Open a New Horizon with 5G

How 5G will change our lives, industries and societies

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Technology Changes Our Lives

It has been almost a decade since 4G's commercialization, which has led us into a brand-new world where life without smartphones is unimaginable. Thanks to 4G networks, we are able to access various types of data freely, thus, smartphones have become a necessity which gradually integrated the functions of digital devices from times gone by (digital camera, MP3 Player, telephone, computer, games console, navigation, etc.) Lots of people question why 5G is being introduced when 4G networks can already satisfy a general user's requirements on every aspect, what changes will be brought by 5G's commercialization, and whether the changes will have enough impact to generate additional profits. Despite all these questions, the first 5G commercialization has come earlier than people's expectation. Governments are promoting importance of earlier adoption of 5G network. This paper focuses on what characteristics 5G when compared with 4G, and what changes will be brought to our lives and industries with the introduction of 5G.
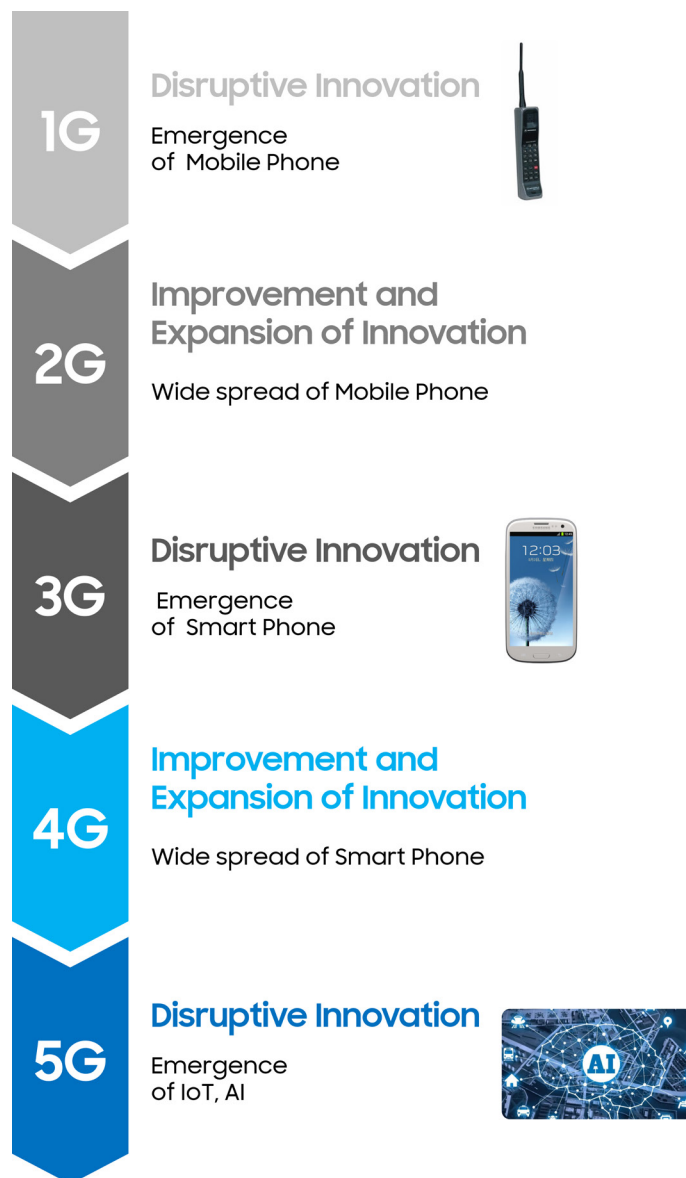
Revolution Brought by 5G

Evolution of Telecommunication Technology

If we look at how telecommunication technologies have evolved, odd generations (1G, 3G) have played a role of conceiving and giving birth to new disruptive innovation, and even generations (2G, 4G) have played the role of establishing and spreading the innovation from odd generations. Public did not really understand the necessity for wireless communication when the frist mobile phone came out, as the telephone seems fully satisfied the communication requirement. With those IT technology pioneers used mobile phone and led the trend, as subscribers accumulated, the value of telecom communication network is also gradually be acknowledged by the public.

Mobile phone spread across the world in 2G era. 3G added data service on 2G voice service, when most of people didn't know how to combine data service with our daily life. Later, with those diversified apps and contents, people noticed that with a small mobile phone, far more can be achieved by the network. As data usage increased, the requirement of high speed, high volume also emerged, and then, 4G solved this problem. From this point, 5G can be viewed as another disruptive innovation and will lead the next technology revolution.

By embracing IoT and AI, 5G is expected to go beyond the traditional smart phone centric telecommunication market. Rather than being described as a technology progress, 5G is marked as a more innovative technology because it integrates IoT. Based on network slicing technology, 5G networks can be logically divided for multiple network usages without really constructing a separate network for each purpose.

Network slicing provides mobile service operators a chance to be the new ruler in 5G era. As mentioned above, just as the smartphone integrated all other device functions, 5G is expected to absorb various connectivity functions (LPWAN, Cellular, WiFi, public network, broadcasting etc.), and help telecom service providers to generate new revenue in both telecom and non-telecom fields.

1G — Disruptive Innovation
Emergence of Mobile Phone

2G — Improvement and Expansion of Innovation
Wide spread of Mobile Phone

3G — Disruptive Innovation
Emergence of Smart Phone

4G — Improvement and Expansion of Innovation
Wide spread of Smart Phone

5G — Disruptive Innovation
Emergence of IoT, AI

(Source: The Bible of 5G, Dong Hyungshin, RSUPPORT)

Figure 1: Evolution of Telecommunication Technology

Three Characteristics of 5G Telecommunication

5G is a mobile communication technology 10 times better in performance compared to its predecessor. In terms of the capacity and data speed, 5G is comparable to high speed broadband connection. At the same time, 5G assures not only the low power IoT connections, but also service security even with massive devices connection.

There are three typical characteristics which makes 5G a revolutionary technology. These three characteristics are ultra-high data speed, ultra-reliability and low latency, and massive connectivity.

eMBB
Play ultra-fast with Enhanced Mobile Broadband

eMBB aims to provide exceptionally fast data speeds, anywhere from 100Mbps up to 20Gbps per user, to focus on services that have high requirements for bandwidth and antennas such as high definition (HD) videos, virtual reality (VR), and augmented reality (AR). For instance, downloading a 15GB (Giga Byte) High Definition movie will take 240 seconds via 4G at a speed of 500Mbps. With 5G however, at 20Gbps, the same movie will only take 6 seconds to download. The goal of eMBB is not just to provide faster transmission speed when you are near a telecommunication base station, but to serve at least 100Mbps data speed where the signal is weak (cell edge). Users in crowded areas such as airports and sports stadiums will be able to enjoy seamless HD streaming services.

URLLC
Feel real-time control with Ultra Reliable and Low Latency Communications

URLLC is aimed at providing real-time services that require extremely low latency and prompt responses such as remote robot control, autonomous vehicles and interactive cloud gaming. The delay time of tens of millisecond (1ms = 1/1,000 second) in 4G will be reduced down to one millisecond in 5G via wireless resource management and network architecture optimization. In 4G, a connected autonomous vehicle traveling at 100km/hour will receive an emergency brake order with a delay time of 50 milliseconds(ms) - meaning the vehicle will stop after traveling 1.4m. With 5G however, the delay time will only be 1ms, and the vehicle will stop after traveling just 0.028m. (Please note that the example does not represent the stopping distance per-se. Rather, it indicates 'by when' a vehicle will start 'applying' the brakes.)

mMTC
Connect everything with Massive Machine-Type Communications

The goal of mMTC is to create an environment where a million IoT sensors and devices within 1 km^2 can be connected. mMTC aims to meet the demands of a highly developed digital society and focuses on services that require high connection density such as smart cities, factories and precision farming.

Revolution Brought by 5G

With the 3 characteristics of 5G mentioned above, 5G is expected to make a huge impact on the whole industry and society beyond the lives of individuals. First of all, we will take a glance at how 5G will change our lives.

Personal Welfare will be Improved by 5G

At the beginning of the 5G era, most services will be provided by the ultra-fast eMBB, which is 20 times faster than 4G networks. How our lives will be changed by this technology? In the initial stage of 5G, major use cases will start form the personal life, from using VR, AR and UHD streaming service. And all of those service need high speed broadband.
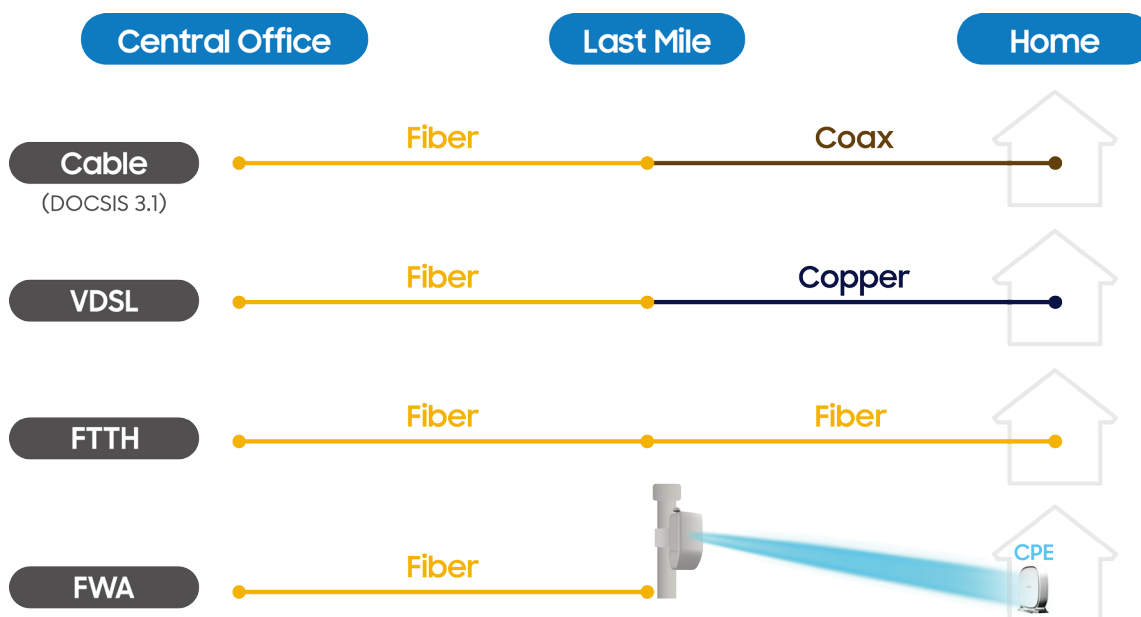
Ultra-Fast Wireless Broadband

Figure 2: Fixed BB Access VS Wired BB Access

Broadband access is vital to socio-economic development. However, deploying wireline broadband networks requires high capital expenditure and mid- to long-term investment. In particular, a few hundred meters of last mile deployment has been a major obstacle for wireline broadband technologies. A solution to this time consuming and costly last mile deployment is Fixed Wireless Access (FWA). FWA is an innovative solution which enables easy and rapid deployment of broadband networks. It allows carriers to meet the increasing demand for high speed broadband services' time to market in a more cost-effective manner.

FWA solutions using LTE or WiMAX have been around for many years but their speeds are not nearly as fast as other high-speed broadband solutions such as fiber. Fortunately, with the introduction of 5G, the speed of FWA is now comparable to fiber.

In the United States, Verizon started to provide the first 5G FWA service in October 2018 under the brand name 'Verizon 5G Home'. 5G Home will deliver typical network speeds around 300 Mbps and, depending on location, peak speeds of nearly 1 Gbps, with no data caps.

Mobile Cloud Gaming

Gaming has always been a killer application from the past PC era to today's smartphone era. From the Snake game of 2G, to Angry Birds in the 3G era, to 4G data killer game PUBG (Player Unknown's Battlegrounds). In every generation, games required faster processers, higher quality of display and higher graphics performance. Without the mentioned above, it is impossible for players to have a smooth gaming experience.

Every technology innovation has brought about industry shifts, and the transformation brought about by 5G and cloud computing are more prominent. Compared with these traditional PC games and mobile games, cloud games is a totally innovative model which not only is it a cost effective solution for players as it eliminates the need for hardware upgrade,

but also provides whole new experience to players by breaking the barriers among various terminal restrictions and the limitation of time and space. As long as a player has a device that can be connected to the internet, he or she can play masterpieces anytime and anywhere just like playing a current web game by simply logging in online.

High quality gaming needs gigabit throughput, and near zero latency of data transmission. 5G has flattened the experience of cloud games under wired conditions and wireless conditions. In the past, it was difficult to achieve a fiber-optic broadband gaming experience under wireless enviroment, but now 5G will dramatically improve bandwidth and latency. This allows players to experience fiber speeds on their mobile devices.
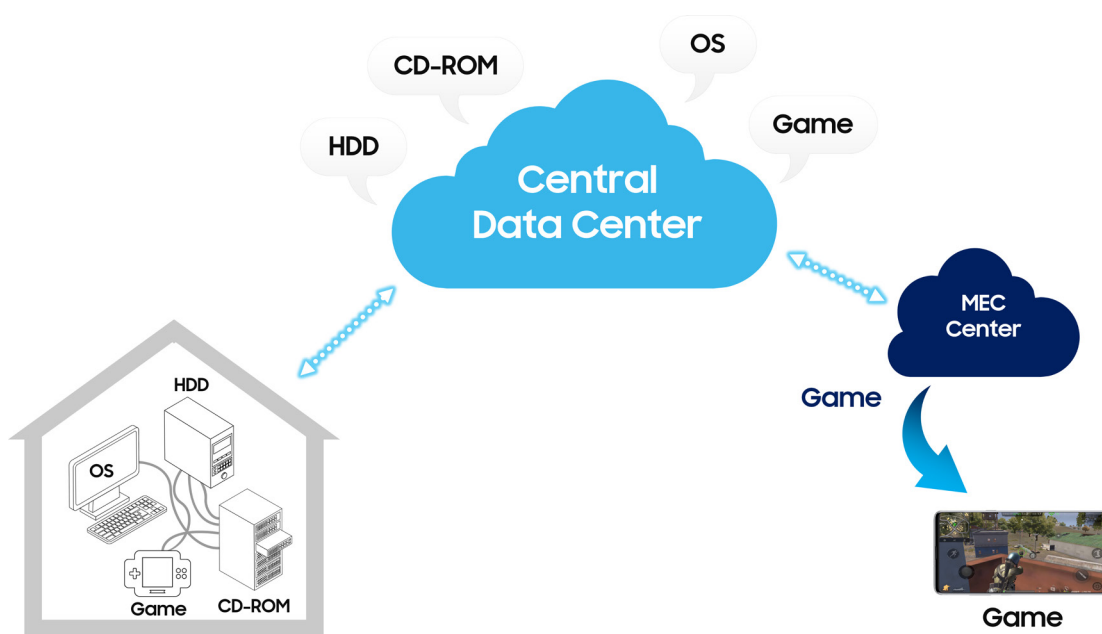

Figure 3: Concept of Cloud Gaming

In Korea, as all three operators have already launched 5G handsets, they have also started to provide all kinds of cloud game content. By using a VR headset and other devices, players can enjoy a smooth, immersive ultra-high quality gaming experience. More than that, they may instantly switch game perspectives whenever they want. With 5G, it is expected that from hardware manufacturers to game content providers, the traditional game industry will encounter a revolution.

Immersive Sports Experience

An immersive experience is changing the way we watch sports. In the past, as a fan located in a stadium watching a live match, it is such a familiar picture that you switch your eyeballs back and forth between the field and your mobile phone with the broadcasting on, so as not to miss any fantastic moment of the game. But now, with a VR headset, immersive sports allows the audience to watch the game from any point of view, with super clear sight and jog back and forth as he or she wants.

Through the numerous cameras, drones, and sensors all around the stadium or even on the athletes' bodies, a huge amount of data is transmitted to the base station and then on to the audience handset devices. According to the audience's very personal preference, he or she will be able to review the highlights focusing on any preferred point or from any preferred angle or even from the first person perspective, and to slice the action frame by frame to see how the athlete makes it. Meanwhile, with all athletes' performance data displayed on the screen, professionals can have better analysis about game strategy. For those non-professional sports lovers, with the rapid and massive data processing capability, 5G allows you to share the happiness of victory immediately. Even when one couldn't be onsite, a 5G supported VR headset can bring you the experience as if you were in the stadium, enjoying the excitement and thrill of the game, through a real-time 360 degree broadcasting service.

12K Video Live

Operator installed three 4K cameras around the stadium to shoot videos from different angle and send them onto the end user's screen by using 5G network.

Motion Tracking

Motion tracking function draws virtualized moving orbit of baseball for audience to better understand the game. Audience can even review the moment they missed.

Position View Service

Position view includes home view, outfield view, first base view and third base view. Zoom in and zoom out function is also available during the real-time game broadcasting. More than that, players' historical records are also at your fingertips for you to analyze the game.

Golf Coaching

The program allows users to watch the coaching video from any view they want. Also, this program will provide 3D guidance during the real golf game with pre-installed 3D map.
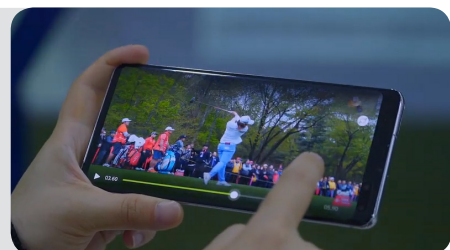

Figure 4: Korea's Immersive Sports Experience

Education and Healthcare Beyond Time and Space Limits

Education

Our world will always be led and pushed forward by the young, ambitious and well educated. Education, usually happens in schools, but now, combined with 5G technology and AR/VR, immersive education can be applied to any country in any corner of the planet, regardless of political and economic barriers. Breaking the education source limitation, the whole education industry is about to undergo revolutionary changes brought by 5G.

What can 5G bring to students while traditional teaching methods cannot? Traditional passive learning method, lectures by an instructor in the classroom, will be replaced by active learning method as the student will have the freedom to decide which way he or she wants to take the class. By interacting with a virtualized character or real human teacher by AR, VR, or hologram, students can get immediate feedback from the teacher. All the content that cannot be provided by traditional media can be visualized by AR or VR. Dangerous, physically impossible, or extremely expensive education will be overcome by virtual training. Those could include: firefighter rescue methods, airplane piloting classes, observing the structure of a black hole in the universe or tracking marine life under the Mariana Trench, etc. 5G will lead you to a new horizon.

Figure 5: AR/VR/Remote Education

Healthcare

Future healthcare will range from preventive medicine by monitoring and predicting potential diseases, to hospice care. For patients, 5G healthcare means tele-medicine and remote diagnosing. For doctors, 5G networks don't merely mean tele-surgery, they also provide a database of symptoms and diseases for diagnoses. For hospitals, 5G can help to decentralize the healthcare model.

Why does remote surgery need 5G networks? During a surgery, stable, fast and near zero latency signal transmission is a must. Any latency in the transmission will lead to medical accident. Moreover it is almost a certainty that robots will not replace doctors in the near future, however, they will be powerful assistants for diagnoses, to set doctors free from the simple, repetitive and time-consuming work. A simple example would be a properly trained AI that can read hundreds of MRI photos to make a rough diagnosis about tumor size and location. Also, by reading the images of a retina, AI can help doctors to diagnose some vision-related diseases such as glaucoma and macular degeneration.

Figure 6: Remote Healthcare

In a broader sense, the wearable and IoT sensors in your home will provide real-time monitoring and provide data, including your living habits, as part of the medical history for doctors to make a diagnoses. 5G technology will change the traditional brick-and-mortar healthcare into a prediction and treatment integrated, totally personalized one. This will improve the public welfare and relieve goverments' medical care burden.

5G Paves the Way for New Industry

In the IoT era, value can be added only when data from a large number of sensors are connected. By connecting AI algorithms with 5G connectivity to provide optimized solutions for situations and purpose based on the collected data, it will bring automation throughout the industrial environment and society and will finally lead to the 4th industrial revolution.

Smart Factory : Improve Productivity and Save Cost

Rather than reshaping, 5G is more likely to reconstruct the whole manufactory. Traditionally, the manufacturing industry has always been defined as a labor–intensive industry. Since human labor was the key for manufacturing as all the basic work had to be done by people, however technology is changing everything.

Massive connection and IoT is an inevitable example of improving efficiency and reliability. There are many use cases including, but not limited to, IoT monitoring.

With 5G, massive IoT sensors are used to monitor product quality; data will be collected and analyzed to predict and solve the problems; supply chain and delivery process will be smoother. Data collection and analysis in real-time, alerts aimed at repair and preventive maintenance, and AR-based troubleshooting systems are integrated to enable more effective manufacturing. With the high reliability and low latency of 5G networks, the future manufactory will be adapted for a more diversified future market.
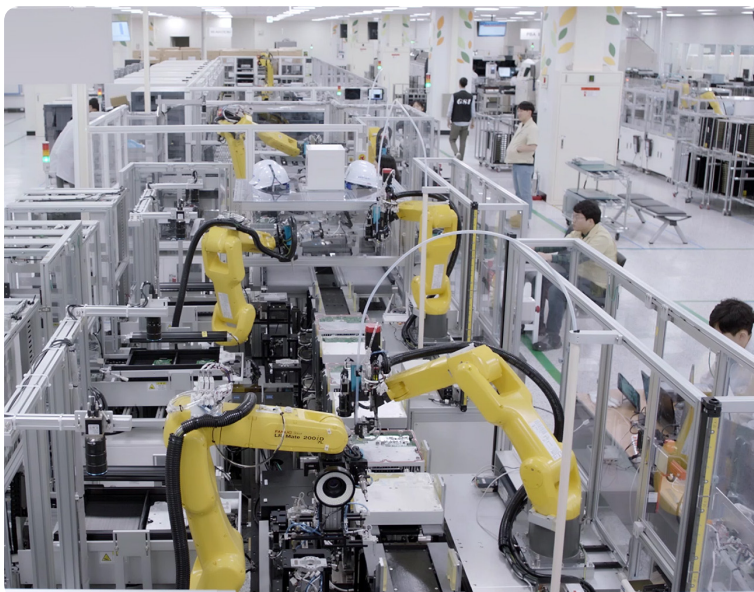

Figure 7: Samsung Smart Factory in Suwon, Korea

Samsung Electronics built a smart factory in 2019 and covered it with 5G network to improve the efficiency.

The entire factory process is automated from material storage to manufacturing, packaging and shipment leading to improve efficiency and productivity.

Images of all these automated process are transported in real time over a high speed network, artificial intelligence oversees the whole process and determines whether the product is defective. Real time remote monitoring solution is also managed by 5G technology. Through out the whole process of automation, IoT, Big Data, AI and 5G, make future technology a reality.

Precision Farming : Grow More Crops with Less Soil

Smart agriculture is a term used to describe the application of modern information and communication technologies to enhance, monitor, automate or improve agricultural operations and increase agricultural production. Millions of sensors are used to collect data including soil moisture, fertility, and weather, and then such data is transmitted to data centers to provide farmers with real-time access to their land, crops, livestock, logistics, and mechanical information and analysis.

Why does smart farming need 5G? Smart farming is basically about making predictions and decisions based on data collected by IoT sensors such as temperature, humidity, and rainfall, which means huge data transmission is required. Taking weather data for example, when weather data is transferred back by the sensors, the irrigation system will be able to figure out how many times, and how much volume each time that the watering needs to be conducted, while optimizing the water usage and saving costs. Similarly, the collected historical soil condition and current environment information will be comprehensively analyzed by the fertilization management system, and the amount of each type of fertilizer to be used will be calculated automatically and conducted remotely by the system. Any real-time feedback data regarding the soil and crop situation will be collected by the sensors 24/7 and sent back to the system for analyzing in order to adjust any deviation from the target. 5G networks can meet the requirement of constant and stable transmission of massive data.

The situation is the same in the stock farming industry. When a stock farm owner possesses thousands of sheep and cows, how can he or she assure there are still same quality of livestock in the evening of the same day without any escaping? With sensors and drones supported by 5G technology, you will be provided with real-time livestock quantity data, and will be able to know the exact location of any single livestock through the GPS positioning function if you want. Furthermore, there will even be systems that can provide you with the real time biomedical data of the livestock.

"Toward 2050, rising population and incomes are expected to call for 70% more food production globally, and up to 100% more in developing countries, relative to 2009 levels(...) The largest contribution to increases in agricultural output will most likely come from intensification of production on existing agricultural land. This will require widespread adoption of sustainable land management practices, and more efficient use of irrigation water through enhanced flexibility, reliability and timing of irrigation water delivery."

The State of the Worlds Land and Water Resource for Food and Agriculture

Food and Agriculture Organization of the United Nations

Source : http://www.fao.org/3/i1688e/i1688e00.pdf

# Autonomous Driving : More Laughter and Less Tears on Road

Autonomous driving is always a hot topic when 5G is mentioned. What makes Autonomous driving so tightly connected with 5G? Autonomous driving is divided into six levels from L0 to L5. The highest level L5 means fully automatic driving, which means the vehicle can make independent decisions based on real-time data without the driver. Autonomous driving consists of three main aspects: data collection from a sensor, data transmission to a data center, and instant AI-based decision-making, which is sent back to the vehicle.

According to this definition, auto driving will never be realized without the networks that enable the decisions to be made based on real-time data transformation. Sensors are responsible for data collection and transmission. After all the data is sent to the control center, it is analyzed to enable safety decision-making. The whole process inevitably needs the support of the network. With the support of 5G technology, vehicles to vehicles, vehicles to base stations, base stations to base stations can achieve ultra-fast communication.

By collecting and exchanging the information including

real-time road conditions, pedestrian movement, weather reports, the control center can reduce traffic congestion, improve traffic efficiency, and provide in-car entertainment. Compared with 4G networks, 5G networks' characteristics of wide bandwidth, ultra-low latency and massive access perfectly meet the requirements for auto driving. We have full reason to believe, with 5G network near zero latency transmission, when we go to the last phase of autonomous driving, auto vehicles will be able to make their own decisions according to the specific situation, which might be far more reliable than a human being's judgment. This technology will not only improve social efficiency but will also change our daily lives and turn our society into a safer, more human-friendly one.

Currently, the entire autonomous driving ecosystem – from vehicle producers and system equipment vendors to telecom service providers all want to take their own market share in this emerging and fast-growing industry. With 5G networks, there will be more laughter and less tears on the road.
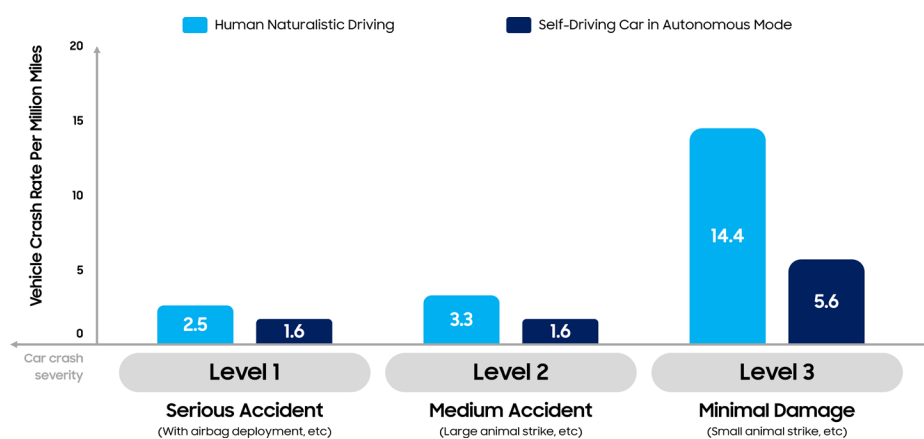
According Automated Vehicle Crash Rate Comparative study by Virginia Tech Transportation Institute, auto driving results in low car crash rate when compare with human naturalistic driving as demonstrated in figure 7.

Figure 8: Vehicle Crash Comparative Study between

Human Naturalistic Driving VS Self-Driving Car in Autonomous Mode

Source : https://www.vtti.vt.edu/featured/?p=422

Make a Safer and Smarter Society

Public Safty : Save Lives within Gloden Hour

Figure 9: Dedicated Network VS 5G Network Slicing

Public safety is always a hot issue in the modern society. In the first place, the characteristics of a public crisis demand a network which can enable a fast responding platform that allows multiple participants to get involved in the decision-making process. This requires telecom operators to adapt their communication platform to fulfill next generation emergency service regulatory requirements. Supports for diverse applications and services with heterogeneous performance requirements, which includs mission critical IoT communication, massive machine-type communication and Gigabit mobile connectivity, is the key factor of this public safety emergency system.

Since the modern society itself is a giant dynamic and open complex system, there are always uncertainties

when emergency happens. However, with millions connected sensors, detailed, real-time, location-based information can be collected for authorities to make decision and take action.

When a fire starts in the forest, IoT sensors will catch the temperature change, and smart controller will automatically respond by deploying water. If the fire is too explosive to be controlled, a message will be sent to the fire station. If there are human beings trapped in the forest, with a 5G network-controlled drone, precise environment information and UHD real-time video can be sent back to the data center.

Before, we had to build up dedicated network for public safety but now only by network slicing we can realize the public safety function.

Smart Powerplant : Efficient Managment of Powerplant

Electricity is the foundation of our entire modern society. Our daily lives, industry development, community safety and national security are highly dependent on reliable, safe and affordable electricity. Since the creation of electricity system, within only a century, new technologies are constantly changing the grid system by providing stronger capacity, lower prices and cleaner energy. What can 5G networks bring to electricity system?

Figure 10: Thermal Camera Attached Drone Taking Photos to Check the Grid Status

Different countries have different strategies when developing its own smart grid, yet, there exists common points of smart grid strategy: instant information transmission and big data analysis. The key point of a 5G grid is balancing supply and demands. Precise prediction will prevent grid productivity from being wasted and improve the efficiency of distribution and transmission. Decision making, problem analyzing and shooting are all based on those huge amount of data provided by smart meter system.

Drone also played a critical role in the smart grid system. By using multi-sensor power-line inspection system of drone, engineers can track and monitor the whole grid system's status. With the characteristic of light weight and fast movement, drone may cover a wide area in short time. By taking huge amount of pictures and gigabytes of video, collecting spectral and thermal data and transmitting them back to data center drones flying over the grid system can monitor the whole grid status.
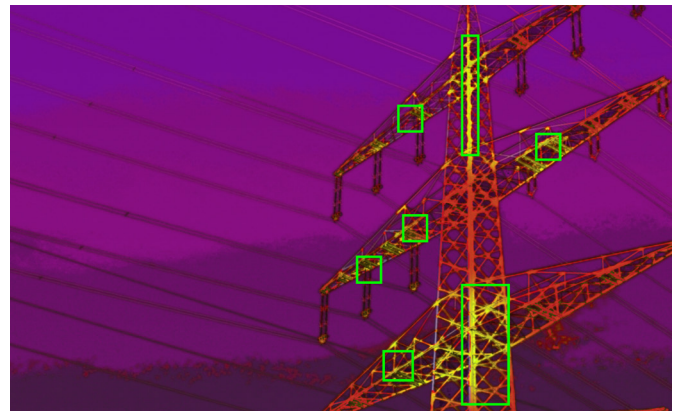

Figure 11: Thermal Photos Taken by Drone Attached Camera

Concerning the future grid, we expect it will be smarter and automated to adapt to the increasing need of electricity and the complexity of grid network. With the help of smart metering and 5G supported drone, problems can be easily predicted and discovered and fixed. With 5G technology, the future grid will be more affordable, reliable and resilient to support our social economic growth and industry prosperity.

Smart City : Build up a Smarter Enviroment

Smart Buildings **Internet of Things** **Smart Health** **Smart Parking**

Smart Factory **Public Safety** **Smart Home** **Smart Energy**

AR/VR **Smart Lighting** **Smart signage** **Traffic Management**

Smart city is a platform which connects every part of a city to improve the quality of life, city operation and management as well as public service efficiency thus escalating city's overall competitiveness. As mentioned above, transportation, healthcare and public safety all can be enhanced by 5G networks. Gas and water leakage management, pollution management, street lighting management are also very important factors that will make a city smart. By gathering and exchanging information from all sorts of sensors and devices, a city can be operated at lower cost and a more convenient life will be brought for its citizens. Following two examples shows how smart city will be enabled by 5G.

Smart lighting systems

Street lighting systems are such a common image in our daily lives that their existence is often ignored. However, a smart lighting system will save energy, monitor and manage the whole lighting system. The landscape streetlights are not only turned on at the peak of the traffic flow, but can also be turned off when

the traffic volume is low such as early morning. Currently, not only switch control, but also the inspection of street lighting still relies on the traditional low efficiency methods all done by human beings. Thus, remote single lamp control, energy consumption information real-time checking are still impossible.

5G Smart lighting systems are targeted at solving all these problems. NB-IoT intelligent streetlights can realize precise control and maintenance of single lamp. It enables the streetlight to switch on and off according to season, weather and other environmental elements. After applying this system, management departments can remotely detect and locate error. Combined with lamp life cycle management, operation and maintenance, costs can be dramatically saved.

Smart signage

By allowing interaction between consumers and retailers, digital signage kiosks provide a totally new way of advertising for the retail industry. Interactive digital signage kiosks can provide customers with product information and also allow retailers to broadcast customized adverts based on demographics and purchase history. Customers can try on virtualized cloth, share the product information with friends, check the storage and compare the price by simply clicking the signage.

Also, the smart signage may automatically create or change advert content according to season, time, environment etc. With the functions mentioned above,it can help retailers to maximize the return on their signage investment and enhance customers' omni channel shopping experience.
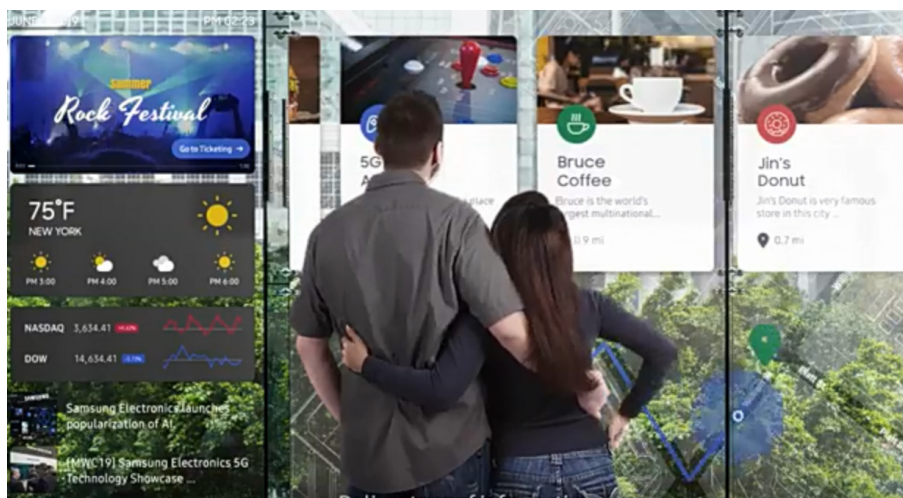

Figure 12: Smart Signage Systems.

5G is not simply an access technology, which makes the estimation of its socioeconomic benefits more complex. The progress of 5G roll outs will not be tracked by simply counting connections, as was the case with previous generations of mobile broadband. Most discussions regarding the role of 5G instead utilises a framework of use cases. These use cases highlight either related applications that can be used in various economic activities or the enabling access technologies upon which such applications can operate.

Source: The WRC Series Study on Socio-Economic Benefits of 5G Services Provided in mmWave Bands

The new generation of telecommunication 5G technology will be the cornerstone of next global economic growth trend. As telecommunication technology has already changed, and continuously changing our lives, industries and societies, we have full reason to believe that 5G will bring us a total new different future. Also, as the data usages requirment grows, the pursuit for higher performance mobile communication will never stop. With 5G and the future telecommunication technology, a fantastic world is just in front of us.

Source : https://www.gsma.com/spectrum/wp-content/uploads/2019/06/mmWave-5G-benefits.pdf

SAMSUNG

www.samsungnetworks.com
www.youtube.com/samsung5G

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