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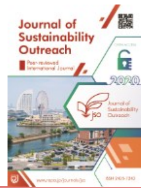

A brief review of the future of smart mobility using 5G and IoT

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ABSTRACT

Rapid urbanization and increasing population concentration in the cities can pose many challenges that need to be addressed intelligently. The smart city can be a proper answer to these issues. With the research and development made for the smart city, smart mobility is an important aspect that can solve everyday transportation challenges the citizens face. Smart mobility introduced the concept of connected vehicles that can sense their surroundings and make intelligent decisions based on the data collected. Such a concept must take decisions requiring a secure interface to reduce the latency in sharing information. This review and analysis of the future of 5G and IoT in smart mobility discusses the current trends in the transport system, autonomous vehicles, public transport, car sharing schemes (mobility as a service) mobility on demand. IoT connects all transport systems and communicates using 5G technology which facilitates fast communication and reduces latency, allowing millions of devices to be connected to the network. In addition, this paper discusses how 5G can cater to the needs of Internet of Things (IoT) technology for smart mobility, which looks into the aspects of smart mobility and 5G technology helping smart mobility. Lastly, this study showcases an overview of 5G that enables smart mobility.

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1. Introduction

Smart cities are the future of urbanization. With the emergence of technologies such as IoT and the next generation of communication (5G), that future is not too far. The concept of smart cities is developed to meet the increasing demands of interrelations in terms of communication. As the number of people increases in urban areas need for sustainable utilization of resources, keeping financial and environmental factors in mind brought the concept of smart cities. It has been defined in many ways, involving using the latest technology and communication, sustainability, and sociological and economic factors. William J. Mitchell at the Massachusetts Institute of Technology compared the concept of smart cities to a picture, utilizing ICT as how humans use their nervous systems, how every element and aspect connect and communicate, and how the human body identifies and solves problems. He showcased the importance of ICT for the development of smart cities. The definition ranges from technology focused to sociology related based on the approaches taken. One of the first definitions was by Harrison et al. [1] defined as an interconnected, instrumented, and intelligent city. This definition describes smart cities that connect ICT, the physical, social and business structures. Brandt [2] stated that a smart city needs to be designed, constructed, and maintained using sensors, electronics and integrated materials interfaced with computer systems like databases and algorithms. Giffinger et al. [3] defined smart cities to have six factors: people, mobility, environment, living, governance, and economy. Al-Hader et al. [4] stated that data collection, processing, and transmission are one of the main keys to monitoring the functions and controlling the framework required for managing cities. Dirks and Keeling [5] described it as the integration of systems, and the systems of systems can be made more intelligent by strong interconnections. Looking into the aspects that make the smart city reality is essential. It comprises specific areas: Smart buildings, Heath, Mobility, Farming, grids, government, manufacturing, and people as shown in Figure 1. All of these concepts have become possible because of the IoT. IoT is one of the emerging technologies in ICT that has changed the way systems work. It has been defined in several ways by authors, innovators, and researchers from different points of view [6]. IoT can be defined as a network of connected devices and objects that make the system smarter, capable of sharing data and information, useful sources, and reacting to changes and situations as needed. As the concept is continuously evolving, IoT has received the most important in recent decades. It can be referred to as a network that creates a communication between objects, objects to humans, and human to human by naming each and everything with an identity of its own [7]. It connects each and every 'thing' in the environment, which can communicate with each other intelligently. All devices such as phones, sensors, computers, and servers are connected with wired or wireless connections sharing information via the internet. In the smart city concept, IoT connects every object including infrastructure such as buildings, roads, poles, lights, etc., to

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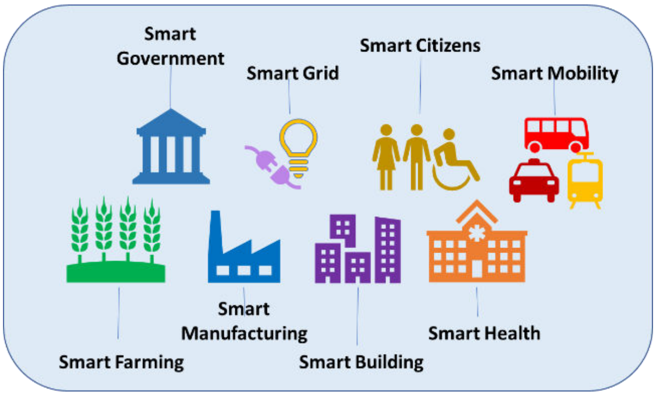

Figure 1. Smart cities components.

each other, which is associated with many advantages, as shown in Figure 2. The IoT can also be defined as the networking and coding of objects in order to make them machine-readable and traceable over the internet [8]. The communication between these objects highly depends on the network technology and how fast the data is shared with minimum delay. Among many IoT applications benefits, some of them are listed as follows:

- Improving systems' utilization and operation
- Optimizing cost reduction
- Enhancing new and integrated services
- Minimizing user interfaces
- Reactivating maintenances and etc.

The heterogeneous networking nature of IoT would require advanced wireless technology to achieve its full potential. The previous wireless technologies are not optimized enough to utilize the full potential of IoT models. There has been a drift in the technologies from 1G towards 5G. Where 5G is said to address the gaps and challenges of previous networks; such as cost, higher data rate, larger bandwidth, intelligent services, low latency, massive connectivity and consistent quality of service. The 5th generation of communication will provide cutting-edge solutions and services with an amalgamation of ultra-low reliability, massive machine type communication, and enhanced mobile broadband.

This paper focuses on one central aspect of a smart city and smart mobility. Smart mobility is the concept of connected vehicles that can share information, visualize data and make smart choices.

This study discusses smart mobility and its various applications and demand, followed by 5G communication integration with IoT to achieve realistic smart mobility. Lastly, it confirms that the 5G will be a key enabler of IoT for implementing smart mobility, followed by its challenges and conclusion.

2. Smart mobility

The concept of smart cities emerged in the nineties as a solution to the challenges faced by the growing urbanization of the cities. As the number of people increases in the cities, so does the need for a better transportation system. Smart mobility is a major part of smart city development, which requires proper planning and implementation in order to facilitate the growing population. Smart mobility has become increasingly important as it is linked to sustainable development. The way people and goods will be transported is going to change drastically. Smart mobility can be defined as connected vehicles providing a safe and efficient journey with clean, affordable, smart modes of transportation. The various attributes of smart mobility are as follows:

- Efficiency: providing passengers with an efficient mode of transport that is cost-efficient with less travel time and no disturbance.
- Sustainability: reduce the emission and provide cleaner operations that are environmentally friendly and sustainable.
- Safety and security: connected vehicles and keeping track of every movement ensure people's satisfaction in terms of feeling safe and secure while traveling.
- Connectivity: every part of the transport system is connected.
- Affordable: the system will be accessible to everyone.
- Integration: end to end planned routes for every mode of transportation.
- Flexibility: travelers can choose their mode and transportation route that suits their journey and needs.
- Automation: all process is automated.
- User experience: the efficiency of all these aspects results in a better passenger experience and provides a better quality of life.

Among the most pressing issues confronting cities around the globe is how to develop an intelligent city that offers efficient and equitable urban mobility services. Congestion, pollutants, and transportation hazards are all concerns for mobility authorities and city planners. In far too many situations, road traffic is caused by a demand systemic issue rather than a lack of road infrastructure capacity. When developing new smart urban transport networks, the regulators must consider the accessibility and sustainability of services for people with limited transportation options and those living in "mobility poverty." smart mobility's demonstrates with many advantages for citizens and administrators as below [9]:

For administrators

- Better traffic management
- Improved route planning
- Informed development

For travelers

- Improved traffic information
- Cost-effective services

– Alternate routes information

Several elements of a smart mobility system are shown in Figure 2, which are discussed in detail in the rest of the sections.

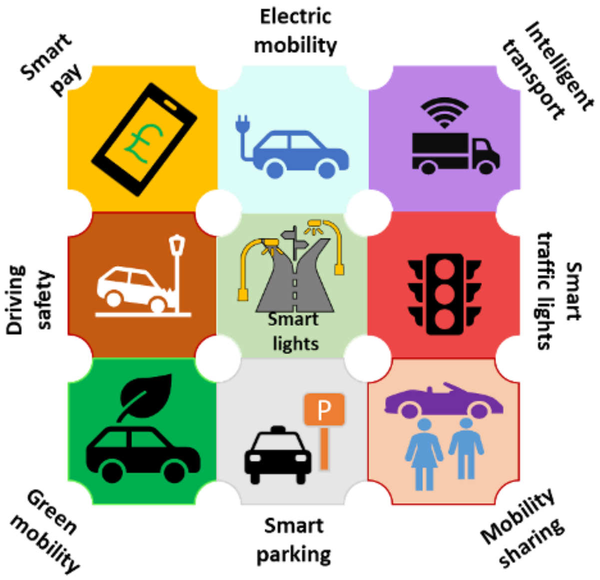

Figure 2. Components of smart mobility.

2.1. Intelligent transportation systems

Intelligent transportation systems are a big part of smart mobility, which uses advanced innovative technologies to solve transportation issues. They contribute to significant improvements and efficiency in the present transportation system, as well as cutting back the need for additional physical resources, such as adding extra traffic lanes. The concept of Intelligent Transportation Systems (ITS) emerged in the 1980s by a group of experts realizing the significance of ICT in transportation systems [10]. Since transportation contributes approximately 20% of a city's energy usage, and many research in the area of smart mobility is associated with environmental concepts and sustainability, investing in intelligent transportation systems indicates potential outcomes in the form of energy conservation and fuel efficiency [11].

The Vehicular Ad-hoc Network, commonly known as VANET, is one of the most important components of Intelligent Transportation Systems. It is a newly developed Mobile Ad hoc Network application (MANET) and provides rapid mobility, large processing capabilities, and exponential changes in the network's structure with a dynamic network density. Vehicles operate as nodes connected in a network communicating with other vehicles through communication channels. Every vehicle is mounted with a smart communication system that allows them to communicate with other vehicles sharing safety information to avoid accidents and additional information such as traffic situations and weather. Many communication protocols are developed for these systems, including vehicle to internet, vehicle to sensors, vehicle to the infrastructure, and vehicles to vehicles wireless systems. These systems provide commuter identification, accidents, lanes, obstacle detection, speed monitoring, distance prediction, and real-time traffic surveillance, helping commuters plan and make more informed choices while traveling.

Neighboring cars/vehicles can communicate in the vehicle to vehicle (V2V) and vehicle to infrastructure (V2I). The former allows vehicles to communicate speed, position, and other information to each other to avoid accidents on the road through VANET. The concept combines technologies connecting vehicles to their nearby infrastructure using sensors and microcontrollers to enhance road traffic safety and security. These modes of communication lead to overall road safety and security; and help reach environmental sustainability and better traffic management.

In VANETS, the information shared between the vehicles, such as speed, position, direction, weather, etc., is known as driving context information, which describes the traveling situation. As this information varies based on location and Vehicle to Vehicle, the smart mobility system needs to be able to adapt itself to these changing situations and give predictions and results accordingly considering different road conditions. Breakthroughs in the field of IoT technologies have facilitated the growth of Intelligent Transportation Systems in innovative ways. Due to advancements in sensors and computing, cars can immediately detect and inform other vehicles about any abnormalities.

The findings in [12] indicated several presents and new in-vehicle ITS technologies that potentially improve motorcycle safety. Among the features are advanced driver assistance systems, smart speed adaptability, driver monitoring, automatic braking and avoidance systems, lane maintaining and lane-change warning systems, visibility enhancement systems, and safety belt reminder systems. Using cloud computing and IoT technologies, authors in [13] developed a revolutionary multilayered vehicular data cloud platform. In the IoT environment, two new vehicle data cloud services, an intelligent parking cloud service, and a vehicular data mining cloud service are also reviewed.

Authors in [14] focus on the experience of using ZigBee protocol for the infrastructure and vehicle sensor network in the Embedded Middleware in Mobility Applications (EMMA) project mainly, how communication between the vehicle (highly mobile) and the infrastructure can be handled using ZigBee as the most suitable communication technology in the EMMA project validation applications.

Authors in [15] proposed a hybrid network under the concept of software defined networking, which provides connectivity to multi-homed automobiles and the opportunities that comes with it. This study shows how ITS facilities are supported by the development of network control algos with the use of well-defined use cases. Data such as traffic density or planned routes can be used to benefit these algorithms and enhance their performance by uploading them to the clouds.

2.2. Smart parking system

Smart parking systems utilize sensors and IoT platforms to detect the departure and arrival of cars helping drivers to save time and gas by reserving parking spaces and planning their journey ahead of time by making decisions based on the availability of parking spaces and time, which can improve the congestion condition in parking areas and pollution. This system can facilitate better parking management and help drivers save time. One of the core technologies for developing these systems are sensors, playing a key role in detecting and alerting users. Other technologies improving smart parking are cameras and surveillance, GPS, smart meters, cloud computing and big data analysis, which play a key role in analyzing huge amounts of data collected from these sensors. GPS and meters in today's smart parking systems. According to Hafezi et al. [16], the smart parking system can be briefly divided into automatic parking, E-parking , Transit Based Information System, and Parking Guidance and Information System (PGIS). Automatic parking uses a mechanism to park the vehicles in spaces allocated automatically. It places the car in the space, which minimizes the area needed for car parking. E- parking facilitates users to enquire about parking availability when they arrive at their destination through internet messaging or SMS. Transit Based Information System gives drivers information about the parking lots, public spaces, and transportation available in real-time with current traffic situations. Users can use this facility to plan their trips and route, scheduling according to the congestion in the destination area. Lastly, Parking Guidance and Information System (PGIS) provides traffic management information, parking availability in regulated areas, analysis, and technologies for variable message-sign (VMS) like LED displays.

Authors in [17] developed a smart parking system based on reservation that can help optimize parking management. They proposed dynamic pricing to meet the needs of different drivers and users by using the real-time information obtained by continuous monitoring. The system is integrated within the reservations-based smart parking, where the price is according to traffic, parking congestion, and parking demands. The users can reserve after accepting the price generated according to the congestion and availability. Authors in [18] developed a system that allows users to reserve parking remotely by providing real-time data and insights about the slot availability in the parking area through an application. The system is an effort to make the parking system more efficient in the cities and enhance the use of time for the people. Authors in [19] developed a smart parking system named SPARK for parking management using WSN (wireless sensor network) with facilities such as monitoring parking remotely, guidance, and parking reservation. The paper provides detailed information about the hardware and software system used for the model. The results show that WSN can be used effectively for parking management systems that can remove the existing problems drivers face in congestion caused by low management. It reduces the time needed to find a free slot by real-time information making smart choices.

Smart traffic light is an intelligent management system that incorporates the traffic lights on the road with Artificial Intelligence (AI) and a diverse range of sensors to direct vehicular traffic and walking pedestrians. As we know, the current traffic light system follows a fixed timing procedure regardless of the traffic congestion on the road and cannot be improved or optimized timing according to the traffic flow. This can create an issue in urbanizing modern cities as the traffic varies from time to time and area to area and affect the management system, fuel utilization, and noise pollution. Many systems are developed by researchers to address these issues. Authors in [20] developed a model to utilize image and video processing by using live junctions videos to collect real-time traffic information. The algorithm switches the traffic signals according to the traffic on the road to reduce congestion and accidents. This provides safer transport for people and also saves gas and time spent at traffic signals. The data collected can be used for further analysis, planning of roads, and traffic management. Authors in [21] developed an algorithm using fuzzy logic to simulate a time management system for the traffic by installing timers so that tracking can intelligently predict the right time required for each signal to reduce the congestion according to the density of vehicles on the road. It adds 15 seconds to the previous time of green light on the path of vehicles. Authors in [22] used google maps, MQTT, and android apps to make a smart traffic lights system that lets users select the app's destination, choose the shortest path using google maps, and position all traffic lights on the route. The arrival time is sent on the mobile app for each traffic signal, and when the vehicle arrives at that signal, it will find it open for a smooth journey with no waiting time needed in traffic junctions. All traffic signals are mounted with microcontrollers and the internet to connect to the users.

2.3. Smart lighting

Also Known as an intelligent lighting system, it introduces intensified intelligence and monitoring multi-functionalities systems by using a diverse range of sensor technology, cameras and photocells, achieving more efficiency and energy use in the public sector [23]. The working and features of smart lights depend on the requirements and technology used. Some of the common features of this system are movement-based lighting control, energy consumption, cost reduction and light pollution, weather monitoring, pedestrian safety by continuous surveillance of the area, increased life span of the lights used due to dimming controls, and decreased maintenance expense.

Authors in [24] developed a novel model that uses many light sensors and LEDs for distributed LED luminary control. The experiments show that the desired illumination can be obtained with user preferences regardless of the presence of external light. Authors in [25] implemented a light system that uses ZigBee and illumination control, sensors, and a distributed wireless network to reduce energy consumption. The module has light sensors, microwave doppler, passive infrared, and light controlling rules. The dimming can be controlled by keeping daylight and occupancy in mind. The system was tested in metro stations and office rooms and showed 45% and 36% energy savings, respectively. The smart road light administration [26] developed a system to track and control the use of street lights remotely and decrease the usage by control and power molding. The lights are mounted with sensors and microcontrollers and the controller can control the LED road lighting and share information between road lights.

2.4. Smart payment

Smart payment system at toll will create a hassle free movement for the drivers going long distances by automatically deducting payment through different means such as RFID, without the need to wait in line to pay individually at the toll gates. These intelligent systems have already been a part of transportation in many developed countries and are in progress in developing countries. Researchers are developed many concepts for smart payment systems, some of which are mentioned below.

Authors in [27] develop a model for transit, parking, and toll fee payments in a common system called MAPS-multimodal access and payment system. The vehicles are mounted with transponders that are interfaced with the MAPS smart cards. This helps in reducing congestion at the payment gates and reduces air pollution as well. The smart cards can also maintain the history of the routes taken from and to work with details of transportation modes used. Authors in [28] writers introduce an RFID-based system for toll collection to solve traffic issues and have a maintained system for toll payment collection. It is an automated toll collection system that creates digital cashless payments without waiting in lines. It reduces the collection junction traffic and detects the number plate tags using RFID readers. Authors in [29] introduces Smart Payment Terminal (SPT) for energy-selling for hybrid and electric car without the need of an attendee to do so. It allows payments through a car and provides a receipt directly installed in petrol stations. This aims to create an automatic payment process and also be able to analyze transactions. It may include machine learning for sales prediction for the same system.

2.5. Sharing and urban mobility

Shared mobility is the concept of sharing transportation either as a group or over time as a personal rental system where the riders can share the total cost, creating a hybrid system between private and public transport. This allows users to access such transportation as per their needs and can include car sharing, bike/bicycle sharing, carpools, etc., so they can pay for the distance they travel and divide the cost accordingly. People who prefer to take private transport but hesitate to travel alone can access such facilities to feel safe and have a hassle free journey. Smart mobility can introduce shared transportation in the future smart cities. IoT and 5G can provide users with real-time information about their locations, distance and time needed to reach their destination, which helps them plan accordingly even in shared mobility. It can also simplify payment methods through online payment, where each individual will receive the amount to be paid automatically using the application. Being connected and aware of the journey creates more satisfied customers and welcomes more users.

Authors in [30] proposed a methodology using sustainability assessment to measure the impacts of Shared Automated Electric Vehicles (SAEV). Based on an integrative literature study and in the context of AVENUE, a European project deploying automated shuttles in the public transport of European cities, a set of indicators is defined. It assesses the impacts SAEV has on social, environmental, economic, and governance. The system considers the comparison between SAEV and other transportation systems and strengthens scientifically based recommendations for transportation policies.

Authors in [31] use empirical data from three of the most emerging sectors in mobility sharing, considering bike-sharing, EV sharing and ride-sharing in Shanghai, China. This study concludes that these technologies have a co-evolution process that uses cohesiveness between sustainable development in the automobile industry and social-ecological innovation and brings people greener and smarter mobility solutions.

2.6. Green mobility

The new Urban Mobility Framework will assist both users of public transport services and the people surrounding them. Millions of people live in cities. The use of public transportation, walking, and cycling will be prioritized. Zero-emission alternatives for urban vehicles, such as cabs and ride-hailing services, the final mile of urban deliveries, the development and renovation of multimodal nodes, and innovative digital solutions and services, are also prioritized for the green mobility initiations.

Authors in [32] report on developing a model for assessing transitions to sustainable mobility. The model employs transitional theoretical principles as a basis for evaluating potential routes for achieving the development of a sustainable transportation economy. Agent-based model tools are blended with a dynamic systems design. It's unique in that it has two layers of agent. A limited number of complex agents, which have an internal structure and thus function as subsystems within society, exist alongside a larger number of simple agents. According to statistics from the United Kingdom, the analysis reveals that

Hydrogen Fuel Cell Vehicles (FCVs) would lead in the long run (after 2030), while biofuels and ICE-electric hybrids will become the major options in the next 10–30 years.

Authors in [33] examined the four technology paths chosen by the "Platform Sustainable Mobility," including vehicle hybridization, liquid biofuels, and using natural gas and hydrogen as transportation fuel to predict major improvements in vehicle propulsion and energy systems. They also vie for the limited available resources to make significant investments in (fuel) infrastructure, implying that all these 'transformation paths' are linked at the mobility network level. The research's primary result has been determining obstacles that are now impeding sustainable mobility development. Barriers are divided into three categories:

1- Technological and automobile advancements,

2- Supply of (fuel) network, and

3- Institutional infrastructure aspects.

3. 5G for smart mobility: The future city

Smart cities need to collect data from millions of devices using the IoT in real-time. It is predicted that by 2025, around 75 billion devices will be connected and communicating. This is not possible without the need for a network that is both fast and can handle billions of devices.

The fifth generation of communication technology now advances the scope and expands the possibility of using sensors and devices to operate and fasten the movement towards smart cities. The three core elements of 5G: mMTC, eMBB, and uRLLC, devices can communicate with fast speed and low latency, connecting millions of devices. The 5G can help a smart city that facilitates mobility comprising of:

- Safety and security: the real-time monitoring of information at high speeds of 5G can allow officers and officials to keep track of security and take action within a few minutes of any abnormalities ensuring citizens feel safe and satisfied.
- Connected mobility: with 5Gs capability to connect millions of devices altogether and communicate with low delay, making it possible to connect all kinds of public transport in real-time, allowing autonomous vehicles to operate smoothly and help people navigate cities easily.
- Traffic flow management: the amalgamation of the 5th generation of communication and IoT will enable real-time road monitoring, manage flows, and track congestions intelligently.
- Save energy: the combination of this tech will help cities save energy by building smart cities and smart homes, smart waste management and meters, becoming more sustainable, managing energy usage, and saving money.

The increasing number of objects and devices increases the volume of data generated and needs to be analyzed immediately to make smart choices or change the current decision. The IoT must improve its scalability and network capacity, better device battery life, and more comprehensive coverage area to achieve its vast potential.

The core features of 5G may fill the gaps of current tech to unlock the total capacity of IoT and introduce new use cases. Smart mobility will be one of the key areas of evolution of the 5G and one of the most important use cases under evaluation. Some key factors and technology of 5G for smart mobility are still under development.

3.1. Network slicing

A slice is a collection of network functions customized logically per the use cases and their service requirements. The network slices can be divided into four categories, as shown in Figure 3, according to the 3rd generation partnership project.

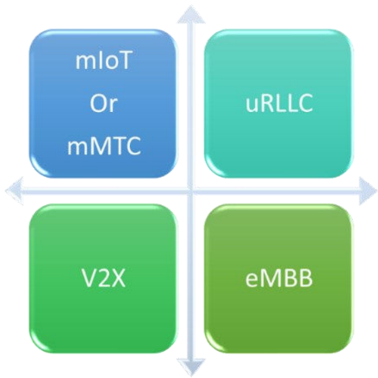

Figure 3. 5G types of network slices.

mIoT: Also known as mMTC, this slice enables many devices and sensors in a limited area. Its applications include low-cost and low-energy devices that generate small amounts of data, such as mass sensing and metering in smart cities. It is expected to support around 30,000 devices per cell, has low device complexity, and has a battery life of 10 years with an AA battery.

Authors in [34] surveyed how 5G can be one of the key factors driving the IoT application for Smart cities. It represents the status and analyzes the current 5G- IoT technology trials providing useful insights on services of innovative infrastructure on multimedia IoT.

uRLLC: often referred to as critical communication, this slice is one of the most innovative sections of 5G development. It supports communication that requires low latency and high reliability. It provides 1ms of packet delivery time and a loss ratio of 105, facilitating technology such as virtual and augmented reality, ITS, and automation.

eMBB: this enables high data rates and coverage for densely populated areas. It is expected to connect one million devices/sq.km with a downlink of 300 Mbps outdoor and 1Gbps indoor, and 1Tbps/sq km data traffic volume.

V2X: Vehicle to everything enables intelligent transport systems connecting vehicles to its surrounding, roads, units and walking pedestrians. The use cases of such technology can facilitate a data rate of 10-1000Mbps range, with a reliability of 90-99.999% and latency between 3-500 ms with a range of communication 50-1000m.

3.2. 5G for ITS: Vehicle-to-everything

With the various types of slices of 5G technology, ITS can enhance its operations towards smart mobility to solve all transport problems and ease transit in all parts of the city. Automobile technology is moving towards making the industry of vehicles that are aware of their physical surroundings with the use of advanced sensors and computing. The sensor platform transmits and receives data. This industry needs a communication framework that includes ultra-reliability, high mobility, extremely low latency for emergency signals and warnings, high data rates to share data among cars and surroundings quickly, and better scalability.

Vehicular communication can be categorized into four types: vehicle-to-vehicle known as V2V, vehicle to infrastructure(V2I), vehicle-to-pedestrian (V2P), and vehicle-to-network (V2N), which are together known as V2X. V2V is communication between vehicles sharing sensory data such as speed, position, direction, etc. V2P is sharing information between cars and pedestrians to inform about locations, directions, etc., to avoid collisions and accidents. V2I is between vehicles and their surrounding infrastructure, such as roads and road units called Roadside Units (RSU). It acts as a forwarding node for communication to expand the range of messages that can be received from a car. V2N is communication between a vehicle and the network application server, providing facilities like sharing media or managing routes or general apps.

Technologies like cloud computing, edge computing, and sensors advancements are crucial for this industry. All these vehicles are to be mounted with sensors, which are surrounded and navigated, in addition to performing usual driving functions. Such vehicles are known to be autonomous and are called autonomous vehicles AV, which is a part of the Future ITS. 5G can help achieve the goal of autonomous vehicles by supporting these emerging technologies with high data rates and connecting many vehicles, infrastructure, and sensors sharing information in real-time. It will also aid the automotive industry with robust connections and improved coverage area with high performance to avoid collisions and accidents [35]. The 5G Automotive Association (5GAA) states that developing ITS through cellular networks is comparatively cheaper than through RSU [36]. The vehicle to everything (V2X) has numerous applications, as shown in Figure 4.

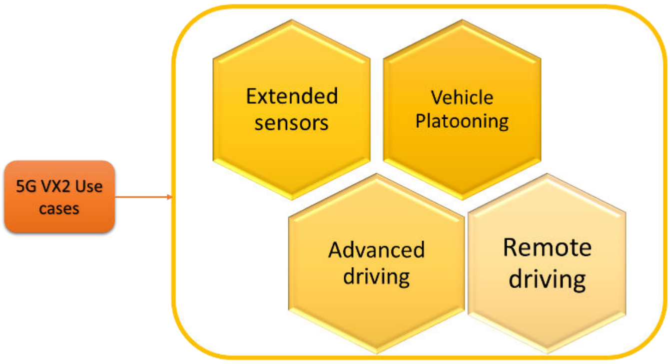

Figure 4. 5G VX2 Use cases [37].

Vehicles platooning: This forms a group of vehicles that are coordinated together to improve the capacity of the road and energy efficiency, decrease the number of accidents and allow drivers to do others to enhance productivity. All the vehicles in this group communicate with each other by sharing data and can operate autonomously. The platooning concept needs support in terms of joining and leaving the platoon: the vehicles need to join and leave while the platoon is active and support signal and warming communication while leaving and joining, announcements: inform the surrounding vehicles about joining and leaving operations to ease the function without disturbing the rest of the platoon and lastly messaging system where vehicles can share info about the speed, brakes, routes and other changes within the platoon architecture.

The platooning concept needs many V2V communication requirements to fulfill the mentioned operations, such as a platoon with the least level of automation must have an edge communication latency of 25 ms. In comparison, the one with the maximum level of automation needs a latency of 10 ms. Message reliability is 90% for the group with the lowest automation and 99.99 percent for the group with the most automation. A relative longitudinal position precision of 0.5mis is necessary for platooning near the vicinity, and messages need to be transmitted at a rate of 10 to 30 per second [37].

Remote driving: a driver or operator can control vehicles remotely using cloud-based apps via the vehicle to network communication. This function is used when vehicles cannot make decisions or proceed like blocked roads, near constructions, extreme weather, or unexpected situations where the car has no experience in making decisions on its own. Autonomous vehicles learn and operate based on experiences and information provided to them. So, the vehicles can use remote assistance in cases where the cars have not experienced a certain situation or abnormalities. Remote driving can also help people who need help in driving or are not allowed to drive, such as old age groups and youngsters.

Public transportation with well-designed and planned routes can use remote driving. It can also reduce the cost of autonomous vehicles, requiring fewer sensors and devices since the car is being monitored remotely. Remote driving requires 1Mbps downlink and 25 Mbps uplink data rates with 99.999% reliability and edge latency of 5ms, and speed of message exchange of 250kn/h between vehicle and applications.

An extended sensor is the vehicle's capability to share data between vehicles, applications, pedestrians, and the RSU that cannot be accessed by the sensors mounted on the vehicle. So, the automobiles that can detect and process these objects send these data to other vehicles for assistance in providing complete information about the area. These can be pictures or videos. This creates a sense of situational awareness for the vehicles to picture the entire environment, enabling them to position themselves correctly and cooperate with other autonomous vehicles. The type of data shared can be weather conditions such as fog or Nonline of sight information. Groups of low-degree automation need 100 ms edge latency with 50 ms latency for videos; larger ones need 3 ms and 10ms for video and 99.999 % reliability for messages. Advanced driving allows full or semi-automated driving where every vehicle shares information from its sensors with its neighboring Vehicle or RSU to coordinate the paths taken. This makes it safer with fewer accidents and enhanced efficiency.

3.3. MEC

The next generation of communication would require multi-access edge computing that allows the cloud computing to be located near the users within the Random Access Network (RAN) to decrease congestion in the particular network and enhance the application's performance. Data from various sources, such as vehicles and their surroundings, can be processed more accurately. It enables driving vehicles to make smart choices. This environment was characterized by ultra-low latency, high bandwidth, and real-time access to the RAN information that can be leveraged by the applications [38].

3.4. Multi RATS

All vehicles need to be mounted with multi-radio access technologies that make it a mobile gateway available for V2I and V2V communications, limiting the drawbacks and complementing the benefits. A new concept named visible light communication is under study for V2V and V2I operations and will bring new opportunities to the vehicular communication industry [39]. It is said to bring lesser interference and more robustness against jamming as compared to conventional Radio frequency-based networking. It may save energy as the two tasks of vehicular communication (communication and guidance for traffic) use the same energy.

3.5. Access point densification

As the number of smart vehicles increases, the demand for better coverage and capacity increases. The network infrastructure needs to modify and add new small cells to complement the markets. Many vehicles can behave like self-deployed cells in case of unavailability in the public network infrastructure in cases of emergencies. This introduces many cell layers that need to be coordinated among the cells to use the resource effectively. One way to limit the complications and overhead of signaling is eICIC-enhanced intercell interference coordination. In this, a small moving cell is considered, deployed whenever and wherever it is needed by the users, which works on the same area of the macrocell using the same channel. The two cells divide the resources based on time slots allocated to them or in joint mode. The system capacity is maximum when the joint allocation works suitably. Figure 5 shows the working of such a system.

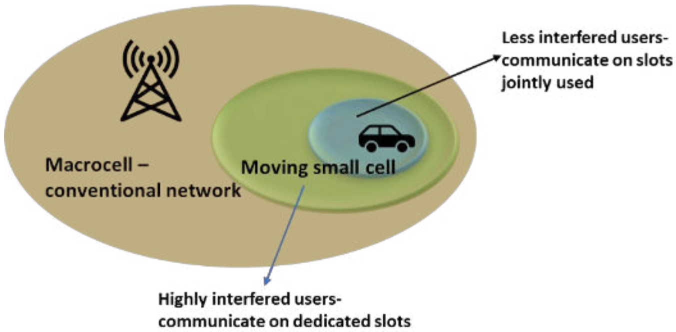

Figure 5. eICIC representations [39].

5G + IoT will come with endless innovations and opportunities that will make the smart cities a reality.

4. Technologies used in the 5G PHY layer to enable 5G-IoT

Many features such as MIMO, HetNets, and COMP standardized in LTE are employed in 5G, including additional features of 5G, which are explained below.

4.1. massive-MIMO

The massive MIMO (multiple input, multiple output) is one of the integral parts of 5G technology. The M-MIMO in macro aided small cells is used in the 5G RAN. Within macro cells, the control plane communicates using an omnidirectional antenna at lower frequencies, while the user plane communicates with a highly directional M-MIMO beam at mm-wave frequencies. The massive MIMO transmits multiple narrow beams simultaneously to the same mobile station from a position of the base station in order to decrease the correlation and enhance the throughput across the elements of the antenna, enabling the use of distributed MIMO.

The MIMO technology increases the spectrum efficiency by utilizing arrays of several antennas and frequency slots that can simultaneously serve many devices and users. It uses the TDD mode and reciprocity mechanism between uplink and downlink channels, proven to be more practical, having around 100 times their radiations and enhanced capacity with maximum protection over jamming and interferences with a significant delay reduction causing low set up cost and lower power needed. This integral part of 5G can help connected cars communicate better with an efficient spectrum and reduce set up cost. Many researches are under study for the utilizing massive MIMO for connected vehicles [40].

Authors in [41] describe a potential solution of using an additional antenna named: predictor antenna" for the challenge of short-term fading in fast-connected vehicles, which enables the prediction of channel between Massive MIMO and the car. The predictor antenna will predict the channel ahead of time. Based on several drive tests and measurements of the channel, the researchers showed the possibility of this theory for Massive MIMO downlinks to predict the complicated OFDM channels accurately. Authors in [42] suggest using mm-wave MIMO for Vehicle to infrastructure networks. They show that this technology can provide Gbps data rates for communication by using data rate, power delay profile, path loss, etc., as the metrics to characterize the communication channel.

4.2. Heterogeneous networks (HetNets)

It is a network comprised of several cells or cell tiers, namely femtocells, picocells, macrocells, microcells, and RATS. It aims to provide efficiency in the spectrum and energy utilization in 5G by reusing it and using low power transmission for both uplinks and downlinks. This network is highly suitable for IoT enabled by 5G as it supports a large number of devices and node density by using enhanced intercell interference coordination (e-ICIC) and further enhanced ICIC (FE-ICIC) [43].

Authors in [44] proposed a technique for efficient handover using PMIPv6 and IEEE 802.21 Media Independent Handover (MIH) standard with additional MIH primitive. It indicates if and where a handover is to be done soon to overcome mobility management issues in 5 G Wii/LTE-A heterogeneous networks. The evaluations show a reduction in path loss, handover delay, signal overheads and handover blocking probability by using this approach.

4.3. D2D communications

The device-to-device communication provides efficiency for a short range of less than 200m with low power consumption, load balancing, and better QoS. The base station has either full or partial control over the resource allocations, destinations, and nodes. Authors in [44] describe device-to-device communication into four categories:

- Device relaying with BS-controlled link information.
- Direct D2D communication with BS-controlled link
- information.
- Device relaying with device-controlled link information.
- Direct D2D communication with a device-controlled link Information.

Besides D2D human centric communication, vehicle-to-vehicle communication is one case that can focus on better D2D communication for smart mobility. Authors in [45] introduce two methods for smart mobility management to rescue the effects of huge delays and extra signal overhead issues by controlling the control handovers and cell selection during the mobility of D2D users.

- D2D-aware handover solution approach allows the first base station to delay handover to the second base station until the former's signal quality deteriorates below a predetermined D2D control condition, specified as the minimum signal strength needed to sustain device-to-device control.
- D2D-triggered handover solution suggests that users of a D2D unit be grouped/clustered within a small cell count or Base stations to reduce system signaling overhead imposed by cross-BS information exchange.

4.4. Coordinated multipoint processing (CoMP)

It is a dynamic transmission and/or reception coordination solution that aims to improve the system's performance and end-user quality of service by coordinating transmission and/or reception at many geographically dispersed locations. It is a useful way to enhance the throughput of the cell edge users. It uses dispersed MIMO from antennas that may not necessarily belong to the same cell to reduce spatial interference and increase the quality of the received signal. Such a technique successfully increases cell edge coverage and reduces interruptions associated with jamming and channel conditions when used with MU-MIMO [46]. Authors in [47] propose a CoMP uplink transmission methodology for communicating between each IoT node and the coordinating base station. The performance is examined in K tier heterogenous network to evaluate accessibility and average rate by using stochastic geometry, taking power capacity and charging rate into account, resulting in the simulations matching the analytical results.

4.5. Carrier aggregation

It's feasible the mobile device will receive more than one carrier component while using carrier aggregation (CC). Several CCs with various bandwidths can be aggregated in the uplink and downlink. Still, the number of aggregated CC in the uplink cannot exceed the number of aggregated CC in the downlink. Intra-band carrier aggregation is when the CCs are in the same band, while inter-band carrier aggregation is when they are in different bands. Contiguous and non-contiguous component carrier aggregation are both conceivable in each type of carrier aggregation.

4.6. *Centralized radio access network (CRAN)*

The CRAN is another idea for cleaner and greener communication by dispersing base station operations. The Base Stations, which are wireless radio units or remote radio heads, are only given radio functions. The cloud-based central processor receives other units, such as baseband units (BBU). At the BS end, this allows for centralized intelligence, cooperative communication across cells, enhanced cell utilization, and reduced complication and expense [46].

5. 5G Network layer technologies to enable 5G-IoT

5.1. *Software-defined wireless sensor networking (SD-WSN)*

Considered one of the 5G enables, SDN's main goal is to decentralize the control logic plane [48] and enable a standardized system of programming the network. As the number of devices increases, SDN can help achieve a constant Quality of Service and ease network administration concerns, deployment, and allocation of resources, thus becoming an enabler for 5G.

5.2. *Network function virtualization (NFV)*

It is a concept of virtualizing the network functions that can be integrated as softwares to use as requirements for network services. It comes from installing virtual machines on different OS using the same server. Its capacity to provide network scalability, network slicing over distributed cloud real-time processing, and heterogeneity maintenance makes it one of the key technical enablers for 5G-IoT. It is also shown as a cost-effective and energy-efficient technology and hence is being under recent study for the deployment of the 5G network.

5.3. *Cognitive radios (CRs)*

The CR helps to handle the increasing number of devices, massive connectivity results in scarcity of spectrum and the challenge of efficient resource utilization by efficiently using these spectrum resources. The cognitive radio can be defined as a radio that can change its parameters based on its interactions with the environment it deals with [48]. It allows the cognitive capability to capture spatial variations with reduced interference and reconfigurability, which provides programming dynamically according to the environment. Thus it can help in transmitting and receiving at different powers, frequencies ad modulation techniques, dynamic protocols, and technologies based on the hardware used [49].

6. Architectural view of 5G-IoT

Scalability, virtualization, densification, cloud services, mobility control services, radio access control, resource allocation efficiency, and enormous IoT data analysis tools are all aspects that must be included in a 5G infrastructure. As needed, a self-configurable Heterogenous Network should be included in a 5G-IoT-based architecture. The central infrastructure of 5G is made up of a front-haul, mid-haul, and back-haul network. The front-haul network connects the remote radio-head (RRH) to the BBU. Backhaul is the connection between the BBU and the core wired network, which is commonly made up of coaxial cable and/or optical fiber. The connection linking RRH and the next link is known as the mid-haul. The radio network and network cloud are the two logical levels of the 5G cellular network architecture [46].

7. Challenges for 5G enabled smart mobility

Along with providing high data rates and massive connectivity, the 5G will have to cater to many challenges on its way. The first is security and ease of connectivity. In the coming era where all the devices will be connected, and each and every information will be shared through the network, the 5G communication has implemented strong security protocols with easy connectivity as well. It needs to be able to predict and prevent malicious and unauthorized networks and nodes that may capture sensitive data or break into the network and stop data flow. Disconnection in smart mobility and data leakage can be highly risky as vehicles, and transport systems may damage themselves or people or disrupt transportation if the IoT system does not take the right decision at the right time. 5G needs to implement strong coordination and association with intelligent devices to protect the network's security. Software and intelligent systems can provide safer communication for the 5G enabled mobility.

Most of the traffic generated by IoT devices is in the uplink with smaller sizes but is sparsely distributed and generated very quickly. These devices may be limited in energy and resource; thus, choosing the right intelligent system and parameter is highly important.

As the number of devices increases, the number of data increases. The network should be able to communicate this volume of data without disruptions and order with minimum latency for analysis. Thus, an intelligent system and management can help deal with large data. 5G needs to focus on providing security, privacy, massive connectivity, and energy-efficient systems to make smart mobility possible. Using AI technology in the 5G enabled smart mobility for making decisions can help achieve this by intelligently taking divisions, predictions and accurate analysis and configurations of the system as the situation requires.

8. Conclusion

Smart mobility can be described from different perspectives according to researchers based on specific domains. This paper provides an overview of what a 5G enabled smart mobility is and what futuristic smart mobility can be with the use of 5G communication. The amalgamation of IoT technologies and the massive connectivity, reliability, and low latency can make communication much faster and more reliable for the automobile industry. This study reviews various aspects of smart mobility, research done in the areas, and the 5G features that are useful for

IoT. Lastly, smart mobility in the city is covered in detail. Every aspect is evolving from sensors to devices to software, making it possible to communicate smoothly. Within the scope of this study, some challenges of the 5G that it can face while being an enabler for the IoT technology are discussed. The 5G technology can be one of the key technologies making it possible to deploy IoT infrastructure in the cities.

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