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Impact of 5G Technologies on Smart City Implementation

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Abstract The concept of "Smart Cities" is very important as it aims to uplift the living standards of the residents by greatly improving the City's Infrastructure, Traffic management, Governance, Water and Waste management, Power management, Health systems, Safety and Security systems, Education systems etc. This paper describes the concept of Smart Cities and enumerates its various benefits. It describes various Services and Applications required to make a City Smart and the role of ICT technologies in their implementation. Further, the challenges in the current ICT systems are discussed in their role to Smart City implementation. The paper discusses the proposed features of 5G technologies and describes how 5G could be the best answer for successful, implementation of Smart Cities. It lists down a few Smart City Use Cases which are enabled by 5G. 5G will act as the backbone of IoT and pave the way for the development of Smart Cities.

Keywords Smart Cities · 5G technologies · Internet of Things (IoT) · Machine 2 Machine (M2M) · Information and communication technologies (ICT)

1 Introduction

The concept of 'Smart Cities' has become very important in developing economies. Here, we look at what exactly is a Smart City and why they are needed. The Services and Applications which are needed to be implemented to make a City 'Smart', is described in detail.

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1.1 Smart Cities: Definition

There is no universally accepted definition of a smart city. It means different things to different cities. The conceptualisation of Smart City, therefore, varies from city to city and country to country, depending on the level of development, willingness to change and reform, resources and aspirations of the city residents. A smart city would have a different connotation in Brazil than, say, Europe. Even in a country, there is no one way of defining a smart city. The definition is constantly changing due to technology innovation. A city is a complex system, involving many different domains, infrastructures, organizations and activities. All of these, needs to be integrated and work together effectively for that city to become Smart.

A Smart sustainable city can be considered as an innovative city which uses multiple technologies and other means to improve the efficiency of the city's operation and services, thereby enhancing the quality of life of its citizens and ensures sustainability with respects to economic, social and environmental aspects [1].

A Smart sustainable city should have forms of Smart ICT infrastructure, Smart mobility, Smart living, Smart economy, Smart environment, Smart governance and Smart citizens. It is about integrating solutions, providing interoperability and cohesion among systems within a city in full collaboration with all stakeholders involved.

The fundamental objective of a Smart City would be to ensure that the residents are assured of adequate water, power and gas supplies; good sanitation facilities, reliable and fast urban transport to ensure that they can reach their destination quickly and safely. It should provide good governance and ensure that the residents are involved and participate in decision making process. It should ensure the safety and security of residents at their homes and elsewhere including public places like streets, bus stops, train stations, airports, shopping centres, places of worships etc. It should enable residents to have access to quality healthcare and education even in remote places [2].

1.2 Need for Smart Cities

Cities are referred to as engine of economic growth. We see that there is a worldwide tendency of mass migration of people into cities, due to availability of work, health and education facilities. This adds to congestion of cities and there is an increased pressure on resources, increasing demand for energy, water and sanitation, as well as for public services, education and health care. Cities have to become more efficient and get smarter to handle this large-scale urbanization and has to find new ways to manage complexities, increase efficiency and reduce costs. The ultimate objective has to be to improve and enhance quality of life for its citizens and ensure its sustenance.

Smart City technologies can expand services to currently underserved communities, by providing remote health management, remote education delivery, better water and power distribution, efficient waste management etc. [3].

1.3 Smart Cities: Services and Applications

The services and applications that make a city 'Smart' can be classified as those required for improving the city's infrastructure, those required for enhancing the quality of life of residents by ensuring better social and economic well-being, and those required for better city governance.

1.3.1 Services and Applications for better City Infrastructure

The city's infrastructure design should, at the minimal, ensure that adequate water, power and gas is delivered to the residents and waste is collected. It should also ensure that there are proper roads with good street lighting, proper public transport systems and the traffic is efficiently controlled and managed to allow smooth transit of vehicles.

Apart from providing the basic power to homes, Utility companies are required to communicate with and control the customer premise equipment, for real-time monitoring of the usage, so that the entire city supply can be efficiently balanced and controlled. This brings the smartness to the service. Residents should be allowed to generate power through renewable sources like roof-top solar, so that the internal needs are taken care of. They should be able to connect the extra power generated back to the grid and should also be able to earn revenue for the same. This would vastly address the growing demand for -power in developing cities.

Water supply to residents should be of good quality and there has to be systems to monitor the water quality at various points of supply—at storage reservoirs, distribution centres and at the end consumer premises. It is very important to ensure water is of good consumable quality. The supply should be reliable and the utility companies should be able to monitor the pressure and flow in real-time and be able to accurately detect water leakages. This would lead to improvement in revenue collections for the Utility company.

City governance should implement efficient Waste Management system, which can monitor and control the waste collection and disposal by tracking and directing the waste collection utility vehicles. Proper methods for waste segregation needs to be in place.

Public transportation should integrate all modes like buses, trams and metro trains, so that single ticketing can be made for all modes. There should be proper systems of announcement of timings at all stations, to ensure that commuters have just-in-time access to departure and arrival times.

A smart city should be able to manage its traffic very efficiently without creating traffic jams anywhere. The traffic flow has to be very smooth. The traffic light signalling system should be integrated with other services like ambulances and police to enable easy passage to them during emergencies.

The street lights should be adequate and efficiently managed so that they can be automatically turned on/off by sensing the users in the street. This would lead to energy savings.

1.3.2 Services and Applications for Better Social and Economic Well-Being of Residents

The Services and Applications for city's infrastructure improvement will also have a positive impact on the social well-being of the residents. In addition, aspects like safety and security, access to good health and education is also very important to their better social and economic well-being.

One of the problems faced in urban cities are increasing crime, social and religious unrest and fear of terrorist attacks. Requirement is to monitor the city, identify trouble spots and take preventive and corrective measures. This may include 24×7 video surveillance of streets, public places like passenger stations (bus/train/airport etc.), shopping centres etc. and intelligently analysing them to detect criminal activities. Even ability to identify individuals in a crowd, becomes necessary. There is also a need for integrating

this data with data from other sources (like driving licence, passport, student IDs etc.) for comparison and taking quick action. Homes should be made secure by providing 24 × 7 security through remote surveillance and control.

There should be quick access to healthcare, even for residents who are not close to hospitals by providing systems for remote health monitoring. This is very important for elderly and infant care.

The energy usage in homes needs to be smartly managed by controlling of light and other appliances and integrating it with the home security systems, leading to Smart Homes.

Education opportunities should be made available to all, irrespective of distance to the teaching institutions, be enabling high speed remote access of class rooms. This would encourage people to study and increase literacy and enable better job opportunities.

1.3.3 Services and Applications for Better Governance

City governance should implement systems to enable resident's active participation. Various public service systems should be integrated to get a holistic view of all services by understanding their inter-relationships. Crime tracking and detection systems should enable faster response by police. Disaster management and emergency response systems should integrate hospital systems, ambulance systems, fire engines and emergency towing systems.

Governance systems should enable transparency and ease of use in all its service like payment of taxes, property registrations, payment of utility bills etc.

Figure 1 shows various city's utilities, like power/water/waste management/transport/crime/etc., having their own independent services and applications. These services and applications do not interact with each other.

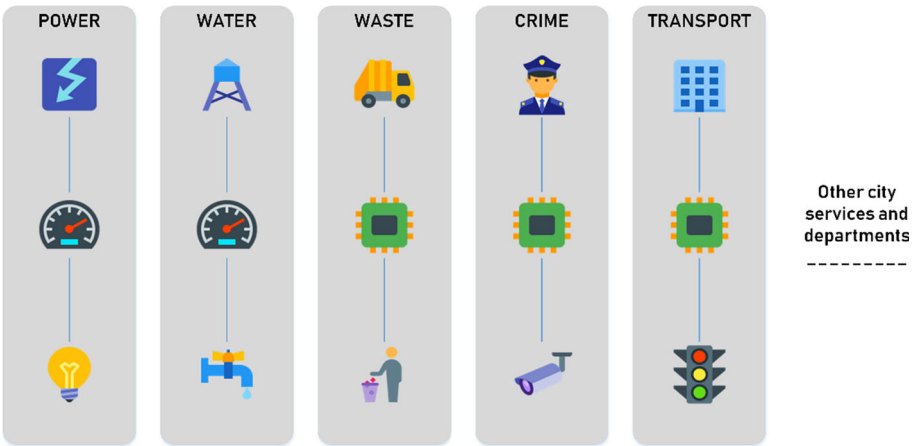

Fig. 1 Independent city services and applications

2 Smart Cities: ICT Requirements

Information and Communication Technologies (ICT) are crucial for successful implementation of Smart Cities. Connectivity and control are key to Smart Cities, which are enabled by ICT. ICT performs remote control and management of all elements needed in the Smart City ecosystem. ICT becomes an integrator of various services and applications, giving a central control and command structure to the City Governance. Huge amount of city data has to be collected and analysed in real-time to enable appropriate response. In this section, we look at how ICT enables a Smart City by analysing its requirements and components.

2.1 Smart City Enablement by ICT

The basic enabling infrastructure of Smart Cities, is the connectivity of the city. Smart cities would include a very large number of IoT applications, wherein billions of low power digital devices like, sensors and actuators, have to be connected by fixed or mobile network technologies. Connecting such billions of devices over fixed wiring is very cost intensive and nearly impossible and mobile networks are the only way for this. The communication world will a have huge shift towards machines rather than humans. It is easier to attach SIM cards to devices and then connect them via a wireless network to some controlling infrastructure, which could be based on optical fibre based fixed networking. This is fundamental to IoT applications on Smart Cities.

2.2 ICT Requirements for Smart Cities

We can classify the ICT requirements of Smart City under the following categories:

- Enhanced mobile broadband: High speeds measured in Gbps,
- Massive IoT: Low power consumption, low cost, and the use of low-frequency spectrum bands to provide broad and in-building coverage.
- Ultra-reliable communications: High reliability, high availability, and low latency down to 1 ms end to end.

IoT is emerging as one of the primary requirement for Smart Cities. There is growing awareness of the transformational impact that IoT can have on Smart City implementation.

The entire city has to be inter-connected with monitoring and control devices. Key places and points have to be identified. Depending on the controlling method, suitable sensors, cameras, actuators etc. have to be installed. These monitoring devices would generate huge amount of data, which needs to be collected and aggregated in a suitable method. They should then communicate with back-end systems which analyse these data and take appropriate control action or feed these data to other applications for suitable response. The backend systems should be able to control the devices through suitable actuators. Thus, detailed real-time knowledge of the city should be available to the City governance.

Different agencies including technical systems, in the Smart City eco-system should be able to access this information in real-time, analyse and act on it appropriately. This would result in the overall effective governance of the city.

2.3 The ICT Components of a Smart City

The different technologies and systems that are used to build a Smart City are as below.

The basic ICT component consists of a Sensor web in the city, wherein all points which needs to be monitored and controlled are installed with CCTV cameras, sensors, RFID tags, Mobile devices, embedded SIMS, actuators etc. These points could include traffic junctions, bus stands, train stations, utility poles, water supply lines etc. These would be connected to sensor/device aggregators which are further connected to wireline or wireless communication networking devices like routers/switches, for controllers for data acquisition and control.

Communication Networking technologies provide the infrastructure of the smart cities to make all the devices, computers and people have convenient, reliable, secretive communication paths with each other. This includes wired, wireless and satellite networks; M2M connectivity; Home Area Networking, Personal Area Networking, Local area networking, Metropolitan Area Networking and Wide area networking.

Availability of data and information in real-time, across various vertical applications, are very important to the success of Smart City. This should be available under any conditions manually to City officials or automatically to any systems which need them, so that appropriate action can be taken. This needs setup of advanced Data Centres and Cloud infrastructure, which integrates different city applications to enable them to leverage and make use of value provided by each other. Officials from different Verticals can make their decisions based on common data and this collaboration in vital.

High performance data analytics using advance Artificial Intelligence algorithms aided by Machine Learning, is a key enabler for Smart City applications as decisions have to be taken in real-time across various domains. This can involve understanding the current state of a system and predicting future state by predictive analysis. This can be used to perform "what-if" and "what-if-not" analysis for different parameters.

The Services and Applications across various verticals would include and not restricted to Smart Homes, Smart Buildings, Smart Security, Smart Transportation, Smart Education, Smart Healthcare, Smart Utilities, Smart Governance etc.

Finally, Integrated Management and Command Centre is required to provide a single interface to view all integrated city level information. These Command Centres do not imply that only one will be applicable to a city, but many smaller ones could feed requisite information along its various nodes.

Figure 2 illustrates integration of various services and departments of a city, enabling data sharing amongst each other as required to provide a holistic view and control of the entire city's functioning, making the city smart.

Thus, ICT is used to automate the city functions, enabling effective services delivery, whereby human intervention is minimized giving rise to transparency in the system. This would ensure that the players involved in Smart City including Citizens, Businesses, Government officials etc. would work cohesively together, leading to effective management of the city.

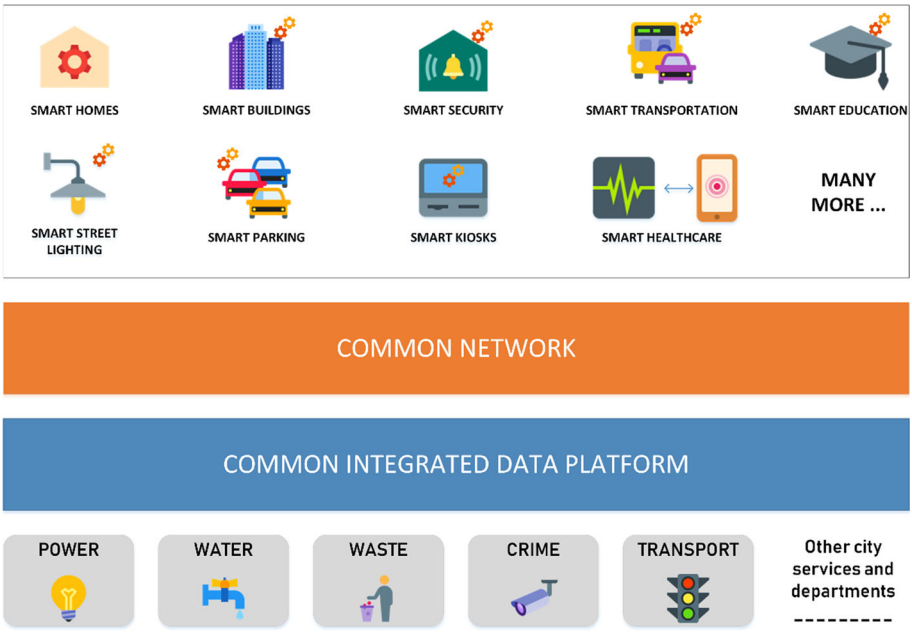

Fig. 2 Integrated smart services and applications

3 Current Limitations in Implementing Smart Cities

The implementation of Smart City depends on the way a City is financed, planned and operated. One of the limitations in implementing Smart Cities would be the reluctance of different government departments to share their data with each other. This is not the focus of this paper and this paper assumes that data sharing has been agreed and looks at the technology of interconnection for sharing of meaningful data to improve City's governance thereby enhancing quality of life for the residents.

Connectivity is key to the common infrastructure on which various applications are deployed, to allow data sharing amongst them. Networks requirements are Changing. Connectivity will be required anytime, anywhere and with anything. i.e. connectivity is required anytime (day/night), anywhere (indoors, outdoors, on the move) between PCs, Human to Human (H2H), Human to Thing, Thing to Thing and Machine to Machine.

This calls for a need for an effective Communication Network with reliability of greater than 99.9999, very little end-to-end delay of around 1mS, support of extreme density of IoT devices, very high bandwidth and support of longer device battery life. The current 3G/4G systems has limitations in meeting the above requirements.

4 What is 5G?

The current 4th Generation Long Term Evolution (4G LTE) system supports data transfer speeds up to 100 Mbits/s downloads [4]. Now, we are progressing towards Fifth Generation (5G). We are advancing towards more and more sophisticated and smarter technology.

5G can be described as a software-based communication network architecture [5], which can be dynamically programmed in order to provide the right control layer for a given application. This will facilitate new and diverse business use cases.

4.1 5G Features [6]

The proposed features of 5G has the potential to change the meaning of mobile communications enabling revolution in connected society.

- 10 Gb/s data rates to support ultra-high definition video and virtual reality applications.
- 10–100 times faster and have greater capacity than current 4G LTE networks. The increased speed and capacity will allow web pages, video, and other data to load faster on mobile devices, as well as enable various innovations such as remote surgery and smart cars that avoid collisions.
- Less than 1 mS latency.
- Seamless delivery of services across licensed and unlicensed spectrum.
- Always-on user experiences.
- Several billions of applications and hundreds of billions of machines.
- Energy-per-bit usage should be reduced by a factor of 1000 to improve upon connected device battery life.
- Supports "network slicing", which allows a Virtual Network Operator to define its own network architecture, enabling rapid roll out of scalable services at lower costs.

4.2 Enablement of Diverse Use Cases

5G would support both strict latency requirements of less than 1 mS for time critical applications and also relaxed latency requirements for applications which are non-time critical. It would also support diverse use cases providing both high levels of network reliability for stringent process control and relaxed level of network reliability for applications which are not very process sensitive.

It would also support diverse applications, which needs either high volume of information to be processed in real-time or those that requires only a low volume of information which can be requisitioned as required.

5 5G: A Technology Enabler for Smart Cities

IoT is emerging as one of the primary use cases for 5G. There is growing awareness of the transformational impact that IoT can have on a City's infrastructure, and hence the importance of 5G technology as an enabler of this process. The discussion of IoT is extending beyond applications, such as connected car and smart metering, to encompass the entire range of business activities across vertical industry sectors such as manufacturing, utilities, and the production of raw materials. 5G will create new possibilities for future Smart City applications. 5G will enable more and more devices to be connected to the internet irrespective of their location and time, which would further enable integration between different vertical applications [7].

5.1 Smart City Demand Drivers

Even though technology capability enhancement to 5G is possible, the decision of its adoption depends on the demand for the services enhanced and new services enabled and their utilization, along with their socio-economic benefits. The key drivers for increases in the City's mobile traffic, are the City's Residents, City's Governance and the City's Businesses demand for and use of the services on mobile network.

5.1.1 City Governance Drivers

City Governance main objective is to ensure well-being of its residents, by delivering adequate utilities like power, water, gas, sanitation facilities etc., in efficient and cost-effective manner. By improving operations and ensuring that there is no leakage of resources, revenue of various utility departments can be increased. By improving City's roads and transport systems, productivity of the Residents can be enhanced leading to increased tax revenues.

5.1.2 City Resident's Drivers

City resident's fundamental needs are to get reliable utility resources like water, power, gas, sanitation facilities etc., good transport system with assured personal safety and security. Going beyond this, Resident's would want to enjoy enhanced quality of life at home and elsewhere.

5.1.3 City's Businesses Drivers

Businesses in the City would want new opportunities created by enhancement of existing services or for new services. This would attract investments and would create employment opportunities for residents.

The above demand drivers would result in:

- Increasing mobile connections and data usage with increased use of data-based services like mobile applications, OTT services etc., as it will become necessary for all people to get digitally connected.
- Next generation communications and entertainment—Online Video for Smart homes and Security/surveillance requirements. Cisco forecasts that Global IP video traffic will be 82% of all consumer internet traffic by 2021 [8]. The youth population would increase, especially in some developing countries like India and Brazil. The so called 'Digital Natives' would be large demand creators of Video and high-speed communication services. Real-time Security and Video Surveillance at Home, Streets and Offices would have very great demand on Video communications.
- The real-time nature of the Services would require very high Reliability on the communication services. There can be absolutely no down-time for some mission critical services. So, the demand for the **'always on'** mobile services would be the norm.
- Business productivity enhances with increased mobility enabling employees to work from any device and from any location. This increased Citizen's productivity. So, there would be demand for people to work from any location at any time from any device.

- There would be a need for increased adoption of Cloud to support new services and enhancement of existing services.

5.2 5G: Smart City Technology Enabler

5G, with its advanced features as described in the earlier section, is well positioned to address the demands of the Smart City. The 5G features that enables IOT adoption on a large scale, required for Smart Cities are:

- *Device Connectivity* Serving a huge increase in the number of devices like sensors, cameras, actuators etc. connected to wireless networks. These are required in Homes, streets, traffic junctions, public places like bus stands, railway stations, airports etc. This will support Smart Traffic Systems, Smart Homes, Public safety, Security and Surveillance requirements of Smart Cities.
- Very large bandwidth is required to support both uplink and download of video rich services over wireless networks and to support high data volumes. This is supported by 5G.
- Ultra-low latency is required for enhanced user experiences potentially including the delivery of 3D images and holograms and for applications such as driverless cars. The latency of less than 1mS provided by 5G supports this requirement.
- The 'Always on' connectivity provided by 5G supports services in high mobility environments such as cars and high-speed trains and with ultra-high reliability requirements for driverless cars and traffic monitoring. 100 per cent geographical coverage is also required to support an intelligent traffic monitoring and management system and driverless cars. Many Healthcare services also require "always ON" function as an outage could have life threatening consequences.
- *Energy Efficiency* The massive increase in connected devices making up a fully formed IoT is likely to require better energy efficiencies than currently possible, with some mobile broadband devices required to be on all the time while others will turn on intermittently.

The highly scalable and contextual proposed nature of 5G networks could support the diversity of IoT and other applications required for Smart Cities, with differing requirements for pricing, mobility, latency, network reliability and resilience.

6 Smart City Applications and Services Enabled by 5G

Few smart city applications and services, which can be enabled or delivered more efficiently by 5G, are described below.

6.1 Smart Homes

A Smart Home has to satisfy the requirements of the residents while they are resident in the house as well as they are outside the house. The requirements include remote monitoring and control of the homes for security, surveillance and management of children and elderly. It has to have a Home gateway platform that accepts different technologies as its inputs, combines them and communicates with the centralized monitoring system.

Use cases in Smart Homes include remote Home security monitor and control, and remote control of home appliances like heaters, fridges, lighting systems, water sprinklers etc. Homes are expected to become massive sources of information and will generate large amount of data. They will be full of connected devices, not only providing information on their environment but also communicating with each other.

Mobile phone has emerged as the preferred medium of entertainment over TV, Movies, Radio and newspaper. Smart TVs, Smart Gateways, Games Consoles and even tablets would vie to be the main hub for delivery of entertainment content in the home. Ultra HD TVs will have become mainstream with hundreds of Pay UHD channels being available in addition to plentiful streaming UHD services. Homes will have a multitude of 'TV screens' and seamless transferring of content between those screens will have become a mainstream activity. "Over The Top" content would also be streamed on multiple screens. Expectation will be for instant download and play of a full-length film, which is made possible by 5G.

The large Device connectivity, high speeds, ultra-low latency features of 5G enables the above features.

6.2 Smart Education

The traditional way of education is disrupted by enabling learning anytime at anyplace. It may no longer be only classroom-based system. Connectivity and network-based solutions will become essential infrastructure. Massive Open On-line Courses, enabled by connectivity, will become the norm. Students will be able to choose their course of choice from global players. There is also a need to provide quality education to differently-abled people who cannot travel.

A **connected world** means that the majority of parents will be able to transparently follow, and be involved in, the learning process of their children. The constraint of physical class rooms will be removed and learning will become virtual with technology enabling virtual and augmented reality features.

The high speeds and ultra-low latency features of 5G enables the above features and pave the way for smart education.

6.3 Smart Health

5G characteristics that will support Healthcare use case, include:

- *Bandwidth and Device Connections* To support high data volumes and service an increase in the number of devices connected to wireless networks, such as health monitors, consumer devices and sensors.
- *Ultra-Low Latency* For applications such as remote surgery.
- *Always on Connectivity* With ultra-high reliability requirements for remote surgery and patient care and monitoring, and to ensure new remote healthcare services are available across metropolitan, regional and remote locations.

5G will have impact on improving the quality for the following remote Health processes:

- *Telemedicine* Through Audio and Video Conferencing.
- Tele Radiology.
- Remote patient monitoring using a Body Area Network (BAN) with wireless sensors, both on-skin and implanted. Sensitive parameters should be measured in real-time and reported to Doctor for immediate attention. Parameters like blood pressure, heartrate,

blood sugar, ECG etc. can be remotely monitored to manage diabetes, asthma and heart problems.
- *Telesurgery* Train local para-medics/surgeons to perform urgent/specific operations with instructions from remote located (even overseas) specialists who would be monitoring the operation in real-time.
- Interactive 3D Brain imaging.
- In emergency care like accidents, enable instant retrievals of Patient EMRs stored in network storage and cloud data storage, which can be lifesaving. The Para-medics in Ambulances and/or the doctors in Emergency sections in hospitals could make use effective use of this data for saving lives.
- Implanted microchips and sensors inside our bodies are the next logical step, at which point the body itself becomes deeply integrated into the surrounding networked ecosystem.

6.4 Smart Transportation Systems

Road accidents can be significantly lowered by deploying local warning systems through vehicular communications. Departing vehicles can inform other vehicles that they intend to depart the highway and arriving cars at intersections send warning messages to other cars traversing that intersection. Automatic braking when the car detects an obstacle will also likely reduce a significant number of rear-end collisions.

Some of 5G enabled Vehicles features includes [9]:

- Passenger infotainment requiring simultaneous high capacity and high mobility.
- Cars with built-in driver assistance systems based on 3D imaging and built-in sensors.
- Vehicles capable of detecting safety critical situations, such as accidents within reach of the car and other hazardous road conditions.
- Augmented reality dashboards which overlay information on top of what a driver is seeing through the front window, identifying objects in the dark and telling the driver about the distances and movements of the object.
- Remotely controlled or self-driven vehicles, taking control of all driving activity, requiring ultra-reliable and very fast communication between different self-driving cars and between cars and infrastructure. This is possible due to ultra-low latencies and ultra-high reliability offered in 5G.

The demand for the connected cars is increasing globally, as per a report by 4G Americas [10]. The cars shipped with connectivity features were only about 7% in 2013. The global car sales in 2020 is expected to be around 92 million, out of which 69 million will have connectivity features i.e. about 75% of cars shipped globally will have connectivity features.

Vehicle-to-Vehicle (V2V) communications comprises a wireless network where automobiles send messages to each other with information about what they're doing. This data would include speed, location, direction of travel, braking, and loss of stability. 5G technology with its specific potential feature of low latency, can enable Connected Vehicles.

Vehicle-to-Infrastructure (V2I) communications comprises a wireless network where automobiles exchange messages with roadside installed infrastructure or satellites, with information about what they are doing. This data would include speed, location, direction

of travel, braking, and loss of stability. 5G technology with its specific potential feature of low latency, can enable such communication.

With the support of such features, status information (e.g., position, speed, acceleration, etc.) or event information (e.g., traffic jam, icy road, fog, etc.) of individual vehicles can be sent to neighboring vehicles, or sent to a central point (base station, backend) where it can be aggregated and then again disseminated to other vehicles to make use of it. This can help in avoiding vehicle collisions at intersections and during lane changes and prevent rear end collisions. 5G could address this and enable such use cases.

5G will enable the next generation of mobility services including connected and automated driving.

6.5 Smart Safety and Surveillance Systems

Provision of safety and security to the residents is a very important role of smart city governance. There could be security threat from theft, riots and terrorism. This can lead to loss of human lives and can have adverse effect on the social life of residents.

Smart cities should have provision for real-time video surveillance and emergency response. City wide traffic surveillance cameras should allow viewing and recording of traffic conditions, and traffic accidents with greater clarity. Video surveillance at ATMs, Banks, Jewellery stores and isolated roads etc. are very important for safety of residents.

5G in Smart City will enable integration of real-time video observation with access to specific locations. This would enable facial recognition to detect known criminals or detecting a person in a crowd.

6.6 Smart Power

Smart grid technology will support accurate, real-time analysis of power consumed and power outages. 5G would enable additional low-cost device connections, so that detailed coverage of the energy grid could be made possible. With 5G, very large number of unconnected energy devices can be monitored and controlled in real-time to allow accurate forecasting of power demands, by their integration into the grid. This could help in load balancing and probable reduction in energy cost to the houses. Outages can be quickly resolved reducing downtime.

5G can enable Smart Street Lighting, as the multitude of devices and sensors in the street can track pedestrians or vehicles in real-time and lower public lighting during times when there are no pedestrians or vehicles in the street.

7 Economic Impact of 5G on Smart Cities

Smart City Solutions applied to management of power grids and vehicle traffic would result in savings and benefits of hundreds of billions dollars through reduction in energy usage, fuel consumption and energy usage. 5G solutions would enable cities to reduce commute times, improve public safety and generate significant smart grid efficiencies [11].

5G networks would be built using small cell networks and would involve 10–100 times more antenna locations than 3G/4G networks. Apart from delivering the high speed and capacities of 5G, these cells would support the increased number of devices that would be connected to the network of the future. Telecom Operators are expected to invest $ 275

billion in 5G infrastructure, which could create new 3 million jobs and boost GDP by $ 500 Billion [11]. The new 5G network infrastructure would itself create lots of jobs. Governments should support the installation of the new 5G infrastructure, as there is going to be a shift from the traditional tall telecom towers to small cell sites installed on lamp posts to utility poles. This may require change in the way the present permission process and fee structures.

According to a study conducted by the New Policy Institute, every transition from the current generation of mobile communication to a new generation, creates lots of new job opportunities in its installation and deployment and also from other services which are enabled from that generation [12] This would have a positive impact on the GDP.

8 Conclusions

The goal of the 'Integrated Vision" of Smart Cities is to improve the Citizens' Quality of Life in a sustainable manner. It is important that there is very good co-ordination amongst various multi-stakeholders in the Smart City eco-system, to make it successful.

Industry and service provides cannot relay on today 3G/4G wireless systems for providing the target immersive experience like Reliability, Short delay, Device energy efficiency etc. which are required for Smart City vision.

5G is essential for the implementation of IoT which forms the backbone of Smart cities and hence becomes enabler to the vision of Smart Cities. 5G will connect wireless networks to billions of devices, such as cars, home appliances, machinery, and wearable technology. Innovative localities will use Smart City technologies like connected sensors and data to provide municipal services more efficiently and effectively. Thereby, 5G will enhance the "Internet of Things" and allow Smart Cities to develop.

5G will disrupt value chains and enable new opportunities on an unprecedented scale for a successful implementation of Smart Cities. 5G could enable new opportunities in Smart Cities by creating employment due to its own network infrastructure implementation and also as a result of the new applications being enabled by it. This would result in enhanced economic growth increasing the annual GDP of the city.

Also, we can expect job losses in the conventional businesses due to the automation facilitated by 5G—Example—Autonomous vehicles replacing drivers, Automated parking systems replacing parking attendants, Smart Waste Management systems replacing many sanitation workers etc.

Faster 5G could expand high-speed broadband access to citizens of Smart City, who currently lack access to the service. 5G could increase these mobile users' access to high-speed broadband. But there is also a risk of this being not available to poor people in developing countries, who mainly live in slums. This could increase the divide between rich and poor, where rich, who can afford 5G services, can greatly benefit with new opportunities and this could be unavailable to poor people.

Smart City Governors should ensure that all citizens of Smart Cities are equally positioned to fully take advantage of new opportunities and enhanced services provided by 5G. Such services should be accessible and affordable by all. Also, clear rules on collection and use of citizen data should be established, to prevent misuse and protect privacy. They should adopt digital inclusion plans to ensure all community segments of the city equally benefit from the opportunities provided by 5G.

The full potential of Smart Cities can be unlocked by 5G networks, creating jobs and new businesses. 5G enabled Smart Cities can drive economic development and improve services and quality of life for all communities in the cities.

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