique to predict the stability of the smart grid network, still using Deep Learning approaches as Gated Recurrent Units (GRU), and Recurrent Neural Networks (RNN) [72–75].

As well as the data generated by the IoT devices need to be processed accurately and in a secure manner requiring blockchain to improve the overall security and trust in the system, providing trust in an automated system, with real-time data updates to all stakeholders, using a predictive model using Deep Neural Networks for estimating the battery life of IoT sensors. Since this data is sensitive and requires to be secured, the predicted battery life value is stored in blockchain which would be a tamper-proof record of the data, this type of approach can help reduce the stress of adaptability to complete automated systems, or even help to plan for placing orders of replaceable batteries before time so that there can be an uninterrupted service [72–75].

9 Conclusions

In general terms, a smart city is a city whose vision of urban development is connected to information technology and advances such as the internet of things, considering that these innovations in the technological, cultural, and behavioral spheres, influence people's lifestyles, directly impacting social development. The Smart Cities use these technological tools to build new models and disruptive practices for solving old problems in large cities [76–78], such as traffic, urban cleaning, economics, public safety, air quality, reuse of resources (such as clean water and energy) recycling, among other factors that influence the development of a metropolis, with a focus on strategic planning aimed at the well-being of the citizen.

Initially, the term smart city was conceptualized thus for using technological solutions to improve operational efficiency, sharing information with the public, improving the quality of public services and, consequently, the lives of citizens, however, this concept has become broader, since there is a noticeable change in the role of smart cities, considering isolated mechanisms and the solutions that need to be structured in order to respond to multiple problems simultaneously. It is also important that citizens participate in the creation of technologies, as they are able to detect local needs before city officials, so they can work collaboratively to solve problems and develop rapid and economical innovations.

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