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New Applications Enabled by 5G Cellular Networks

What is 5G Cellular Network?

5G cellular network is the 5th Generation technological standard for broadband cellular networks. It is a new global standard after 1G, 2G, 3G and 4G networks. 5G network is designed to connect people, machines and devices together virtually. It is able to deliver higher multi-Gbps peak data speeds, having lower latency, more reliability, having a larger network capacity and increased availability to users as compared to its predecessors. In simpler terms, 5G enables us, as users, to have quicker downloads and uploads of digital information, as well as lower lag. 5G can support up to 10 to 20 Gbps of data download speeds, which is 100 times faster than its predecessor 4G, while having a latency of less than a millisecond, as compared to 4G which has a latency of around 10 milliseconds. Furthermore, 5G is also more secure than 4G as 5G uses 256-bit encryption, which is a large update compared to the 128-bit encryption in 4G. Due to these benefits of using 5G, especially having very low latency, 5G has enabled some new applications which have not been possible using its predecessors such as 3G and 4G LTE.

Smart Road Technology

Traffic accidents have been an issue in any city throughout the world. In Singapore, there is around 100 – 150 fatalities in traffic accidents yearly from 2016 to 2021. While in the United States, around more than 46000 people die in car crashes every year. Every country with vehicles would face this problem. However, using 5G network with Internet of Things can solve this problem.

Internet of Things is the collective network of connected devices, with sensors, processing capabilities and software. Internet of things enable devices and technologies to communicate digital data over the Internet or other communication networks with other devices which are connected to the network.

Using the 5G and Internet of Things (IoT), traffic and transportation in cities can become much safer for drivers and pedestrians due to the faster and greater connectivity between devices enabled by the 5G cellular network.

On 2 December 2021 in Turin, Italy, there was a live trial of the 5G connected vehicle. This trial was hosted by the City of Turin and the 5G Automotive Association. This trial also involved collaboration from companies such as Intel, Telecom Italia (TIM), Telefonica, BT/EE and Capgemini. This trial involves using 5G network for fast update of locations of pedestrians and vehicles around the area. It also involves using technologies such as the Cellular Vehicle-to-Everything (C-V2X) and Edge Computing. C-V2X technology is a unified connectivity platform designed to offer vehicles low latency vehicle communication to other vehicles,

infrastructures around roads, such as traffic lights and CCTV cameras, or pedestrians. Edge computing is a distributed computing paradigm that brings computations and data closer to the sources of the data. Edge computing can help reduce response time and save bandwidth.

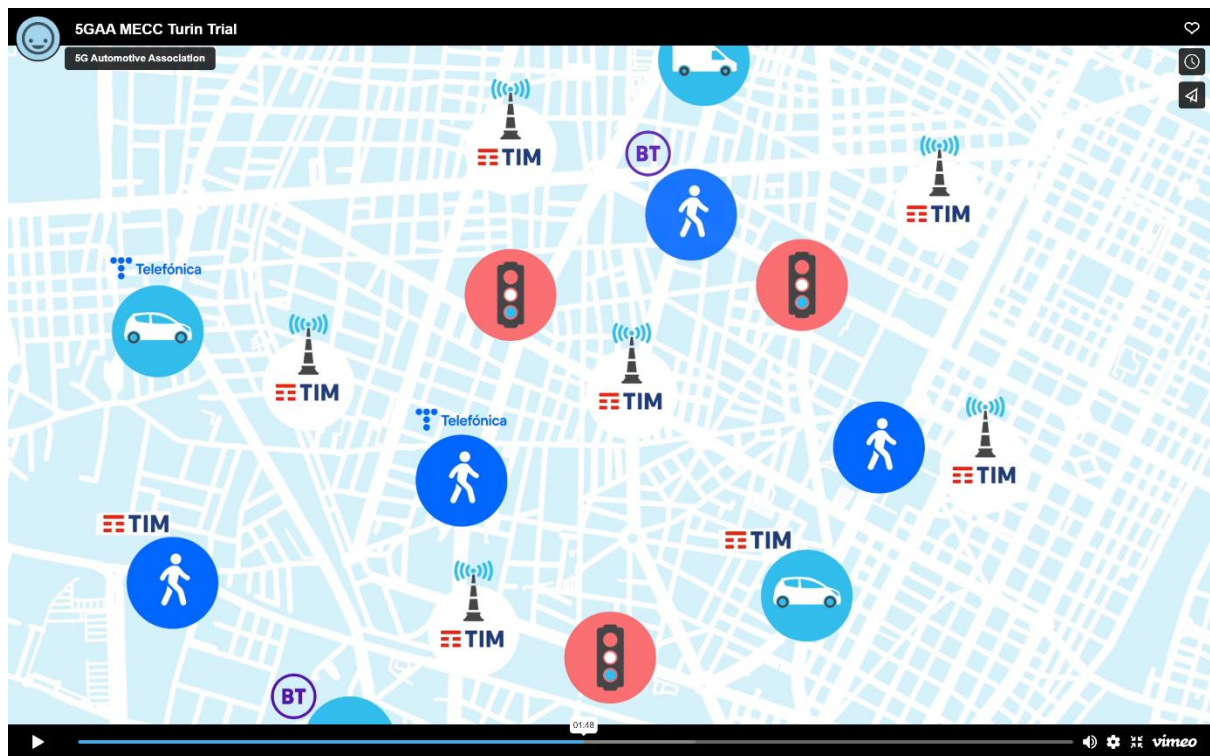


Fig 1. Image from 5GAA MECC Turin Trial Video in 5GAA website

TIM provides the live 5G coverage for TIM users and roaming users from Telefonica and British Telecom (BT) as shown in Fig 1. The trial involves active users and passive users of this system. For active users, the pedestrians and the roaming vehicles communicate their real time locations to each other, with the low latency provided by the 5G Network. The information is then processed. When a dangerous situation occurs, a warning message is broadcasted in the devices help by the pedestrians and the vehicle, which will alert the users to act accordingly as to not cause an accident. For passive users, the vehicle communicates with the infrastructure around the roads, such as the CCTV cameras installed beside roads, using the TIM 5G network. The camera takes a real time video of the distance between the pedestrian and the vehicle. The machine learning algorithm inside the platform used by the vehicle will process this information and give a warning broadcast to the driver of the vehicle if an accident is going to occur, which will alert the driver, thus preventing an accident from occurring.

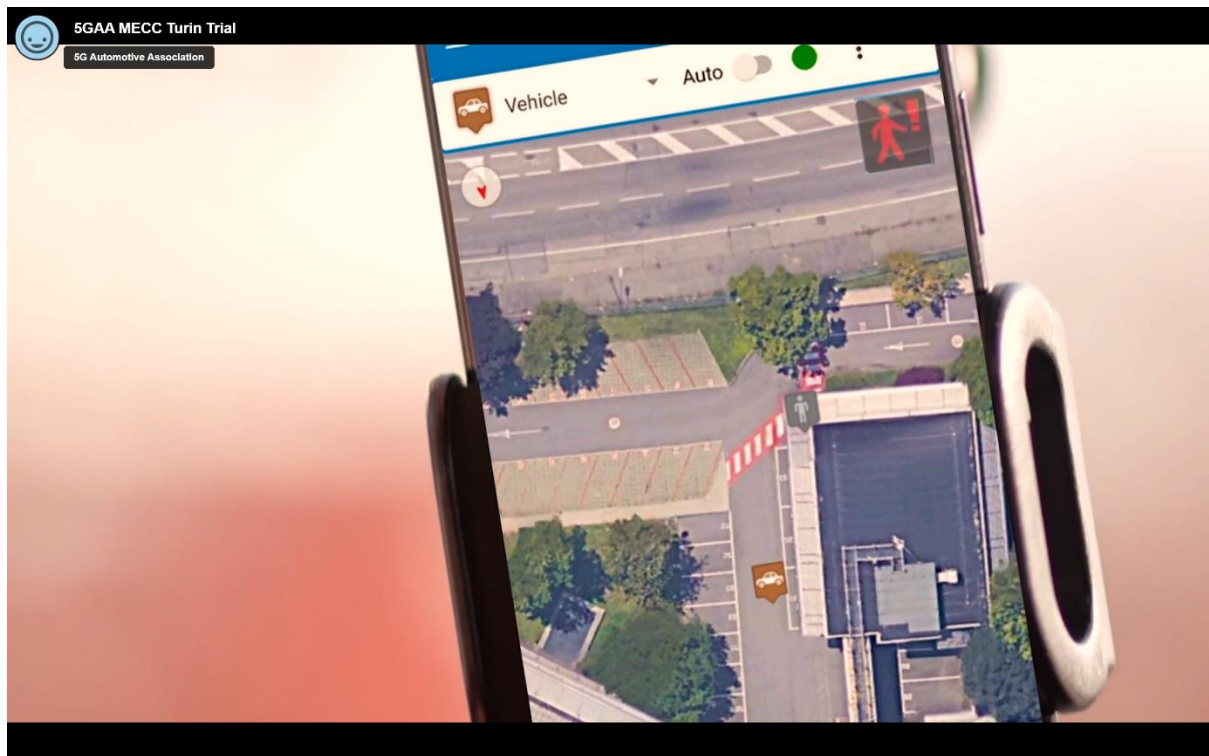


Fig 2. Example of Warning Broadcast from video in 5GAA website

From this MECC live trial held on Turin, Italy. It can be seen that 5G Network can empower the application of safety methods to ensure that the traffic and transportation in cities become safer. Using real live constant exchange of digital information between vehicles, infrastructures and pedestrians, traffic accidents can be prevented, which will make cities safer for their citizens. With the low latency provided by the 5G network, the exchange of information through the Edge Computing Architecture and the C-V2X technology will be much faster and accurate, making it possible to prevent an accident from happening through warning broadcast to users of the 5G network when a dangerous situation is about to occur to them.

Remote Surgery

Remote surgery is a process where a surgeon does a surgery from a large distance away from the patient. This surgery is done by a surgery robot in the surgery theatre, controlled remotely from a long distance by the surgeon.

Remote surgery can be done with 5G cellular network due to its low latency. Before 5G network was implemented, remote surgery has not been possible due to the lag time between input and output, which could be from a quarter of a second to two seconds delay. This delay could be fatal to patients. Furthermore, 5G network also allow greater volume of data to be processed at a higher rate, thus allowing the surgery robot to be able to be operated at a high precision by the surgeons operating it. With 5G cellular network only having a delay of less than a millisecond, it caused remote surgery to be able to be implemented.

A case study of this remote surgery is the remote surgery done by a surgeon in China called Dr. Ling Zhipei, which is the chief physician of the First Medical Centre at China's People's Liberation Army Hospital. Dr. Ling Zhipei conducted a surgery on the brain of a Parkinson's disease patient in Beijing from the PLA Hospital in Hainan, which is 3000 kilometres apart. As of how this happened, Dr. Ling Zhipei take turns working in Beijing and Hainan. It was when he was at Hainan that he got the information that there was a Parkinson's disease patient in Beijing, and he couldn't fly to Hainan to meet the doctor for surgery. The remote surgery ended in a success after three hours.

According to Dr. Ling Zhipei, the surgery had been successful due to the 5G network. Due to its low latency, it has enabled Dr. Ling to operate on the patient without any video delay on the condition of the patient in Beijing, as well as without any remote control delay of the surgery robot, which would not have been possible if it had been executed using the 5G's predecessors such as the 4G network.



Fig 3. Dr Zhipei working on the brain surgery

Another case study of remote surgery is done by Professor Matteo Trimarchi at the IRCCS Can Raffaele Hospital in Milan, where Professor Matteo performed a procedure from Vodafone Village, to treat diseases affecting the vocal cords on a synthetic larynx model at San Raffaele hospital.

This was a breakthrough in medical services as now surgeons can do surgery even if they are far away from their patients. This can save peoples' lives as there are cases where some hospitals may not have surgeons capable enough to execute certain surgeries on patients, possibly due to the lack of expertise, and have to transfer the patients to another hospital. The time in between the transfer could be critical to the success rate of saving the patients' lives through surgery. Through remote surgery being available, surgeons which are more

capable in the certain field of surgery can work on patients even if they're far away from them, potentially saving their lives.

Other than surgeons directly executing surgery on patients through remote surgery, 5G can also help through the improved communication between surgeons. If there's the case where the surgery robot has not been implemented in the hospital, expert surgeons can gain access to real live surgery procedure of the patient, giving instructions to the surgeons present in the surgery theatre, which can also potentially increase the likeliness of the surgery being a success.

Remote surgery does not come without some disadvantages. At the early stages of implementing this technology in hospitals, it may increase medical costs due to technical investment. Surgeons will also need to learn how to implement this technology, especially for older generation surgeons which may be unfamiliar with these kinds of technology. However, in the long term, as technology becomes more advanced, the cost of surgery would also decrease. And for utilising this technology, hospitals and medical institutes would need to start educating current and upcoming surgeons on how to use this remote surgery. Nevertheless, remote surgery is still largely positive to society as it can potentially save many lives from critical medical conditions as high quality medical surgeries will be more accessible in many areas around the world through remote surgery.

In the future, researchers are trying to find methods such that the surgery robots can be implemented without intervention from surgeons. However, this has proven to still be difficult as there are issues such as ethical issues where if a mistake occurs during the surgery procedure, what would the robot do and who would be responsible for the mistake, especially if it involved the death of a patient. Thus, currently, remote surgery with an expert surgeon controlling the surgery robot would still be the most optimal decision in the current age of medical technology.

Augmented Reality/Virtual Reality

Augmented Reality is a technology which superimposes a computer generated image on the user's point of view of the real world, thus providing a composite view, a combination of the virtual and reality view. While virtual reality is a computer generated simulation of a three-dimensional digital environment, in which users can seemingly interact with the objects in the simulation, using certain gadgets such as a helmet or a glove.

Currently one of the most popular example of augmented reality would be the mobile game Pokemon Go. Pokemon Go is a game where players catch Pokemon from their mobile phone. The pokemon will be the virtually-generated image on the screen while the background, which is captured by the phone's camera, would be the real world point of view.

On the other side, an example of virtual reality is the console Oculus Rift. Oculus Rift is a gaming console which involves a headgear and two consoles for both hands of the users.

Users who wears the whole set of the Oculus Rift console can play video games while seemingly also interact with the virtual objects in the game.



Fig 4. Oculus Rift Console Set



Fig 5. Pokemon Go

The main reasons why 5G network has enabled Augmented Reality and Virtual Reality is due to the low latency and high bandwidth for augmented reality and virtual reality to work without any noticeable delays for better user experience, since it requires a large amount of data transfer. And since 5G provides for these requirements, Augmented Reality and Virtual Reality would be more usable many purposes.

In the near future, with further development and more accessibility to 5G cellular network, Augmented Reality will be able to be widely used in not only entertainment, but also in businesses as well. Currently large businesses such as Nike, IKEA and L'Oreal are using Augmented Reality. For example in the case of IKEA, IKEA's Augmented Reality App, called The Place, lets users use their smartphone camera to place IKEA furniture in their houses, letting the users see how the furniture they are planning to buy will look in their rooms before they decide to purchase the furniture. This makes it easier for users as they do not need to go directly to IKEA to check the dimensions of the furniture they are going to buy. This application can also reduce the number of returns of furniture of IKEA potentially due to customers purchasing the furniture but ended up not having a space in their home to put the furniture in.

Another way of using Augmented Reality and Virtual Reality is for training employees in the workplace. For example, in the company Arvizio, the instructors for the employees using these technologies to guide employees through complex task-oriented workflows, as well as

to assist technicians through step-by-step instructions to guide the repair, installation and maintenance of equipment.

As shown in the examples above, Augmented Reality and Virtual Reality can be used in various methods in society, and 5G network has empowered these technologies to be used in more diverse methods. 5G supplying lower latency and higher bandwidths has allowed for Augmented Reality and Virtual Reality to have better connections and increased traffic capacity, which are important for both Augmented Reality and Virtual Reality, especially if there are many users in a single server. 5G has proven to be able to offer up to 100 times in improvement in traffic capacity as compared to 4G, which makes these technologies more accessible at the same period of time for greater number of users. Higher bandwidths also means that there will be better screen qualities when using Augmented Reality or Virtual Reality, which would mean better user experience in using these technologies, whether its for entertainment, business or other activities in society. Thus, 5G network has enabled Augmented Reality and Virtual Reality to be used in many more different ways than previously before 5G network was implemented.

Smart Farming

Smart Farming is the process in which Artificial Intelligence (AI) is used to operate on farming tools and gadgets.

As we know, farming is an essential part of human society, especially with the increasing global population. However, farming also has many factors which may affect the crop yield, such as climate change and pest occurrences.

The purpose of smart farming is to increase the productivity of farming while decreasing the total cost of the farming process. Currently, companies are creating smart farming systems that can benefit from utilising 5G network, AI and edge computing. Using these smart farming systems, farm management will become more customizable and data-driven, instead of the old method where farmers just use one kind of approach for farm management, which includes factors such as crop yield, water usage, pesticide usage and waste management.

An example of these smart farming gadgets is the John Deere's tractor, this tractor is equipped with cameras, with 360 degrees obstacle detection, geo-awareness and calculation of distance. When farmers use this tractor, they only need to set up the tractor at the field they want to work on, and the autonomous tractor will operate accordingly. Farmers can check on the progress and activities being done by the tractor though a mobile application. This allows farmers to be able to monitor the tractor's activities while doing some other tasks in the farm. Farmers can also alter some of the attributes of the tractor such as the speed of the tractor to optimise the performance of the tractor.



Fig 6. John Deere 5G Tractor

5G, due to its high bandwidth, low latency, and massive connection, allows massive amount of original data to be generated for the tractors to be controlled remotely. 5G also allows real time data transfer to occur, which is important since real time information on the condition of the field and the crops will also affect the decisions made by the farmer on the next action to take.

Other than the John Deere 5G Tractor, the concept of smart farming can also be used in the form of drones which can be used to survey the condition of the fields and the crops. Drones can be equipped with cameras to closely monitor the field more easily and faster as compared to checking the fields and crops manually. It would also be less laborious to use these drones. Similar to the case of the John Deere 5G Tractor, the farmers can also just look at the fields through the drone's camera's point of view from a mobile application, which also allows them to do some other tasks while monitoring through the drones.

An example of this project is built by a start up in Israel called Taranis. They created drones which can capture ultra-high resolution images down to leaf level while the drones are rotating around the fields. Taranis' AI analyses these images and aggregates this data to search for early signs of crop diseases, insect outbreaks, nutrient deficiencies and other factor which may affect the crop yield. Taranis' fleet of drones and low-flying aerial vehicles can cover up to 400,000 square metres of field in 20 minutes, claimed by the company itself.

5G network assists in these drone activities as it allows the images and data captured by the drones to be transferred to the farmers at real time, thus allowing the farmers, and

potentially scientists and researchers, to analyse the data and gain insights from the data. If for example there is a potential crisis which may affect the crops is identified, then the farmers can act fast on what to do next to prevent the crisis, such as insect outbreaks or crop disease outbreaks from spreading further to the other fields.

Another application of smart farm technologies in the current reality is a ground robot, created by a company called EarthSense, called TerraSentia, which uses sensors such as visual cameras, light detecting and ranging tools, and GPS devices. These ground robots can gather data such as the plant health, physiology and stress responses. Gathering of real live data using 5G network can assist scientists in gathering information which can give insights to the wellbeing of the crops, whether if it is healthy or if there is an external factor which is affecting the health of the crops in the field. Since it uses a cloud-based platform, it makes it easy for scientists to teach the robots to automatically measure a range of key traits of the crops such as the height, the condition and the leaf-area index, which is the projected area of leaves over a unit of land, which can also tell the scientists and the farmers about the current conditions of the crops in the field.



Fig 7. TerraSentia

Both the drones created by Taranis and the ground robot created by Earthsense, TerraSentia, collects real time information regarding the crops in the field at a faster rate for farmers and scientists to obtain insights from the data and plan on the next course of actions to do on the field. The main difference between these two smart farming technologies is that the drones collect information from above mid-flight while for TerraSentia, it collects data from the ground, thus it collects data in which we can call under-canopy data.

However, since these kinds of smart farming technologies are still in development, it may still be costly to implement these technologies in farms, especially in developing countries.

Thus, to ensure that this technology can benefit countries around the world, it may still take quite a long time for it to happen. However, with future developments in technology, the cost of creating and implementing these technologies will decrease eventually, thus allowing countries around the world to implement this technology in their farms, digitalising farming to some extent around the world. This would help increase farm productivity and yield around the world, thus possibly help cope with the issue of growing global population in the long term.

Other than the tractor and the drone, there may also be more ways in which 5G can be implemented into smart farming, giving rise to new kinds of machines which could help in increasing crop yield in the future.

Conclusion

In conclusion, the new applications that 5G cellular network has enabled are smart road technology, remote surgery, augmented reality and virtual reality, and smart farming. In these four new applications, we can see a trend in the properties of the 5G cellular network which enables these applications to be executed in the reality today. These properties are low latency, high bandwidth and massive connection. These properties of 5G cellular network allows real time data transfer, which is important in the applications smart road technology, remote surgery and smart farming technology. While in the case of augmented reality and virtual reality, it allows larger data transfer rate, which improves the user's experience using the gadgets involved in augmented reality/virtual reality. Larger data rate also benefits remote surgery as it allows surgeons operating the surgery robot from a large distance to make more precise actions using the surgery robot. We also see that there is often an association of 5G network and Internet of Things, as 5G complements IoT very well such as in the Smart Road Technology section. From this paper we have seen that the creation of the 5G network has benefitted society majorly, from maybe more minute things such as faster connection and smoother graphics for entertainment such as watching videos or movies or playing video games, to larger more important uses which could change how the world does some types of activities, such as smart road technology, remote surgery and smart farming.

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