How 5G Will Transform Smart Cities: A Literature Review

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Abstract. The expectation created around 5G is great. Major changes are foreseen, in very different areas, which will have a great impact on people's daily lives. It is expected that smart cities will be more efficient, more sustainable and safer, with significant impacts on the people who inhabit them and also on the people who visit them. 5G technology is not being implemented in the world in a comprehensive and similar way, there are countries that already have a large coverage of this network and others that are still barely talking about this fifth-generation technology of mobile communications. Given that there is still a great unknown and uncertainty in relation to 5G, the question that this research work intends to address is to what extent this technology can initiate an intelligent era, which, in turn, provides a better quality of life for people, which each they are in greater numbers, living in cities. Thus, this work intends to cross these growing trends, with the new paradigm that is the implementation of 5G. For this, the Scopus database was used, where a search was carried out in the most recent scientific literature on these topics, since they are very current trends. The results are discussed in the light of the literature and future work is identified with a view to contributing to the enrichment of those who are dedicated to these recent themes but which are in great exponential growth.

Keywords: 5G Network · Smart Cities · Technology

1 Introduction

If we focus on the evolution of cities, we are clearly faced with a phenomenon that is no longer new. The displacement of citizens to large urban centers is increasingly evident and notorious, a phenomenon that makes the rural environment increasingly depopulated.

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It is estimated that more than 50% of the world's population now lives in large urban areas, compared to just 34% in 1960. This population relocation poses new challenges to governments and local authorities, as demands in areas as disparate as Health, Environment and housing are major challenges that cities have to face.

Challenges that raise some important questions, which are linked to the incitement to guarantee quality of life for the populations that live there and also how to make urban spaces more innovative, participatory, connected and sustainable places.

The answer to these questions can be given if cities become more and more intelligent, more inclusive, more sustainable and more technological. One thing is for sure, "the intention underlying any of these situations is to make the city a community which can be friendly to people and for the people" [1].

The concept of "smart cities" has come to dominate both the academic literature and the public policies agenda. Several worldwide projects are being conceived and implemented, with different characteristics, motivations, maturity levels, government models and funding sources. However, the motto is always the use of information and communication technologies to make urban life easier [2].

Undoubtedly, the way people live in smart cities "has changed significantly due to various technological advances. There are many skyscrapers in smart cities, replacing old buildings. They are much smarter, not just because of the innovation of building materials science, but also because of the rapid development of sensor technology and the convergence of new data streams" [3].

These technologies are now applied on a large scale, and a large number of cities around the world are already considered "smart cities". This is the current reality! What is expected with the application of 5G technology is to accelerate the transformation of cities into even more promising scenarios.

Thus, this research work, in addition to contextualizing what is meant by smart cities and what is the fifth generation of mobile communications, aims to answer the following questions:

What is the relationship between technology and smart cities?

How should 5g accelerate the transformation of smart cities?

What are the main changes expected in cities with 5G?

The structure of this research work begins with this brief introduction, followed by the contextualization of the fifth generation of mobile networks and smart cities (Sects. 2 and 3). Next, we will address the methodology used to carry out this research work. Then, in Sect. 5, we present possible changes that can be expected in cities with 5G. The last section presents the main conclusions of the present study, as well as the identification of future works that can be carried out in these themes, since the desirable and expected knowledge in such current areas is a great umbrella where so many other points deserve attention from researchers.

2 Fifth Generation of Mobile Communications

The fifth generation of mobile communications is being rolled out albeit at different rates around the world. There are countries where 5G has already reached the homes of many citizens, regardless of whether they live inside or outside large urban centers,

and others where little or nothing has yet been done to implement this new generation of mobile communications, as in some countries it has not yet been implemented. They have so little 3 and 4G. But as the standards underlying this new technology become more mature, industry observers predict that societal developments will lead to changes in the way communication systems are used and that these developments will, in turn, lead to a significant increase in mobile and wireless traffic volume; such traffic volume is expected to increase a thousand-fold over the next decade. Observations such as this one are common in the literature positioning the technology: "Unlike previous generations of mobile networks, the fifth generation (5G) technology is expected to fundamentally transform the role that telecommunications technology plays in the society" [4].

5G is expected to satisfy various requirements regarding latency, data rates, bandwidth, coverage, connectivity, and energy consumption [5, 6]. The fifth mobile generation will make it possible to connect, on an almost infinite scale, smart devices that communicate with each other at high speed [7, 8].

This new generation of communications began in the 1970s with 1G and continues to the present day, where 5G technology is now beginning to see the light of day. The evolution of different mobile communication generations from 1G to 5G with time are in Fig. 1.

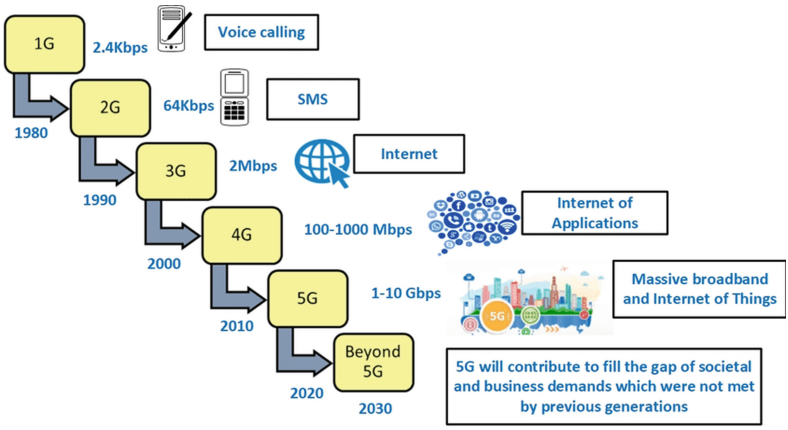

Fig. 1. Timeline of Mobile communication generations [9]

5G is a revolution and a potential discontinuity in the country's socio-economic progress over the next decade:

- **Companies** – is the fundamental basis for the competitiveness of companies in the next decade in the Industry 4.0 *framework*;
- **Cities and territories** – it is a fundamental basis for the intelligence of cities, for territorial cohesion and for environmental development;
- **Education/Training** – is the fundamental basis for new forms of teaching/learning, more immersive and centered on the student/trainee and/or on the context;
- **State** – is the fundamental basis for a new generation of more efficient and inclusive public services;

- **Health** – it is the fundamental basis for a more efficient and more effective health through all the added intelligence throughout the chain;
- **People** – and the fundamental basis for improving the quality of life of families benefiting from the economic and social progress of these new companies, cities and public services.

5G is an opportunity for start-ups and highly innovative companies to have access to more and better data, namely taking advantage of Artificial Intelligence, and to create new businesses taking advantage of the innovative features of 5G through real-time services and a integration of millions of devices never seen before [7, 10] (Fig. 2).



Fig. 2. Uses of 5G technology [11].

It is expected that the fifth generation of mobile communications will structurally change the role that telecommunications technologies play in society, a result that was not as noticeable in previous generations of mobile communications. 5G is also expected to enable further economic growth and pervasive digitization of a hyperconnected society, where not only are all people are connected to the network whenever needed, but also many other devices/things virtually creating the society with everything connected (i.e. Internet of Everything) [12, 13].

With 5G, cities will undergo transversal transformations, which depend on excellent mobile communications, impacting various sectors and industries, such as health, environment, transport, education and public safety. "We talk, for example, about improving air quality and energy consumption, reducing pollution and waste or implementing mobility systems that reduce traffic; to facilitate access to healthcare systems, powered by telecare, wearables for measuring vital signs and remote diagnostics; and the reinforcement of public safety by monitoring and reacting instantly in case of emergencies, using drones or connected ambulances" [14].

3 Smart City

The smart city concept "smart city" has come to dominate both the academic literature and the public policy agenda. Several projects are being conceived and implemented worldwide, with different characteristics, motivations, levels of maturity, governance

models and funding sources, despite the motto always being the use of information and communication technologies to facilitate the urban life [15].

Defining what smart cities are "smart cities" and measuring levels of sustainability, quality of life and well-being are topics that still lack consensus.

However, the first step in this direction seems to have been taken: the publication of the ISO 37120:2014 standard is the first ISO reference (the International Organization for Standardization) with indicators for cities, measuring the ability to provide services and quality of life [16].

Although a universally accepted concept of "smart city" is not clear. There is a set of aspects that are referred to with greater or lesser incidence in the definition of smart cities. These aspects are the concern for the environment, the use of information and knowledge technologies and urban and sustainable development.

But how can you define a "smart city"? The International Data Corporation defines a smart city "as a city that has declared its intention to use information and communication technologies to transform the modus operandi in one or more of the following areas: energy, environment, government, mobility, buildings and services. The ultimate goal of a smart city is to improve the quality of life of its citizens, ensuring sustainable economic growth" [17].

As we see in these definitions, the term technology is repeatedly present, resorting to technology and the fastest and most effective way to innovate. With the advancement of technology, today there are more and more innovations that contribute to the growth of the concept of Smart Cities and that can be applied in the daily lives of citizens who live in these cities.

According to the IESE Cities in Motion index, for a city to be considered smart, it is important that it uses a large number of these solutions [18]:

- Use of information and communication technologies (ICT)
- Building automation and control
- Efficient urban planning
- Urban mobility and sustainable public transport
- Smart management of solid waste
- Improved environmental sustainability
- Concern for the social environment
- Technologies applied to education
- Technologies applied to health
- E-commerce system
- Transparency between governments and citizens
- Shared data in Open Data

This number of solutions are of the utmost importance for cities to be smart, however many of them applied in isolation would not have the desired effect by themselves. The sum of many of these complementary solutions is necessary (see Fig. 3). For example, it is not enough for the city to have only a strong economy, if wealth is not well distributed or if the means of production harm the environment.



Fig. 3. Complementary solutions to each other.

4 Methodology

The methodology adopted for this research work was done through a brief systematic review of the literature, where several scientific articles present in the Scopus databases were selected, according to the themes under study [19].

The systematic review of the literature intends to provide a small theoretical contribution, since it brings together the most recent knowledge in the area of 5G and smart cities, also serving to expand knowledge through empirical research carried out.

The process began by searching the Scopus databases under "article title, abstract, keywords" with the following keywords related to the theme of this work: "smart cities"; "5G smart cities applications"; "using 5G in smart cities". This research had the first filter by restricting the time horizon to the last decade (2013–2023). This choice was due to the fact that both 5G technology and smart cities are very current topics.

The first search resulted in 36 documents, of which only 17 were left for a second phase of analysis. This second filter was due to the fact that the excluded articles did not respond in any way to the main question of this research work, which is to know how far to what extent 5G technology can initiate a smart era in our cities, which in turn provides a better quality of life for its inhabitants.

The 17 articles resulting from the search and initial filters considered eligible and included in the study. The exclusion of the remaining documents results from the reading of the respective articles and the verification that they would not be relevant because they are not related to the question for this study (see Fig. 4).

But the inclusion and exclusion criteria (see Table 1) went beyond the question posed in the previous paragraph.

It was the application of these three inclusion criteria and four exclusion criteria that delimited the horizon of the articles that will serve as a basis for the literature review of this research work [19] (Table 2).

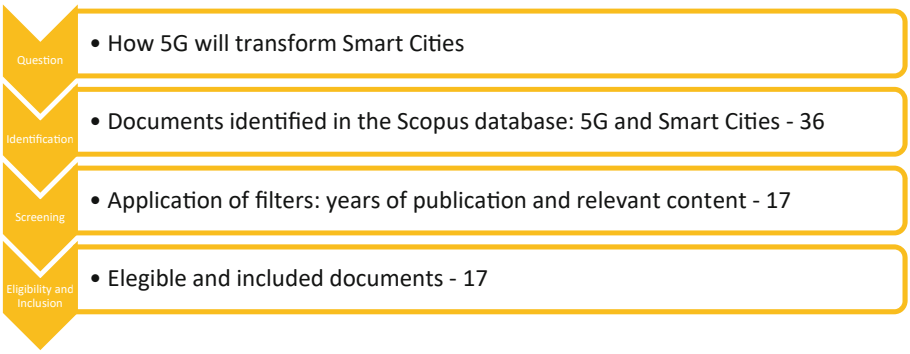

Fig. 4. Document search and evaluation steps. Adapted from [19, 20].

Table 1. Inclusion and Exclusion Criteria [19]

Inclusion Criteria	Exclusion Criteria
– Articles in English; – Magazine articles, lectures, congresses, technical reports and conferences; – Articles that meet the question that this work wants to answer	– Articles prior to 2013; – Articles such as company web pages; – Short articles of less than 4 pages; – Articles not available

Table 2. Title and publication year of the selected paper

Paper title	Year
How the 5G network will boost the concept of Smart Tourism in Portugal	2023
Using 5G in smart cities: A systematic mapping study	2022
Securing Cyberspace of Future Smart Cities with 5G Technologies	2022
5G Smart IoT Poles	2022
Research on Application of 5G to Smart City	2021
Urban Mobility Services based on User Virtualization and Social IoT	2020
5G Promoting the development of smart cities	2020
5G Boosting Smart Cities Development	2020
Application Analysis of 5G in Environmental Protection Informatization	2019
Smart cities and 5G networks: An emerging technological area?	2019
5G smart city vertical slice	2019
Standardization: The Road to 5G	2018
Impact of 5G Technologies on Smart City Implementation	2018
Analysis of smart city transportation using IoT	2018
Integrating smart city applications in 5G networks	2018
Analysis of vehicular mobility in a dynamic free-flow high way	2017
Deploying 5G-Technologies in Smart City and Smart Home Wireless Sensor Networks with Interferences	2015

These 17 articles were fundamental to answer the main research question of this work, with their analysis described in the section that follows.

5 Changes Predicted in Cities with 5G

To realize the potential of Internet of Things (IoT) for smart cities, with 5G and AI, we present a framework for IoT systems (see Fig. 3). The framework is organized into 4 dimensions: data collection; the data centers; data processing; and applications.

Large amounts of cities data can be collected from various IoT devices and then sent to data centers via 5G. This data will be processed through AI techniques and models, and then distributed through 5G to the various IoT devices (see Fig. 5).

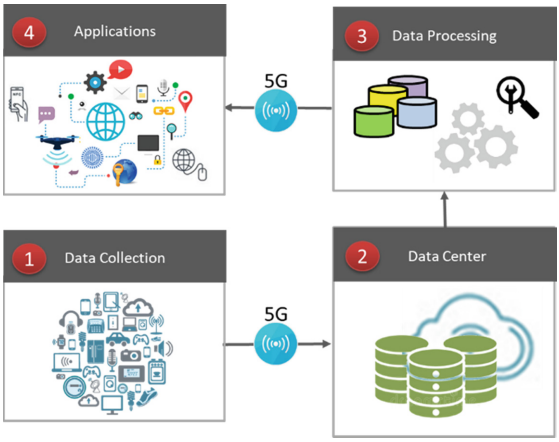

Fig. 5. Framework of 5G and AI-empowered IoT systems for smart cities.

All generations of mobile communications have influenced the development of the smart cities. With 5G it is expected, given its characteristics of high speed, large bandwidth, high confidentiality and low latency, a significant advance over 4G.

These essential 5G advances lead us to think about the challenges associated with taking advantage of these resources in cities. The Fig. 6 describes these possible uses:

Resilience - It is important to have ways of efficient recovery in order to automatically recognize and handle erroneous operations in 5G communication networks [21].

Standardization - Enormous efforts are needed to develop 5G communication network standards to be compatible with existing technologies and future technologies, many of which will be paramount for the evolution of smart cities [21, 22].

Energy efficiency - For the fifth generation of mobile communications, it is of paramount importance to achieve high energy efficiency for wireless communications in cities.

Scalability – This is yet another challenge in the design and implementation of 5G-enabled smart city solutions, where mass communications will stand out.

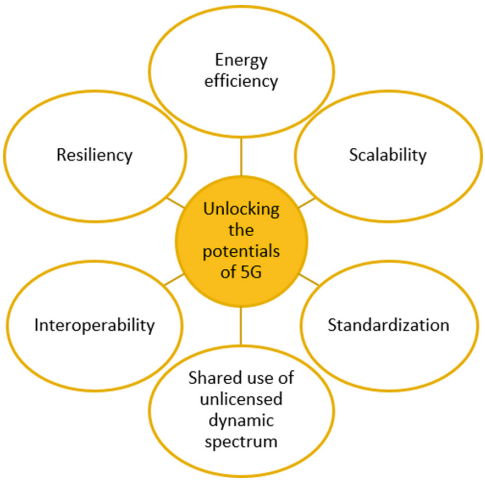

Fig. 6. Harnessing 5G capabilities [21].

Interoperability - To support a wide range of IoT "application scenarios, 5G communication networks need efficient mechanisms to effectively support heterogeneous data handling capabilities and manage different radio technologies and integrated mobility management schemes" [21].

Shared use of unlicensed dynamic spectrum - Communication network researchers need to conduct more research on the development of effective spectrum management techniques [21].

You can't talk about 5G without talking about the IoT because the connection between them is intrinsic. Therefore, it can be said that the 5G will enhance the "Internet of Things" and allow Smart Cities to develop [19, 23, 27, 28].

The IoT is emerging as an essential use case for this new 5G technology. It is common knowledge of the impact that IoT can have on the transformation of any city and this combination with 5G will build a scenario in cities that was unthinkable a decade or two ago. The IoT discussion is extending "beyond applications such as connected cars and smart metering to encompass the full range of business activities in industry verticals such as manufacturing, utilities and raw material production" [23].

It is expected that the following 5G-related technologies will contribute in the future in urban management [24, 25]:

- Artificial Intelligent
- Wireless Network Technology
- Cloud Computing and Big Data
- Precise Positioning Technique
- Terminal and Chip Technology

5G technology will bring both quantitative and qualitative changes, allowing for new features and a significant increase in the number and speed of connections.

Although 5G succeeds previous generations, its characteristics indicate that it will not only bring incremental improvements. For example, video surveillance can take

advantage of 5G high-bandwidth technology, remotely controlled drones can be operated through low latency services, and sensors such as water quality monitoring can be operated through large-connection services. In short, many successful cases have emerged in the innovative application of "5G + smart city" [26].

Next, we will analyses the advantages of 5G applied to smart cities from five scenarios [29]:

Smart Security - The characteristics of 5G such as large bandwidth can meet the needs of video transmission, in addition, applying 5G technology in surveillance solutions, the near elimination of latency will provide a boost to the camera's responsiveness and real-time tracking.

Smart governance - The characteristics of 5G, such as high bandwidth, will allow many online applications, applications that began to transmit online various aspects of our daily lives that will streamline the lives of citizens living in large urban centers.

Intelligent protection of the environment – The characteristics of 5G will bring environmental gains, which result from the use of applications that allow better real-time monitoring of the conditions of agricultural land, energy, waste management and traffic in cities or weather conditions, through different devices, many of them connected to IoT technology [30].

Smart medical – The characteristics of 5G will allow through advanced IoT technology to perform interaction between patients and medical resources. Telemedicine is based on low-latency, high-definition image transmission technology, allowing doctors to remotely diagnose and even treat patients. In addition, during outdoor emergency care, the 5G network can ensure the quality of communication between the ambulance and hospital medical staff.

Intelligent transport – The characteristics of 5G will create favorable conditions for the realization of new scenarios for the application of intelligent transport [23]. Car remote control is one of the application scenarios of intelligent transport, which requires the car image data can be transmitted to the control room in time, so it has higher requirements on the uplink bandwidth. On the other hand, "the vehicle mobility model under the assumption of time-varying vehicle speed is quite challenging" [31].

6 Conclusion

Smart cities are characterized by smart heterogeneous devices that can interact and cooperate with each other by exchanging regularly low amounts of data in the context of IoT [32, 33].

On the other hand, 5G technology "offers a number of features that will positively affect digital experiences and smart cities. In addition to greater speed for uploading and downloading data, it guarantees very short latency times and the ability to connect multiple devices simultaneously. The combination of high density and low latency will profoundly transform our cities" [34].

5G and the emerging 6G must be further investigated to address the security needs of fast-growing smart cities and improve the quality of life [21].

In this research work, we discuss the positive effects and how 5G can accelerate the transformation of smart cities. However, smart cities are a complex ecosystem that

involves all aspects of our society [35, 36]. Thus, we propose as future work the approach of the challenges that smart cities will face with the fifth generation of mobile communications.

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