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Discussion

The Role of 5G Technologies: Challenges in Smart Cities and Intelligent Transportation Systems

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Received: 4 June 2020; Accepted: 16 July 2020; Published: 11 August 2020

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Abstract: The new mobile technology, 5G, challenges the current scenario in communications by overcoming the flaws of currently working 4G. Such new technology offers to smart cities and intelligent transportation systems a new way to become fully integrated by allowing massive simultaneous connections and ubiquity of network, even under high mobility situations or dense populated areas. In this way, 5G will become a key enabler for real Internet of Things and its corresponding Internet of Vehicles. This discussion is aimed at providing, in a comprehensive manner, how 5G technology will impact on smart cities, intelligent transportation systems –including autonomous or semi-autonomous vehicles– and vehicular communications, its technical, economic and legal challenges, in the following years.

Keywords: 5G; vehicular communications; IoT; smart city; autonomous driving; ITS

1. Introduction

Approximately every 10 years appears a new generation of wireless mobile telecommunications technology. This evolution is characterized by the use of new frequency bands, higher data rates, and new services that push one step closer to enabling the connectivity of virtually our entire physical world. Figure 1 shows the evolution of mobile communication in a time-line with the main features of each generation.

The first generation –1G– was introduced in the early 1980s. It was characterized by the capabilities of transmitting voice using analogue technology. Although it represented a significant advance at that time, it had limitations. For instance, it did not have data service to convert the voice into digital signals, it had poor voice quality and global roaming service was not yet available [1].

Digital technology was introduced during the second generation –2G– in the late 1990s, improving voice quality and increasing data rate capacity. During this generation, Global System for Mobile Communications (GSM) was a digital standard that included services like: Short Message Service (SMS), Multimedia Message Service (MMS) powered by the appearance of devices with color screen and Wireless Application Protocol (WAP) that allowed Internet access services using a mobile device. Although such multimedia applications consumed considerable energy, a remarkable advantage of 2G mobiles was that the device battery lasted longer time than current devices, since radio signals actually consume low power [2].

The third generation –3G– appeared in late 2000's. It brought the first true wireless data, giving users wide Internet access. A relevant feature of 3G technology was its high data transmission rates, allowing the development of multimedia advanced applications. In addition, the new frequency bands and location information allowed the disruption of applications not previously available to mobile devices, such as web browsing, e-mail access, TV streaming, video conferencing and GPS (Global

Positioning System), among others [1]. Such a broad range of applications made the 3G a remarkable generation for the consumer market but also caused an increase in cost for the 3G devices and a greater energy consumption; i.e., they required more power than most 2G models [2].

The fourth generation –4G– entirely based on Internet Protocol (IP), was introduced in the year 2010 and it is used up to this day. The main goal of 4G technology is to provide high quality, security, low cost services, multimedia and Internet through IP, with quite higher data rates when compared to earlier generations [1]. In particular, 4G delivers the ubiquitous high-speed wireless broadband currently used, unlocking the potential of mobile video and cloud services such as video games, high-definition mobile streaming and 3D television.

Today, 4G offers consumer data rates in megabytes order, latency in milliseconds order and device density for approximately 2000 connected devices per square kilometre worldwide, which has supported the introduction of Internet of Things (IoT). Despite such capabilities and due to an exponential increase of the demand and the new mobile telecommunication innovations, 4G would be replaced with the next generation (5G) by the start of the next decade, as stated in [3].

The 5G era will bring network and service capabilities not previously available. It will ensure continuity, higher data rate, lower latency, massive simultaneous connections and ubiquity of network across the world ([2]) even in challenging situations for current 4G such as high mobility (e.g., in trains) and in very dense or sparsely populated areas (e.g., stadiums, shopping malls). In addition, 5G will be a key enabler for a real IoT, providing a platform to connect a massive number of sensors and actuators with stringent energy efficiency and transmission constraints [4].

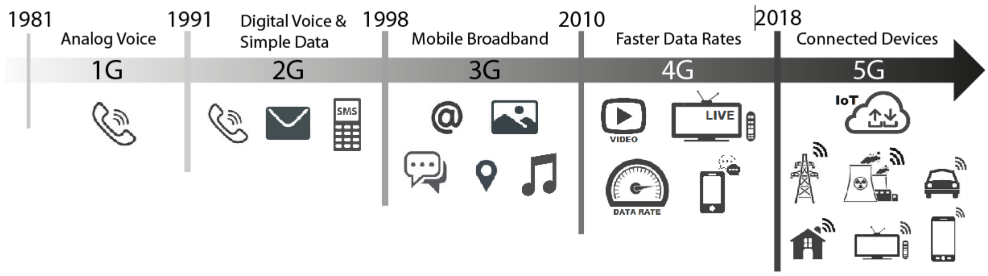

Figure 1. Evolution of Mobile Communication, from 1G to 5G.

Fuelled by this unprecedented growth in the connected devices number, mobile data traffic, and the limitations of the 4G technologies to address this enormous data demand, industry and academia efforts are focused on defining the specifications for 5G services, signaling the dawn of the 5G era [3]. A device with 5G will be able to maintain network connectivity every moment and everywhere, opening the possibility to connect all the devices in the network. To this end, the basic 5G system design is expected to provide support for up to a million simultaneous connections per square kilometre, enabling the introduction of a variety of emerging concepts within IoT services [5].

The IoT is a recent digital communication paradigm in which the everyday life objects are able to communicate with each other and with the users using Internet [6]. Hence, the IoT aims at expanding the Internet concept, making it more immerse, by enabling easy interaction with a wide variety of devices such as home appliances, surveillance cameras, industrial actuators, traffic lights, vehicles, among others [5]. In this context, data are being generated and gathered from the vast number of connected devices. The integration of Cloud Computing and Big Data technologies play a significant part in handling different types of data, according to the requirements, creating more valuable services [7]. Such technologies are crucial to ensure the IoT paradigm in urban scenarios, which is known as Smart City. It responds to the need of most national governments to adopt Information and Communications Technologies (ICT) solutions in the management of public affairs [6,8].

2. 5G for Smart Cities

Smart cities are aimed at improving the use of the public resources, increasing the quality of the services with focus on comfort, maintenance and sustainability, while the operational costs of the public utilities are reduced, within an IoT framework [9]. Figure 2 illustrates how an IoT-based smart city is expected to be. In general, IoT-based smart city applications can be grouped into four categories, as can be seen in [10]. Personal and Home Applications is the first category and includes home appliances connected and ubiquitous e-healthcare services which help doctors monitor patients remotely [3,5,11]. Utilities Applications is the second category and includes smart water network monitoring, air quality, video-based surveillance, public safety and emergency services [6,12,13]. The third category is Industrial Applications which usually consists of a network of industrial machinery within a production environment [14]. The last category is centered in Intelligent Transportation Systems (ITS) or in general, Mobility Applications. The latter category includes emerging concepts such as autonomous vehicles, vehicle networks, traffic management, congestion control, among others [15].

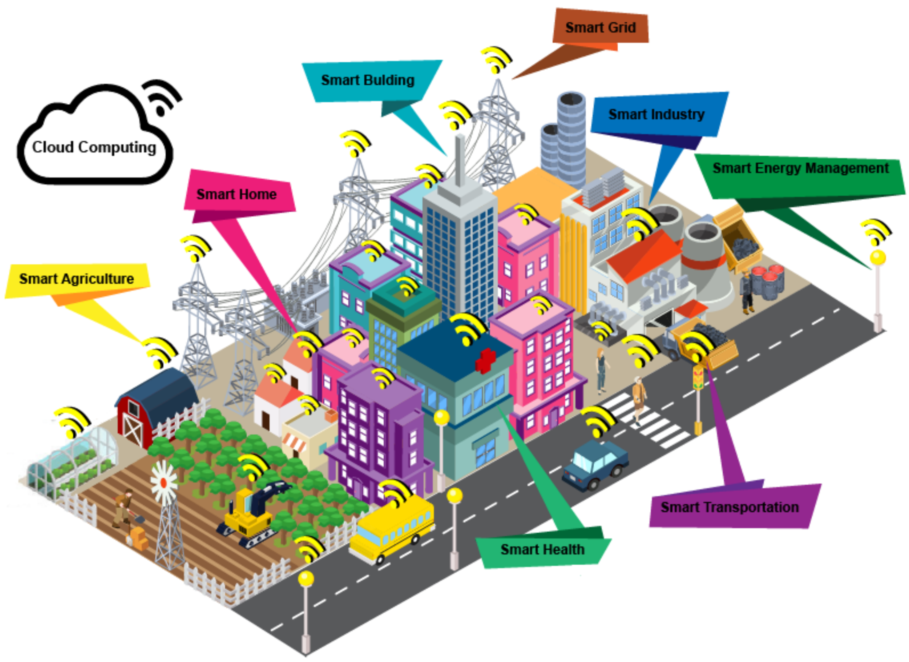

Figure 2. Illustration of an IoT-based Smart City, where all services are connected into the grid.

Several research efforts have been made to integrate 5G technologies and IoT services in smart city environments, some of them powered by industries and others by academia. Herein, we will introduce some of the most relevant approaches within each application category focusing on mobility applications.

2.1. Personal and Home Applications

Presently, a small percentage of people have a fitness device also known as tag device, but the opportunities are vast and with 5G, smart tag devices are expected to become more prevalent. Unlike todays devices, future 5G devices will be fully connected since there will not be a need to be tied to a smart phone for internet access [3]. Companies such as Samsung are developing health care and fitness devices that not only record exercise performance and make recommendations about exercise routines, but also send to the user vital health information to an expert in real time to prevent or monitor medical emergencies [5].

Moreover, with 5G, homes are expected to continuously become smarter through security (remote video security monitoring and control and wireless-controlled door locks), and comfort (command by voice, remote control using smart-phones and thermostat regulation), as illustrated in Figure 3 (see [16,17] for further reading).

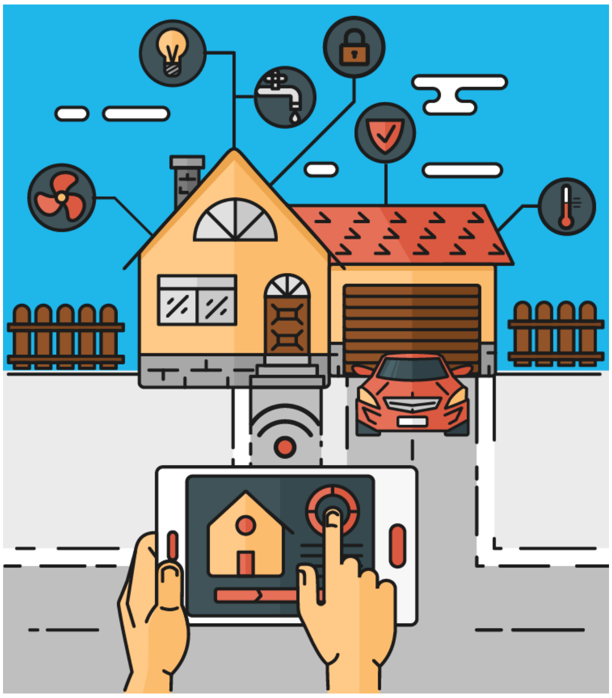

Figure 3. Smart home: all functionalities are part of the IoT (designed by vectorpocket/Freepik).

2.2. Utilities Applications

Using 5G for urban IoT might provide monitor service of the whole energy consumption in the city, thus enabling authorities to access a detailed and valuable information about energy required by the different public services (e.g., public lighting, traffic lights, surveillance cameras, heating/cooling of public buildings, among others). This will allow identifying the main energy consumption sources and then to plan in order to optimize city energy management [6,12,13].

In addition to the economic benefit of optimizing energy resources, 5G is expected to help public safety by saving lives through disaster and emergency response or improving crime detection and monitoring. Suspicious baggage in airports, vandalism and criminal identification can be combated by using surveillance cameras and computer vision techniques, as stated in [13]. When the threat is detected, using 5G fast connection, this will be informed to public safety personnel of the status of threats and might help to coordinate response actions. Moreover, in [12] is presented a security system which when detecting the face of a known criminal even if the crime has not yet been committed, the system capture live photos and actual location for sent to the nearby police stations.

2.3. Industrial Applications

The exponential rise of recent technologies (including big data, cloud computing, artificial intelligence, and 5G) has attracted great interests from industry to integrate ICT in the production environment. The melding of industrial machinery with ICT opens up opportunities to accelerate productivity, reduce waste, increase efficiency and improve the working experience in the production environment [14]. Agriculture is a specific area where IoT has enormous potential. Using sensors with wireless connectivity for crop fields can help to optimize growing and minimize use of water and fertilizers. Livestock, tanks and other farm equipment can be monitored remotely, making farming more efficient by reducing production costs (see [16,18,19]).

2.4. Mobility Applications

Increasingly, urban vehicles are becoming a moving sensor platform that provide environment information to drivers and soon such information could be uploaded to the cloud. The sensors data will be available to a network of autonomous vehicles that exchange their information among each other in order to optimize a well-defined function [20]. Thus, vehicles would become another device connected to the Internet.

Ideally, when the human control is removed, the autonomous vehicles should cooperate to allow handling traffic more efficiently, with lower delays, less pollution and better driver and passenger comfort. For instance, for disaster management, the vehicular network should be able to coordinate the evacuation of dangerous areas in a quick and orderly manner. This requires being able to communicate with each other also have access to resources as ambulances, police vehicles, or information about escape routes, as shown in [21].

Nevertheless, due to the complexity of simultaneous control of hundreds of thousands of vehicles, current 4G technologies are not able to support such a large device density. Some other critical features as latency and quality of service are necessaries to achieve it. For instance, it would take about 1.5 m for a vehicle with 4G to apply its brakes. While a vehicle with 5G would only require 2.5 cm to do so, helping avoiding accidents. In the same way, if a vehicle enters in an area with low coverage or very populated, a 4G connection fails. However, a 5G connection theoretically will always have coverage, allowing keeping stable the connection anywhere and anytime [3].

Therefore, within the objectives of IoT and smart cities, vehicles play an important role that leads to Internet of Vehicles (IoV) which is not only centred on interaction between vehicles, but also on humans, cities or even countries [20,22]. In this context, the remainder of this article covers the paradigm of smart cities regarding vehicular communications, showing the limitations of current technologies and the necessary requirements of 5G for ITS, as well as the impact on the environment and the society of concepts such as intelligent navigation and autonomous driving.

3. 5G for Intelligent Transportation Systems

The number of vehicles on the roads has been constantly growing. It is expected that they will surpass two billion by 2030. This is due, partly, to global urbanization, where the United Nations estimates that 21 percent of the world population will live in cities by 2050, up to 12 percent in 2013 [23]. The later represents serious problems to be faced such as the increasing number of casualties by traffic accidents, and the deteriorated natural environment worldwide. For this reason, the concept of Intelligent Transportation Systems (ITS) is fundamental to solve the problems of transportation using ICT, as stated in [24], in order to prioritize applications which have a potential to improve safety, fuel economy, traffic efficiency and riding comfort [25,26].

3.1. Vehicular Communication

Nowadays, a modern vehicle is a sensor platform, absorbing information from the environment. This information is processed by an on-board computer and then used to assist navigation, pollution control, and traffic management, among others. However, to achieve fast data processing it is required an extremely powerful on-board computer. This is the reason behind the high cost of luxury vehicles with driver assistance systems. To avoid the use of expensive equipment, through Internet it should be possible to upload the information onto the cloud to perform heavy processing burden. Thus, IoT can contribute to collect additional information of traffic management centres, complementing the data already collected by vehicles. With this premise, the Vehicular Cloud Computing paradigm is a challenging scenario to test future 5G capabilities [27]. Vehicles can exchange information with other vehicles (known as V2V communication), with the roadside infrastructure, with the Internet, with a pedestrian and in the same way with any element within a smart city [28]. The term Vehicle to Everything or V2X is used to refer to all these types of vehicular communication, depicted in Figure 4.

Taking into account these scenarios, the main trends for vehicular communications are presented herein, introducing relevant cases for safety, mobility and comfort.

Figure 4. Vehicular communication: transport shares information with the city and among vehicles.

3.2. Autonomous Driving

There are several intermediate levels that involve the way we interact with vehicles, before thinking in fully autonomous ones. In particular, six levels of driving automation have been identified by Society of Automotive Engineers (SAE), from no automation to full automation [29,30]. Briefly,

- No Automation (Level 0): Driver continuously in control.
- Driver Assistance (Level 1): Minor driving task performed by system.
- Partial Automation (Level 2): Driver must monitor dynamic driving tasks.
- Conditional Automation (Level 3): Driver does not need to monitor driving tasks, but must be able to resume control.
- High Automation (Level 4): Driver not required during defined use case.
- Full Automation (Level 5): The highest level refers to a fully autonomous system, no driver required.

In principle, autonomous driving is possible without V2X communication, for levels 1 and 2, where human driver monitors the driving environment. However, level 5 without any support from wireless communication systems, i.e., based only on on-board processing and sensor systems, is not practical according to [31]. Without vehicular communication, uncertainty must be considered since it cannot be assured what another vehicle, or pedestrian, will do in the next seconds. If vehicles share their available information, then other vehicles could use them to reduce uncertainties. Thus, autonomous driving can be benefited from local communication V2V, and react faster to maneuvers, preventing collisions [32].

A prominent use case of autonomous driving is Cooperative Collision Avoidance. According to the European Union community road accident database (CARE), intersection related fatalities accounted for more than 20% during the last decade [33]. After all other traffic control mechanisms have failed, the communication between autonomous vehicles are required to take actions and prevent collisions. In such a dynamic and complex environment, upon identification of a collision risk, vehicles cannot decide individually, since different individual actions applied without prior coordination might cause additional collisions or uncontrolled situations. Therefore, all involved vehicles should work in a cooperative manner to compute the optimal collision avoidance actions, as stated in [34].

3.3. Tele-Operated Driving

It is expected that autonomous vehicles, in addition to having autonomous and assisted driving modes, will have the capability to be controlled by an external operator in a tele-operated mode. This is useful when the autonomous mode fails, or human assistance is required in a complicated and unsafe scenario. Since the driving task is performed remotely, the driver safety increases in dangerous environments such as mining or under-water robots [35].

The major requirement in the tele-operation of vehicles is the live video feed from an on-board camera of the vehicle to a remote human operator to easily understand the potential hazard of the vehicle. Then, based on the live video, the operator will send motion commands to the vehicle. A key role is played by communication networks. Dedicated short range communications and visible light communication are wireless communication technologies that are currently used presently but are not suitable for long distance communication. The 5G mobile network is best suited for vehicle teleoperation as it allows covering longer distances with a high throughput and low latency for continuous video streaming [36].

3.4. Road Safety

The production of full autonomous vehicles is growing very quick, powered by competition in the automotive industry and electro-mobility. However, high-level of automation is not necessary in several potential applications. The information provided by the on-board sensors such as cameras or lasers, through cloud connectivity also enables the provision of warning applications to the drivers [37]. In this context, vehicles are expected to use local V2V and global V2X communication to allow for a safe, more efficient and more comfortable driving, since the vehicle will be able to recognize dangerous situations pre-emptively, even if these were out of visual range due to a bend or other vehicles ahead. This will be possible by sharing information with the nearby vehicles using V2V communication. In other words, it would increase the knowledge that the driver has about what it is happening around the vehicle, on the road. Let us consider the following example presented in [38]: a vehicle is moving behind another one and suddenly, a pedestrian is crossing the road in front of the first car. The first vehicle camera detects the situation and shares the image of the pedestrian with the vehicle behind it. The vehicle processes the information and shows a visual alert on the wind shield along with the image of the pedestrian in augmented reality. This use case requires a very high reliability, availability, low latency and a high data rate. Some emblematic road safety and traffic efficiency use cases include: intersection collision risk warning, emergency vehicle approaching, lane change warning, blind spot warning, road works warnings, road hazard warnings, among others [39,40].

In a smart city, safety on the road is not only targeted towards vehicles. According to the National Highway Traffic Safety Administration (NHTSA), pedestrians account for 14% of US road fatalities with over 4400 annual fatalities. In this context, the integration of Vulnerable Road Users (VRUs) is going to be one of the fundamental aims. The latter includes a wide range of road users such as pedestrians, cyclist and powered two wheelers. Recent research tackling VRU safety, such as [41,42], mainly focused on detecting the pedestrians and avoiding accidents using vehicular cloud computing as a branch of mobile cloud computing.

3.5. Intelligent Navigation

Autonomous vehicles will use digital maps and geo-positioning to provide navigation guidance to drivers. These guidance services improve driving efficiency by choosing appropriate routes according to online traffic information. This information is computed from data provided by vehicles in the vicinity, road infrastructure or traffic management centers. More useful data will be collected with the 5G thanks to the IoT and big data, allowing for the provision of more value added services, complementing the navigation as shown in [43–45]. A driver will receive notifications with personalized information about interest points (e.g., tourist attractions, restaurants, parking places, gas stations, among others) as illustrated in Figure 5. A Similar service is already done by several mobile applications such as Google Maps, Waze and Maps.Me, to mention a few [46].

Figure 5. Map with points of interest provided by the intelligent navigation system (designed by Freepik).

3.6. File and Media Downloading

For the next years, society will demand high data rate and low latency in the connectivity at any place and any time, as stated in [47]. Moreover, the introduction of driverless vehicles could increase the consumption of data traffic on the move, as drivers will no longer need to keep attention on driving and can focus their attention on other more comfortable activities. The later involves the increase in quality and quantity of entertainment services such as web browsing, file download/upload, email and social networks. In addition, a strong increment is expected in ultra-high definition video and immersive multimedia experiences powered by emerging technologies as 3D video, virtual reality and augmented reality [47,48]. This represents a significant challenge due to the sparse network infrastructure actually deployed in highway scenarios and the high velocity of vehicles. Capacity requirements, especially due to consumption of high definition video by multiple passengers in each vehicle, will create significant load on the mobile network [49]. In this context, efficient downloading of multimedia to passengers could be a critical marketing strategy for autonomous driving [50].

4. Deployment Challenges

As reviewed in the previous section, vehicular communication will bring efficiency, safety, and comfort to drivers and passengers alike. However, to attain such goal before autonomous vehicles onto market, variety of technical, social and economic hurdles will have to be overcome by the next generation mobile communication systems 5G [51].

4.1. Technological and Economic Implications

According to the use cases mentioned in the previous section, the main technical challenges that must be addressed could be grouped into following categories: mobility, latency, reliability, data rate, simultaneous connection and energy efficiency. For each category exists a 5G key enabling technology such as:

- Device-to-Device (D2D) communication: To direct transmission between proximate devices, without relaying information through a network infrastructure [52]. Such a direct transmission improves spectral efficiency, increases simultaneous connection and reduces end-to-end latency by using short-range links. Additionally, D2D communication guarantees a lower energy consumption by consequence of the lower transmission power required by short-range connections with nearby devices [53]. This implies that the device activity time in data transmission and reception can be severely reduced, getting energy consumption reduction, highly valuable in the view of meeting the energy efficiency requirements into smart cities [54].

- Massive Multiple-Input Multiple-Output (MIMO): Use large antenna arrays at base stations to obtain a wireless network that allows for transmitting and receiving of more than one data signal simultaneously over the same radio channel [55,56]. In fact, massive MIMO ability to reach multiple users simultaneously within a dense area while maintaining fast data rates and consistent performance makes it a perfect technology to address the needs of the IoV services.
- mm-Wave: Millimetre Waves (mm-waves) are broadcasted at frequencies between 30 and 300 GHz, compared to the bands below 6 GHz that were used for mobile devices traditionally [57]. This technology promises higher data capacity than the one that we currently have now. Nevertheless, there is one major drawback in mm-waves. Higher frequencies are traditionally not potent enough for outdoor applications due to high propagation loss and susceptibility to blockage from buildings and rain drops. Once solved by 5G networks will likely augment traditional cellular towers with another new technology, called Small Cells [58].
- Small cells: A small cell is a portable miniature base station that requires minimal power to operate. To prevent propagation loss, thousands of these stations are to be installed in smart cities. A small cell is a term that encompasses pico cells, micro cells, femto cells depending on the output power. It can comprise of indoor or outdoor systems [59]. With a traditional macro base station, there is one path to going into the network; with small cells, it breaks the principal path generating many others. The main goals of small cells are to increase the data capacity of macro cells, the data rate and overall network efficiency.

Small cells are typically used in densely populated urban areas, such as shopping malls, sports events, airports, train stations, streets, and highways with dense vehicular traffic. Beyond satisfying the demand of users in dense areas, high mobility users are expected to be benefited, which are inside the vehicles and high-speed trains. Mobile small cells are positioned inside the moving vehicles to communicate with the users inside the vehicle, while the massive MIMO unit consisting of large antenna arrays is placed outside the vehicle to communicate with the outside base station [2].

While traditional cell infrastructure required for the predecessor networks was quite broad, 5G will require an even larger cell infrastructure to achieve the expected performance. A strategy to face this is to take advantage of the antenna's size, due to the fact that with small cells, antennas can be much smaller than traditional antennas if mm-waves are transmitted. This size difference makes it even easier to stick cells on light poles and at the top of buildings [60]. On the other hand, the economic cost associated with the expansion and deployment of this new infrastructure with millions or even billions of small cells is a problem that still has to be solved by the operators. They have to consider both received coverage per user and revenue generation per cell site to decide how to deploy the new infrastructure with the minimum cost. According to the demand-driven analysis presented in [61], if they decide to purely integrating 5G into the existing macro network, then an average speed of 30 Mbps per user cannot be delivered everywhere or in every time. However, this strategy is the cheapest one when compared to the cost of mass small cell deployment. In this context, operators should analyze if it is worth spending on new infrastructure for sparsely populated rural areas or only concentrates on the densely populated urban and suburban areas [62].

4.2. Security and Privacy Implications

Seeking to provide more valuable services to road users and to improve road safety, cloud computing model called VANETs (Vehicular ad hoc networks) was proposed by [63]. Various transportation services are provided by VANETs, but in particular, three security services are mentioned herein.

The first service deals with human-related security issues, where vehicle internal sensors are responsible for driver security, incorporating healthcare monitoring and mood detection of the driver [64]. The second service is related to road safety, enabling the cloud to collect information from vehicle external sensors as well as from the roadside infrastructure, to help vehicles avoiding obstacles, such as pedestrians and other vehicles [63]. The third service is related to security and privacy of information. As automation is introduced in the vehicular industry, more invasive remote services are expected to appear. Therefore, there is a need for a more stringent authentication method to prevent unauthorized access to vehicles and related personal data [65]. According to [4,66], some important security aspects to improve are the following:

- Identity management. Networks should uniquely identify and authenticate users/vehicles and control access to remote services with a timely update of certificates. Due to the very high-speed data rate and extremely low latency requirement in vehicular communications, authentication in 5G, it is expected to be much faster than legacy mobile networks.
- Privacy protection. Anonymity service in 5G deserves much more attention than in the legacy cellular networks. The massive data flows in 5G carry extensive personal privacy information such as identity, position, and private contents [65]. In some cases, privacy leakage may cause severe consequences. For example, health monitoring data reveals the sensitive personal health information or vehicle routing data can expose the location privacy [67] (and the references therein). Depending on the privacy requirements of the applications, privacy protection is a big challenge in 5G wireless networks.
- Data encryption and protection. Data encryption has been widely used to secure the data confidentiality by preventing unauthorized users from extracting any useful information from the broadcast information.

4.3. Sustainability Implications

According to [68], the ITS will help to reduce the waste of time and energy by optimizing routes, reducing congestion, improving vehicle and driver performance and promoting better the management of the transportation system. In terms of sustainability, the optimization of the transport system will result in energy savings, lower pollution levels and reduced environmental impact [69]. The latter is not to be neglected, since it is estimated that cars are responsible for approximately 30 percent of the carbon dioxide emissions behind climate change [70]. According to Los Angeles Transportation Agency, up to 30 percent of the traffic in metropolitan areas is due to parking seekers [71]. That represents a significant source of traffic congestion, air pollution, and environmental degradation [72]. In addition, it is estimated that up to 45 percent of traffic congestion are produced by intersections. In fact, traffic lights and stop signs are inefficient due to their static nature. The lights are preprogrammed to remain green or red for fixed intervals, regardless of how much traffic flow comes from each direction [73]. With 5G there should be intelligent traffic signals that include dynamic functionalities. They gauge the traffic in real time and adjust continuously throughout the day based on vehicular volume, as shown in [33]. In addition, intelligent navigation will help drivers to get to their destinations more quickly and not wasting time in traffic and reducing pollution in the process. Public transport services will be improved through a correct use of online transit information (bus line or subway schedules) in real time. This will change the mind of users who prefer single occupancy vehicles over ridesharing, biking, public transport and other alternatives which decrease the number of vehicles on the road, reducing congestion and even noise pollution [74].

Information collected from sensors attached on parking lots can provide maps showing available parking places [75]. This means that drivers will not have to circle the block aimlessly trying to find an open space but can go directly to those places, thereby reducing traffic congestion, driving time, and vehicular pollutants. Additionally, autonomous vehicles are expected to help in terms of energy savings, productivity and air pollution. More efficient traffic management will enable this energy savings as well smoother driving will help in terms of carbon dioxide emissions and traffic congestion through autonomous driving. Cruise control, automated braking, and other autonomous driving features can deliver fuel cost savings and productivity gains [72].

4.4. Ethical and Social Implications

Increasing automation in transportation has both a positive and a negative side. On the one hand it opens up attractive benefits for society and economy in terms of productivity enhancement and safety [76,77]. On the other hand, it is associated with significant risks. Mostly, problems go hand in hand with various issues relating to social acceptance of driverless vehicles [78,79]. The first problem is liability, as it is currently unclear who would be at fault if a vehicle crashed while self-driving [80]. Traffic policies that regulate this type of situation are still not created. Ideally, when the entire transport system be intelligent and autonomous, the danger of possible traffic accidents will be eliminated. This leads to the following problem. It is expected that ultra-safe vehicles be able to avoid most or all accidents, meaning that many insurance companies will vanish. Additionally, the robotization of mobility will increase the vulnerability of wireless hacking: a hacker would be able to remotely take control of a vehicle. Thus, a person could be kidnapped remotely, using their own vehicle as a tool for crime. Another problem that goes hand in hand with introducing autonomous vehicles is the possible abuse of the users themselves and other road users, i.e., if the vehicle drives too conservatively, it may trigger road rage in human drivers with less patience. On the other hand, if users themselves know that they can safely come to home, that may encourage a culture of more alcohol consumption, since they will not be a need to worry about drunk driving, as stated in [81]. Into public transport, it is openly planned to replace human drivers with self-driving buses once be feasible, as shown in [82]. Thus, the position of a bus driver will not be necessary. If they do not have to drive the vehicle, their role will become more of a customer service person, providing passenger assistance, information and security [83]. In the same way, Uber, Cabify and taxi driving will probably be the first professions to be replaced by autonomous vehicles. Far from it, the driverless paradigm is not just about taxis or transportation, it has the potential to radically transform the entire economy. Robots taking human jobs mean that those humans can spend their time doing higher valued work that will drive even more progress [84]. Finally, the most controversial problem is the ability of an autonomous vehicle to make ethically complex decisions when driving, particularly prior to an imminent crash [80]. In this scenario, autonomous vehicles would choose the lesser evil. The machine must decide if is better to save an adult or a child, or saving two (or three or ten) adults versus one child [81]. People do not usually like thinking about these uncomfortable and difficult choices, but programmers may have to do deal with that. Ethics by numbers alone seems naive and incomplete; therefore rights, duties, conflicting values, and other factors often come into play [85].

5. Discussion and Conclusions

Even though 5G technologies have not yet hit the market, there is a great expectation of all the possible applications that will arise thanks to their qualities, in many cases improving the services presented by the previous networks but in other cases bringing new and more innovative services never seen before.

The emerging concepts of the Internet of Things, Smart Cities, and Intelligent Transportation Systems are three of the main paradigms that will be promoted with the appearance of 5G technologies. At the moment it has been possible to reach a basic level of services based on IoT due to the limitations of 4G technologies, but thanks to the possibilities of network availability anywhere, at any time with a higher data rate, we could finally have a real connectivity among a dense population of mobile devices.

The particular case of Intelligent Transport where vehicles are seen as intelligent mobile devices capable of connecting to the network to share information of their environment is a topic with a great impact within the intelligent planning of resources into a Smart City. In fact, for governments and modern economic development in general is vital to improve the transportation management system and promoting sustainability. The optimization of the transportation system will result in a reduction of the environmental impact and energy saving, as well as time and money.

Despite all the great advantages that show the coming of the 5G era and of the IoT, there are still problems to face in the technological field (such as solving the problems of coverage and bandwidth required for real-time applications). However, there are also social and ethical problems related to the inclusion of new services that will not be easy for the population to assimilate, as it is the case of self-driving vehicles inside the city and possible undue access to personal information of the users due to the fact that all our data will be shared in the cloud. Such problems are related to security, but, seen from the side of avoiding fatal accidents in one case and in the other hand seen as protection of private information.

Author Contributions: Conceptualization, F.A.C.; methodology, L.G. and F.A.C.; formal analysis, L.G. and F.A.C.; investigation, L.G.; resources, F.A.C.; writing—original draft preparation, L.C.; writing—review and editing, F.A.C.; visualization, L.G.; supervision, F.A.C.; project administration, F.A.C.; funding acquisition, F.A.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research was supported by ANID-Basal Project FB0008, and ANID-PFCHA/Doctorado Nacional/2018 21180470.

Acknowledgments: We would like to thank to the AC3E (Advanced Center for Electrical and Electronic Engineering), to the Department of Electronic Engineering and to the Federico Santa Maria Technical University, and to Freepik for their graphic resources.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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