E. 5G and AIoT Applications

Chapter #5: 5G and AIoT Around theWorld

With sincerest thanks to: Lucas CHEONG Wai

Use Case: Singapore Polytechnic's Sustainable Smart Cities Project - 5G, AIOT, V2X in action

- An example of real-life 5G application in smart cities is Singapore Polytechnic's Sustainable Smart Cities Project
- Involves engineering a V2X platform at SP Smart Campus using DSRC and Cellular-V2X tech to redefine sustainable, smart mobility.
- The focus spans V2X wireless connectivity, 5G, AI, data analytics, IoT, and intelligent Electric Vehicle (EV) charging (V2G and V2H).
- Safety gets a tech boost too, as V2V communication expands drivers' visibility range, enhancing road safety and response times.
- Plus, the LoRaWAN-enabled sensors guide EV owners to available charging lots with pinpoint precision.

https://youtu.be/j9Nke9ZoAYM

Source: https://www.sp.edu.sg/engineering-cluster/eee/spii-showcase/spii-2024/sustainable-smart-cities-5g-aiot-v2x-in-action

Here is a detailed explanation of each technology used in Singapore Polytechnic's Sustainable Smart Cities Project:

1. **5G**: 5G technology was used to implement prototypes and smart Electric Vehicle (EV) charging solutions [1]. It provides high-speed wireless connectivity and ultra-low latency, which is crucial for real-time data sharing and improved coordination between various components of the project [5]. It also assists in expanding drivers' visibility range, enhancing road safety and response times [1].

2. **AIoT (Artificial Intelligence of Things)**: AIoT was used to enable data analytics and intelligent control in the project [1]. It helps in creating a complete end-to-end system by integrating embedded hardware like sensors or devices and gateways to connections with software cloud platforms and application developments [5]. This technology is part of the 5G innovation ecosystem in SP, which aims to foster innovations in enterprises through 5G, enabling them to be more competitive in the market [5].

3. **V2X (Vehicle-to-Everything)**: V2X technology was used to engineer a platform at SP Smart Campus using DSRC and Cellular-V2X tech to redefine sustainable, smart mobility [1]. The focus spans V2X wireless connectivity, 5G, AI, data analytics, IoT, and intelligent EV charging (Vehicle-to-grid (V2G) and Vehicle-to-Home (V2H)) [1].

V2X communication expands drivers' visibility range, enhancing road safety and response times [1]. It also improves the overall safety of streets by enabling advanced levels of connectivity, data sharing, and improved coordination between cars and infrastructure, bicycles, pedestrians, and scooters [11].

4. **LoRa (Long Range)**: LoRaWAN-enabled sensors were used to guide EV owners to available charging lots with pinpoint precision [1]. LoRa technology helps in setting up a Low Powered Wireless Area Network (LPWAN) using LoRa sensors that are deployed across SP campus while being assisted by 5G wireless communication [3]. It contributes to the development of sustainable smart cities, as they are linked to the concepts of a circular economy [2].

This project is a transformative initiative for smarter, safer, and more sustainable transport [1].

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Guangzhou is the third largest metropolitan area in China, with a population of around 20 million. Guangzhou Metro is the urban rail transit system of Guangzhou. As of first half of 2022, it has a total of 16 lines, reaching621 kilometers, with a daily ridership of 11.5 million. Guangzhou bus services include 1,280 bus lines and the city has a total paved road area of 191 square kilometers. Given its size, the city is facing multiple challenges to its transportation system. These include ensuring the smooth and efficient operation of trains while limiting incident rates, ensuring the safety and comfort of a large number of passengers, and optimizing resources while reducing costs to create a sustainable transportation system. Since year 2020, with the advent of 5G, the local transportation industry, together with China Mobile and ZTE, have transformed the traditional transportation system into 5G-enabled smart transportation system. For example, with 5G's large bandwidth and throughput and ultra-reliability and low latency features the safety and efficiency of the transportation system are further improved. Advanced 5G indoor positioning technology enables passengers to search for points of interest even without GPS. This large-scale initiative spans the city's entire transportation ecosystem and involves unique deployments of 5G solutions in three major transportation scenarios:

Guangzhou 5G Smart Metro:

Enhanced operation efficiency and safety: The total 5G solution was created for operation efficiency and safety. Especially, it changes the operation and monitoring

system from traditional passive mode to more active and online mode. For example, the metro train on-time rate has been greatly increased. Also metro operation environment is quite challenging. For example, cracks of the tracks, the track offset may cause severe accident to the trains. Unfavorable waterlogging and fire and unauthorized intrusion may lead to severe adverse situations. Thus, the implemented 5G real-time metro monitoring solution helps to significantly reduce the rate of incidence and cost of maintenance.
Better station operations and management: In the metro stations, mobile electronic guidance screens, intelligent customer service machines, turnstiles , intelligent security control are gradually 5G enabled. These measures help shorten the average processing time for each passenger by 20% during peak hours. 5G enabled HD video cameras in the stations and back-office AI analysis is used for passenger flow analysis, abnormal behavior analysis, and people evacuation. The high-precision 5G indoor positioning can be accurate up to 2 meters, providing passengers with in-station navigation and other position-related services.
Gigabit internet experience on-the-go: Passengers also enjoy wireless gigabit Internet anytime and anywhere in the station hall, platform, and other metro locations. Even in a metro train moving at the speed of 160 km per hour, the download speed can be up to 600Mbps.

Guangzhou 5G Smart Railway:
5G early warning system: Due to the high speed of the train, which can be as fast as 100 m/s, even a tiny object on the track may lead to disaster. Thus, for safety, at least 8km in front of the moving train must be monitored with 5G enabled system. If there is any potential intrusion onto the tracks, the back-end system will be analyzed and send a warning message through 5G to the train.
5G train operation data auto backup: For train operations, there are large amount of operation data to be sent back from trains to central back-end system. But currently it relies on tedious manual copying of the data. With the 5G-enabled system, the transmission efficiency is improved by more than 10 times.
5G train suspension inspection system: With 5G, traditional manual train suspension inspection is replaced by 5G-enabled remote inspection system. What would have required two hours of manual inspection back then, takes just two minutes of camera-assisted and AI-driven inspection now.
5G smart railway marshaling station: With a dedicated 5G private network for railway marshaling and production, the integrated automated system reduces the number of front-line production staff from 215 to 150 and the average daily train processing capacity increases from 8,000 to 10,000.
Rich train passenger online services: For the high-speed train passengers, the boring long-distance traveling experience is transformed into an enjoyable one, thanks to rich online videos, audios, eBooks and online courses provided by Tencent.

Guangzhou 5G Smart Bus and Road Management:
5G Smart Bus: This enables bus control center to monitor bus operations in real time and have a full view of the buses from different angles. Also, the bus drivers' driving behavior and driving track record are captured and analyzed by the back-end system, which greatly improves the safety of bus operations. Also, with 5G intelligent bus scheduling system, the time needed to schedule bus lines is reduced from a week to a day. And the bus

system capacity is increased by about 10%.

Guangzhou Travel Information Service: This mobile app integrates services from bus, metro, and railway by offering up-to-date travel planning and information services, such as when the next bus comes or how crowded a bus is. Besides travel information, passengers can use 5G-enabled high-precision positioning to search for nearby shopping and dining information to better utilize their transit time.

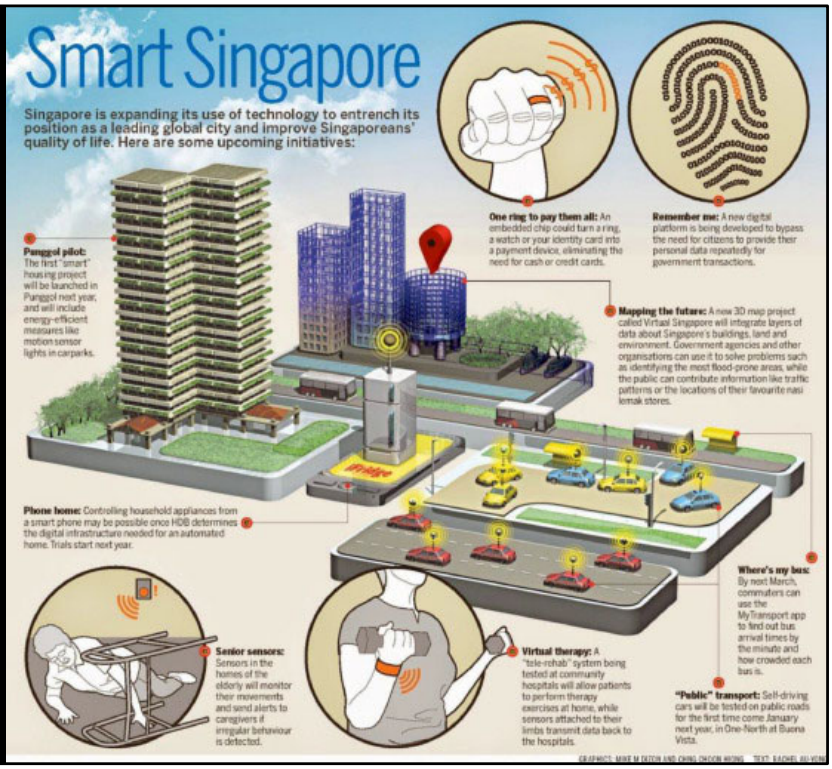
5G Traffic Monitoring and Road Inspection: With 5G, road administration and road safety inspection are more efficient and less resource consuming. For example, the real-time traffic monitoring system better coordinates the traffic and lessens traffic congestion that has become part and parcel of big city road transportation experience. Also, a road and bridge inspection application using drones has been developed. For example, in the case of drone-assisting bridge inspection at the Nansha Bridge spanning the Pearl River, the detection rate is increased by 65%.

See also: https://youtu.be/jMHEzgs1fvU?si=A2My5s7edDYpSRrN

Use Case: Smart Singapore

https://youtu.be/qeQbERHv0u8

Source: https://www.sciencedirect.com/science/article/pii/S2666546821000653



1. **Punggol Pilot**: The first "smart" housing project in Punggol will incorporate various energy-efficient measures like motion sensor lights in carparks. This project is part of a broader effort to develop smart, sustainable urban solutions and is aligned with Singapore's vision of transforming its housing estates into eco-friendly and tech-savvy living spaces.

2. **Phone Home**: Trials will begin to enable residents to control household appliances via smartphones. This initiative aims to build a digital infrastructure that supports automated home systems, enhancing convenience and energy efficiency in public housing.

3. **Senior Sensors**: Sensors installed in the homes of elderly individuals will monitor their movements and send alerts to caregivers if irregular behavior is detected. This initiative enhances elderly care and safety, reducing the risks associated with living alone. The program aims to integrate advanced health monitoring systems into daily life, providing peace of mind to both seniors and their families.

4. **Virtual Therapy**: A "tele-rehab" system is being tested to allow patients to perform therapy exercises at home while being monitored remotely by therapists. This reduces the need for frequent hospital visits and makes rehabilitation more

accessible and convenient.

5. **One Ring to Pay Them All**: Singapore is developing an embedded chip technology that can turn everyday items like rings, watches, or identity cards into payment devices. This eliminates the need for cash or credit cards, making transactions seamless and secure.

6. **Remember Me**: A digital platform is being developed to allow citizens to bypass the repetitive provision of personal data for government transactions. This initiative aims to streamline interactions with government services, enhancing efficiency and user experience.

7. **Mapping the Future**: Virtual Singapore is a new 3D map project that will integrate layers of data about buildings, land, and the environment. It aims to identify flood-prone areas, optimize traffic patterns, and provide other insights that can improve urban planning and management.

8. **Where's My Bus?**: Starting next March, commuters can use the MyTransport app to check the real-time arrival of their bus or the availability of parking spaces. This initiative aims to make commuting more efficient and less stressful by providing timely information.

9. **"Public" Transport**: Self-driving cars will be tested on public roads for the first time in January. This pilot program is part of Singapore's broader efforts to integrate autonomous vehicles into its transport system, potentially reducing traffic congestion and enhancing safety.

These initiatives are part of Singapore’s larger Smart Nation strategy, which aims to harness technology to improve the quality of life for its citizens, boost economic competitiveness, and build a digitally inclusive society.

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OpenGov Asia: https://www.opengovasia.com

See also: https://youtu.be/i4TBMXkNhRg?si=V38jmaWhCyrSjRPu

Use Case: First fully connected 5G smart factory in Southeast Asia, Thailand

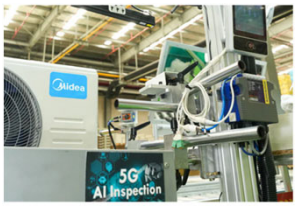
5G Data Collection and Analysis

5G Automated Guided Vehicles (AGV)

5G Robotic Arms

https://youtu.be/uAosJ2Uy5nw

5G Operating Room



5G AI Inspection

Source: https://www.huawei.com/en/news/2024/5/first-5g-fully-connected-factory

Harnessing the comprehensive 5G network coverage of the Midea Industrial Park in Chonburi and a 5G+ industrial Internet platform, each production phase is seamlessly connected through 5G terminals to enable faster machine operation. A dedicated 5G private network has been deployed to support factory operation requirements and leverage intelligent industry applications, which facilitates manufacturing scenarios and interconnects each production line.

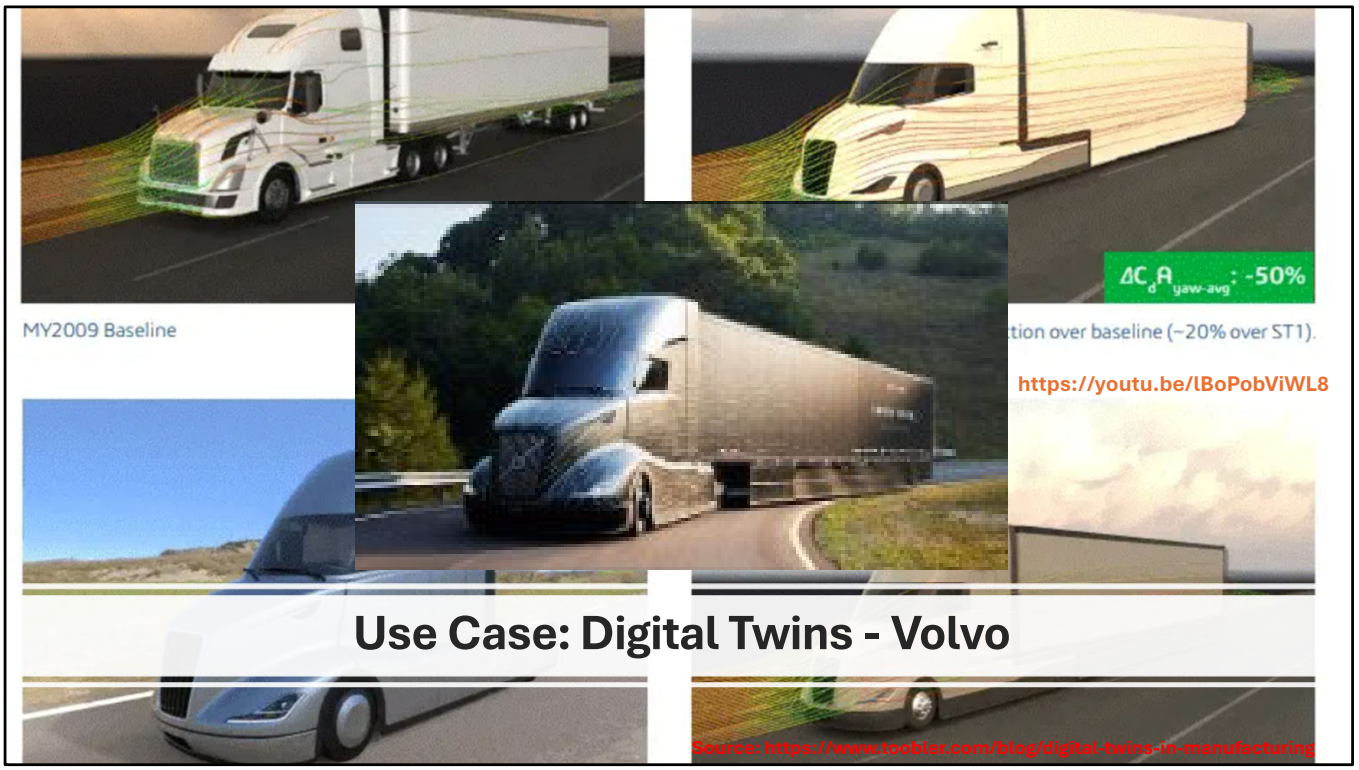
Among the key solutions that make the factory "5G fully connected" are:

- 5G Data Collection and Analysis: The combination of massive connections and high reliability offered by 5G networks enables real-time monitoring and analysis of production devices. Continuous data collection and analysis optimize equipment utilization, mitigate downtime, and enhance overall equipment capacity.
- 5G Automated Guided Vehicles (AGV): Through the power of 5G technology, AGVs have undergone a paradigm shift, moving beyond preset routes and physical markers for navigation. Dynamic path planning and real-time environmental data analysis enhance flexibility and adaptability, significantly improving operational efficiency in complex factory environments.
- 5G AI Inspection: Leveraging AI, production efficiency sees a significant boost with a 4% increase in "first-time yield" (the percentage of units produced that pass QA the first time). AI detection drastically reduces the number for reworked devices from 4000 to 1000 per year, representing a 75% slashing in rework rates and minimizing

operational errors.

- 5G Robotic Arms: Workers are now empowered to remotely control robotic arms via 5G smartphones, eliminating the need for hazardous manual intervention in the production process. This not only enhances worker safety but also optimizes production material flow, resulting in higher product quality.
- 5G Operating Room: Equipped with 5G technology, operating rooms simulate and test the status of outdoor compressors, ensuring efficient and reliable operations. With zero data loss and low latency capabilities, 5G backhaul guarantees seamless data transmission for critical applications.

See: https://www.huawei.com/en/media-center/our-value/2024/midea-thailand



Volvo has implemented a virtual twin of their vehicles to test its design. The twin allows them to test the entire functionality and performance of the new designs before physically implementing them. Thus, it helps shorten lead times.

Volvo's Digital Twins initiative is meant to be their significant step towards digitalization and connectivity, enabling new business possibilities. The Innovation Lab at Volvo Group has been focusing on exploring value enabled by digital technologies and harnessed within smart business models since 2017.

One of the key projects under this initiative is the development of a “digital twin platform”. The vision of Volvo CE (Construction Equipment) is to virtualize all products, systems, and components, so that physical prototype verification can be avoided completely. Instead, Volvo CE aims to predict and verify their products’ performance in the virtual space.

The company aspires to create a so-called digital twin for every machine (physical twin) that they sell. It is fed with data from its physical twin through sensors, edge-based algorithms, and data analytics. Digital twins are expected to generate increased sales and affect site optimization, requirement engineering, product development, and after-sales.

For instance, a precise virtual twin of a production cell can test the entire functionality in product quality, resource use, maintenance, process stability, and cost. This includes logic, mechanics, security, electricity, patterns of movement, speed, sensors, and all connected devices.

One example of a digital service offering is ‘Lokate’, created to increase the efficiency for inbound traffic at construction sites. At the core lies real-time tracking and digitalization of manual tasks. Suppliers, construction companies, transporters, and everyone else in the eco-system of a construction site, will be able to see deliveries and transports in real-time and can plan and re-schedule deliveries accordingly[1].

These initiatives are part of Volvo's broader strategy to drive business growth through new digital ventures and partnerships. They believe that digital business innovation and new technologies are key to creating growth in sustainable transport and infrastructure solutions.

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Use Case: Fujitsu's Smart Factory

https://youtu.be/sm7MUG9cGH4

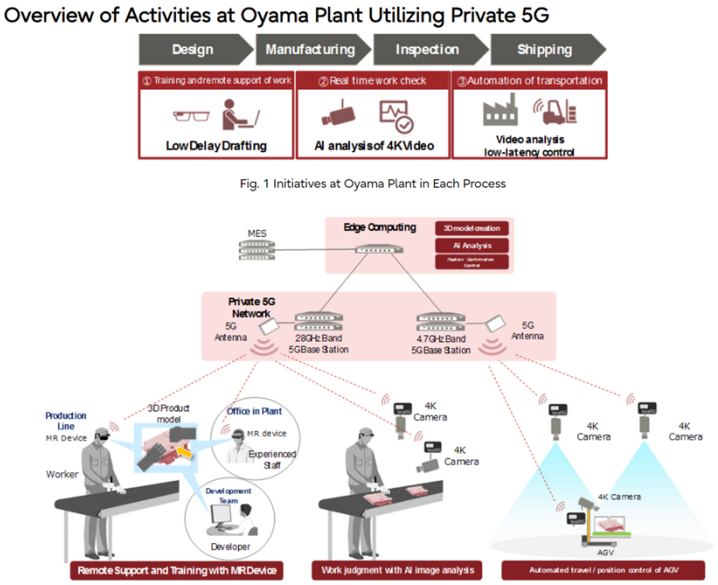


Fig. 1 Initiatives at Oyama Plant in Each Process

https://www.fujitsu.com/global/about/resources/news/press-releases/2021/0330-01.html

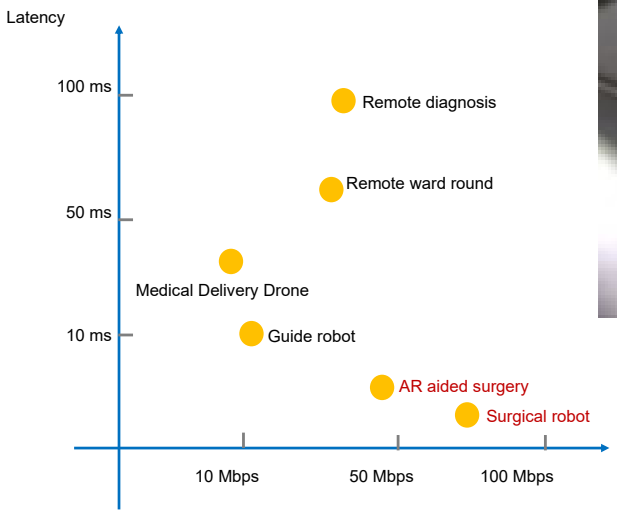
Here is a brief summary of the key points from the Fujitsu press release:

Private 5G Network: Fujitsu has launched a private 5G network at its Oyama plant in Tochigi Prefecture, Japan, using both 4.7 GHz and 28 GHz bands to enhance digital transformation in plant operations.
Smart Manufacturing: The network supports advanced technologies like AI and IoT, aiming to improve automation, precision, and efficiency in manufacturing processes.
Real-Time Communication: The 4.7 GHz band network facilitates real-time communication with automatic guided vehicles (AGVs) for accurate position measurement and route control.
AI and MR Integration: The 28 GHz band network enables real-time AI image analysis and mixed reality (MR) devices for remote support and training, enhancing assembly work and quality control.

See also: https://youtu.be/-oAgHpzm_FU?si=nuweBPckoVwv6ai-

Use Case: 5G Remote Surgery in China

https://youtu.be/sm7MUG9cGH4

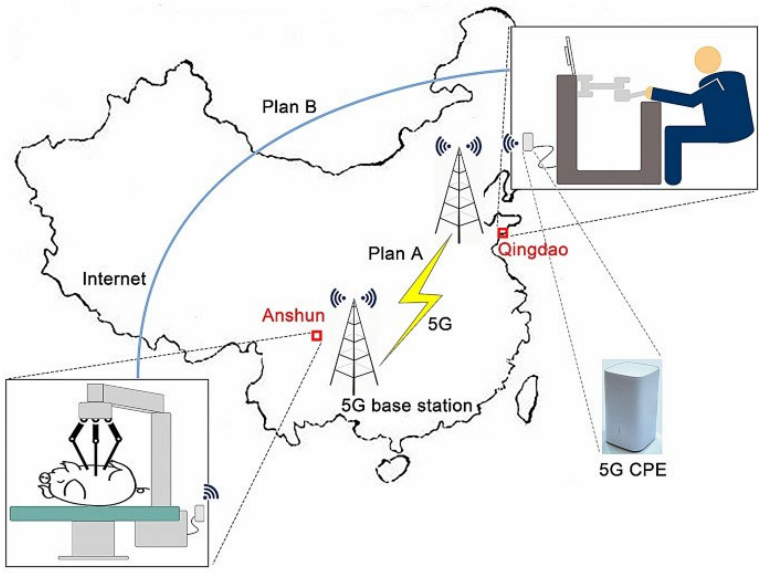


China has successfully tested the world's first remote-surgery equipment using 5G mobile network technology. A doctor in the southeastern province of Fujian removed the liver of a laboratory test animal at a remote location, by controlling robotic surgical arms over a 5G connection (large bandwidth, low latency and large connection)

Source: https://www.therobotreport.com/remote-surgery-via-robots-advances-china-5g-tests/

Here is a summary of the report:

5G Remote Surgery: Doctors in China successfully conducted remote orthopedic surgeries using 5G and surgical robots, demonstrating the technology's potential.
Global Efforts: Various countries, including the U.S. and India, are exploring 5G for remote surgeries, with notable achievements in reducing lag time.
Technological Advancements: 5G technology significantly reduces video lag and remote-control delay, enabling nearly real-time operations.
Future Prospects: The combination of 5G and robotics is expected to make advanced medical procedures more accessible, especially in remote areas.



5G Remote Surgery in China: System Diagram

Source: https://doi.org/10.1007/s00464-020-07823-x

The diagram represents a system for 5G remote surgery in China. Here is a detailed explanation based on the information available from the source:

The system involves performing surgery remotely using 5G technology to connect surgical robots and medical staff. The diagram shows a 5G base station located in Anshun, which connects to surgical equipment and personnel in Qingdao (also via a 5G base station) through the internet and 5G network.

Plan A, represented by a yellow lightning bolt, indicates a direct 5G connection between the 5G base station in Anshun and the remote site in Qingdao. This connection is used for real-time control and monitoring during the surgery.

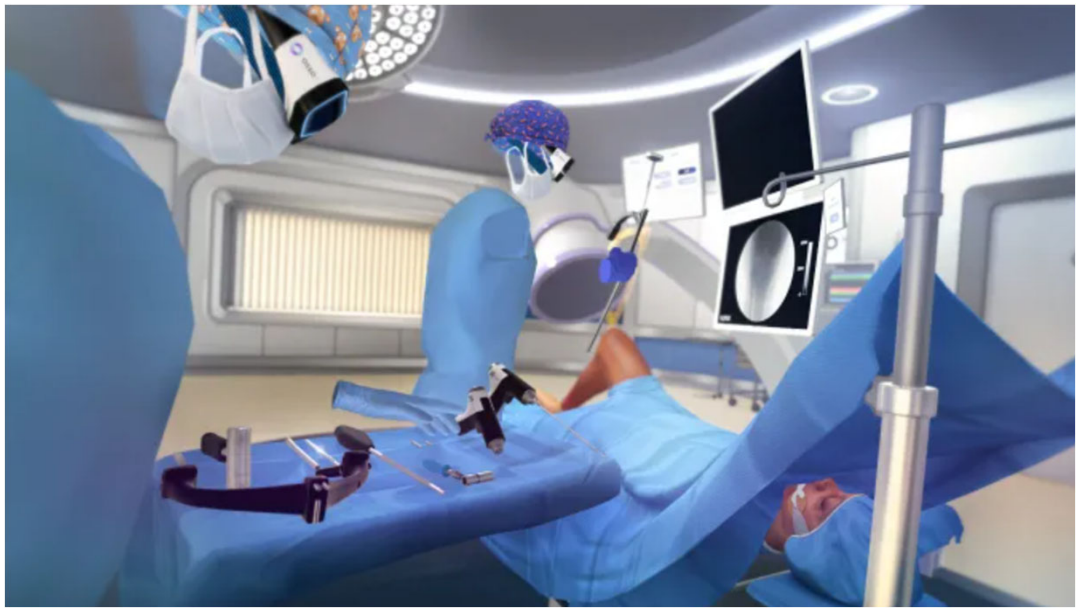
Plan B involves an internet connection as a backup route, providing an alternative communication path if the primary 5G connection fails. This redundancy ensures continuous and reliable communication, which is crucial for the precision required in remote surgery.

The surgeon operates the robotic surgical equipment from Qingdao, manipulating the instruments remotely while receiving real-time feedback through the 5G network. The 5G CPE (Customer Premises Equipment) in Qingdao serves as the local 5G terminal that facilitates this high-speed, low-latency communication. The

same purpose goes for the 5G CPE at the surgery table in Anshun.

This setup exemplifies the potential of 5G technology to revolutionise healthcare by enabling complex medical procedures to be performed remotely with high precision and minimal delay.

Use Case: Virtual Reality (VR) Accelerated Surgical Training



Source: https://orthofeed.com/2022/06/21/new-study-demonstrates-value-of-vr-training-in-surgical-technique-performance-and-radiographic-accuracy/

Here is a summary of the webpage:

A study highlighted on OrthoFeed demonstrates the value of virtual reality (VR) training in improving surgical technique performance and radiographic accuracy. The research underscores how VR training can enhance the skills of surgeons, leading to better outcomes in surgical procedures. This study adds to the growing body of evidence supporting the integration of VR technology in medical training and education.

Use Case: Smart Buildings – NUS's SDE 4

https://youtu.be/jIUY8Xq6xg4

Source: https://cde.nus.edu.sg/dbe/5gdbt/labs/5g-bim-xr lab/#:~:text=SDE%204%2D%20First%205G%20Net%20Zero%20Building&text=NUS%20got%20IMDA%20trial%20license,by%20advanced%20equipment%20and%20devices.

Singapore's first 5G-enabled net-zero energy building in NUS:
A Memorandum of Understanding (MOU) was signed by the National University of Singapore (NUS) and StarHub on the 12th December 2019. The aim of this was to promote joint innovation efforts in the fields of virtual reality (VR) and artificial intelligence (AI) using StarHub's 5G network located in the NUS' net-zero energy building at the School of Design and Environment (SDE). This partnership is the start of an intense process to facilitate the use of 5G. The two collaborating parties will work together to apply 5G in a multitude of use cases and to provide solutions which will significantly improve education, enhance cutting-edge research and address industry needs and challenges.

Use Case: Smart Buildings (Hotel)

https://carrier.huawei.com/en/success-stories/Industries-5G/5G-Smart-Hotel

Huawei's 5G Smart Hotel initiative showcases how advanced technologies can transform hospitality experiences. The 5G network enables high-speed, low-latency internet access throughout the hotel, providing seamless connectivity for both guests and staff.

Key features and applications of Huawei's 5G Smart Hotel include:

1. Enhanced Guest Experience: With 5G connectivity, guests enjoy ultra-fast internet, enabling smooth streaming, virtual reality (VR) entertainment, and immersive experiences. They can use their smartphones for room controls, such as adjusting lighting, temperature, and curtains, enhancing convenience and comfort.

2. Smart Room Service: Integrated 5G technology allows for real-time communication with hotel services. Guests can use voice commands or mobile apps to order room service, book spa treatments, or request housekeeping, ensuring prompt and efficient service.

3. Robotic Assistance: The hotel employs service robots for various tasks, such as delivering items to guest rooms, providing concierge services, and guiding guests around the hotel. These robots leverage 5G's low latency to navigate and interact effectively.

4. Security and Surveillance: Advanced security systems, including AI-powered cameras and facial recognition technology, ensure guest safety. These systems can quickly identify and respond to potential security threats, providing a secure environment for all guests.

5. Operational Efficiency: The hotel's management benefits from 5G-enabled IoT devices that monitor and control energy usage, predict maintenance needs, and manage resources efficiently. This results in cost savings and a more sustainable operation.

6. Remote Work Support: For business travelers, the hotel offers high-speed, reliable internet access suitable for video conferencing, cloud computing, and other remote work activities, making it an ideal location for working professionals.

These examples highlight how Huawei's 5G technology enhances both guest satisfaction and operational efficiency in the hospitality industry.