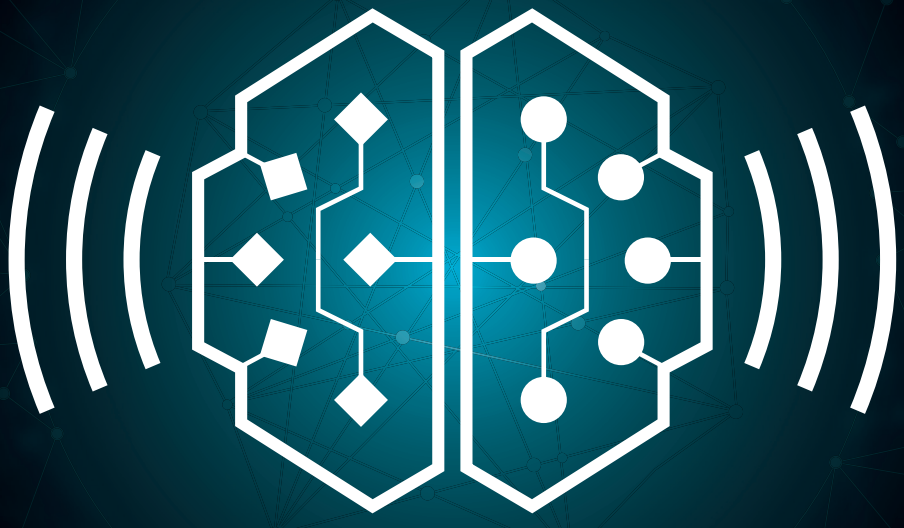
INTELLIGENT CONNECTIVITY

HOW THE COMBINATION OF 5G, AI AND IOT IS SET TO CHANGE THE AMERICAS



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FOREWORD

'Intelligent connectivity' is the term we use to describe the powerful combination of flexible, high-speed 5G networks, the Internet of Things (IoT) and artificial intelligence (AI). Underpinned by ubiquitous, hyper connectivity, intelligent connectivity marks the beginning of a new era defined by highly contextualised and personalised experiences, delivered as and when you want them. It will have a significant and positive impact on individuals, industries, society and the economy, transforming how we live and work.

Many aspects of daily life, from the way we consume entertainment to the way in which we learn and interact with colleagues, will become much richer and more fulfilling. We will watch live sports or music events from our homes via augmented reality (AR), and virtual reality will enhance our gaming experiences. Virtual personal assistants will manage our lives and drones will deliver packages to our doorsteps. Our Cities will be safer and more efficient through mobile video surveillance and smart-traffic monitoring.

Real-time information from cars and bicycles will make our roads safer and more efficient and always-on connected cameras with sensors and alarms will enhance the security of properties and public places. Smarter platforms powered by AI and machine learning will use data collected from the IoT to improve decision making, driving efficiencies in factories and delivering higher quality products and services. Individuals will have the information and services they need at their fingertips, meaning both businesses and the public sector will become far more efficient and effective.

Intelligent Connectivity sits at the heart of this new world and the Americas is at the forefront of this revolution. Mobile operators across the region are already making great strides in the rollout and delivery of 5G networks, which will form the basis of this revolution. 5G connections will reach 1.2 billion by 2025 worldwide with the Americas accounting for 22 per cent. 5G will dramatically improve network capacity, throughput and responsiveness, while enabling operators to tailor connectivity to each application. At the GSMA, we believe that new 5G networks, the increased application of AI, Big Data and the upscaling of the Internet of Things, will positively change the world. In this new era, mobile will intelligently connect everyone and everything to better future.

Mats Granryd
Director General,
GSMA

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EXECUTIVE SUMMARY

The combination of 5G, artificial intelligence and the Internet of Things will usher in a new age of intelligent connectivity. Drawing on interviews with mobile operators and analysts, this report describes the exciting services and experiences that will be enabled by intelligent connectivity:

• **Compelling commerce -** People will have continual access to a personal assistant in the cloud, regardless of where they are, while connected glasses or contact lenses will display personalised information and adverts. Self-navigating electric vehicles will take care of last mile deliveries.

• **Crystal clear communications -** Digital communications will capture many of the subtleties and nuances of in-person meetings and enable people to be virtually present in remote locations. By remotely controlling a drone, people will make virtual visits to friends or take virtual vacations. The drone will transmit live 360-degree images and audio to a virtual reality headset worn by the user.

• **Entertainment everywhere -** 5G promises to deliver ultra high-definition video, holograms, augmented reality (AR) and virtual reality (VR) for gaming and immersive TV, as well as digital services and content for connected stadia. Live sports coverage will be broadcast with a 360-degree view from the athlete's perspective.

• **Safer and smoother transportation -** If every person and thing using the roads can communicate with everything else in the vicinity, then road transport will be much safer and more efficient. Smart cities will deploy traffic control systems that use 5G connectivity to instruct vehicles when to slow down and when to accelerate, removing the need for traffic lights and speed cameras.

• **Slick supply chains -** With a 5G network in place, individual elements of a supply chain could easily communicate with each other in real-time, coordinating their movements to optimise efficiency and keep waste to a minimum. Connected to each other by 5G, trucks will be able to platoon on motorways, automatically maintaining a safe distance between each other.

• **Remote control of robots in real time -** Remote operators will be able to see what a robot's on-board cameras are filming and make adjustments to the robot's actions in real-time. This kind of tactile Internet application relies on a high-bandwidth, low latency and ultra-reliable connectivity.

• **Holistic wellness and healthcare -** People will routinely wear connected wellness and security monitors providing continuous information about their vital signs, while enabling emergency alerts in the event of a fall or an attack. 5G will help healthcare managers to maximise the use of scarce resources and ensure that clinics don't run out of critical medicines and equipment.

• **Stronger security, greater safety -** Large numbers of continuously-connected cameras, sensors and alarms will make both private properties and public places more secure, while also enabling law enforcement to tackle so-called white-collar crimes.

• **Enhanced education and training -** trainee engineers, mechanics and medics could learn how to perform specific tasks by following instructions relayed via AR or by using VR simulations. Similarly 5G could enable these technologies to be used to teach science and geography students about specific habitats and environments.

• **Richer resource management -** Consumers and companies will have real-time information on everything from soil acidity to water pollution to the availability of parking spaces, increasing efficiency and reducing waste, while better managing energy usage.

INTRODUCTION

By 2021, 50 million people worldwide could be using 5G, rising to 1.2 billion by 2025[1]. They will be the first to enjoy an array of pioneering new mobile services. By vastly improving network capacity, throughput and responsiveness, while enabling operators to tailor connectivity to the application, 5G will change daily life for the better in many different ways.

As well as delivering high quality mobile services, 5G will further scale the Internet of Things (IoT) to encompass 25 billion connections by 2025[2], with more and more connected products capturing essential data. At the same time, smarter platforms enabled by artificial intelligence (AI) will use data collected from the IoT for machine learning and to improve decision making to deliver higher quality and more efficient products and services. Through the combination of 5G, AI and the IoT, the world will benefit from a new age of intelligent connectivity.

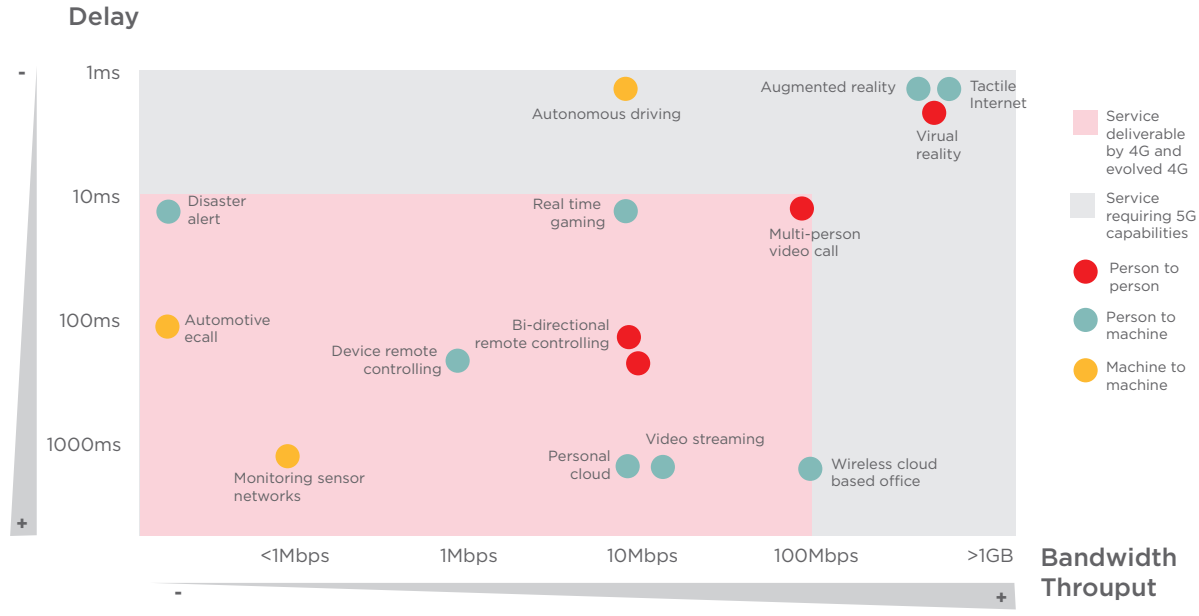
The seamless combination of 4G, 5G and Wi-Fi will deliver reliable, superfast broadband connectivity anytime and everywhere. Ubiquitous download speeds of up to 1Gbps will enable a consistent high quality mobile broadband experience delivering continuous and seamless Internet access at home, office and on the move. People will, quite literally, always have a broadband connection available.

In many places, 5G connections will serve as a wireless, maintenance-free substitute for a fixed-line broadband connection. "We are seeing this to some degree already, with operators offering a disruptive fixed-line substitute, which could be priced at $30 to $40 for 100Mbps connection," notes Matthew Bloxham, Senior Analyst, Bloomberg Intelligence.

At the same time, the unprecedented responsiveness of 5G networks will enable both businesses and consumers to benefit from the so-called tactile Internet, in which people will have fingertip control over remote machines and devices. In many cases, operators will be able to all but eliminate network lag, making it straightforward for individuals to interact virtually with each other and the environment using virtual reality and augmented reality. Low latency connectivity will enable vehicles and other machines to respond immediately to changes in their surroundings, supporting the rollout of self-driving cars, drones and robots (see Figure 1), while enabling an array of smart city applications, including intelligent traffic management and real-time detection of crime.

As 5G evolves from theory to reality, the world's mobile operators are preparing for some profound changes in their service proposition. "We have formed a 5G advisory board with 20 prominent CIOs from enterprises in which we discuss what 5G can do for their particular industries," says Mishka Dehghan, Vice President, 5G Development at Sprint. "On the business side, we have considered 400 different types of use cases involving dozens of technologies across all verticals. 5G is going to democratise artificial intelligence, mixed reality and next generation robotics."

Figure 1: The most demanding services will depend on 5G



Source: GSMA

[1] *Source: GSMA Intelligence*
[2] *Source: GSMA Intelligence*

The Americas are at the forefront of the development and deployment of 5G. AT&T, for example, plans to begin introducing mobile 5G services to customers in a dozen cities this year.

Verizon also plans to launch 5G in US cities during the second half of 2018. "5G has the potential to join a very exclusive club– the handful of technologies throughout history that transform industries across every sector of the economy ... redefining work, elevating living standards, and having a profound and sustained impact on our global economic growth," says Ronan Dunne, Executive Vice President and Group President, Verizon Wireless.

Drawing on interviews with mobile operators and analysts from the investment community, the following sections of this report describe some of the most compelling services and experiences that will be enabled by a fusion of 5G, AI and IoT.

"5G will change the way we live, work and enjoy entertainment,"says Susan A. Johnson, executive vice president, Global Connections & Supply Chain, AT&T. "We're moving quickly to begin deploying mobile 5G this year and start unlocking the future of connectivity for consumers and businesses. With faster speeds and ultra-low latency, 5G will ultimately deliver and enhance experiences like virtual reality, future driverless cars, immersive 4K video and more."

COMPELLING COMMERCE

Want to find a restaurant, buy a ticket and receive personalised offers and discounts? The combination of 5G and artificial intelligence will make retrieving information and buying goods and services a breeze.

Intelligent and omnipresent personal assistants

Artificial intelligence has progressed to the point where powerful computers hosted in the cloud can generally understand natural language as it is spoken. As a result, people will be able to query a personal assistant in the cloud, regardless of where they are, via a seamless combination of 4G, 5G and WiFi connectivity. Individuals might wear a headset, connected via Bluetooth to their 5G handset, allowing them to converse with the personal assistant, which will be able to respond in milliseconds to requests for information, while handling related transactions in the background.

For example, a tourist visiting an unfamiliar city could ask the assistant to find a local seafood restaurant serving lobster and then see if it has any tables free. Similarly, a city resident walking to their local railway station could ask the assistant when the next train to the desired destination is. If the timing works, the assistant could purchase a ticket and deliver it electronically to the resident's handset.

"Today, the connection speed on mobile networks is often not good enough for a personal assistant," says Simon Weeden, a former financial analyst and telecoms industry expert. "It turns up one in three times, but you get a good experience with WiFi and fibre in the home. 5G could get the bandwidth out there to support personal assistants on a continuous basis."

Low cost autonomous delivery carts

Self-navigating, connected electric vehicles could conduct last mile deliveries of pizzas, groceries and home shopping parcels. These vehicles will navigate roads and pathways, avoiding traffic, street furniture and pedestrians, by using a 5G connection to the cloud to rapidly process data from on-board cameras and sensors. Using artificial intelligence, navigation platforms will reduce delivery times and learn how to increase efficiency. Customers will order from their mobile handset, request a delivery time and unlock the delivery cart using their handset once the item arrives.

Billboards show rich and relevant advertising

Over time, static billboards will be replaced by electronic screens that will use 5G connectivity to show video advertising tailored to the time of day. For example, when a football match is taking place at a nearby stadium, electronic billboards might feature videos of players promoting sportswear. Early evening, the billboards in a town centre might display adverts promoting local restaurants and live music events.

Connected glasses deliver personalised promotions

With 5G, connected glasses or contact lenses could display information and adverts personalised to the individual as they walk through a town. For example, a consumer passing a department store might see an offer for a pair of shoes in their size and their preferred style. Similarly, a commuter who has just missed their train might be offered a ride share with other commuters in the same predicament.

"When you are walking down the street, you could get advertising tailored to you," says Matthew Bloxham, Senior Analyst, Bloomberg Intelligence. "With 5G, the advertising would change in real-time and be delivered via augmented reality to your glasses or contact lenses. To do this effectively, you need both the low latency and the capacity to allow lots of people to use these services simultaneously"

CRYSTAL CLEAR COMMUNICATIONS

Today, a video call can't deliver the same experience as a face-to-face chat with a friend or in-person meeting with a business contact. But 5G will move digital communications much closer to the point where the virtual experience can capture many of the subtleties and nuances of in-person meetings. High-definition video and audio transmitted in real-time will enable people to detect raised eyebrows, half smiles and other facial expressions, while ensuring people don't talk over each other and can catch every syllable. Moreover, individuals will be able to easily share live video of what they are looking at, enabling a technician to show colleagues a damaged component and families to share a live music concert or school sports day.

Sharing high-definition video

Instead of posting photos and short video clips, people will increasingly upload bandwidth-heavy live, 360 degree, 3D and high-definition video streams, enabling friends and contacts to enjoy more immersive experiences in the moment. You will be able to experience more of what your friends are experiencing in real time.

For example, NTT DOCOMO and Tobu Railway have broadcast live 8K images from the 350-metre high Tokyo Skytree Tembo Deck using an experimental 5G signal. "We were able to use 5G to transmit 8K video in an actual communications environment, something that would be possible with LTE only in an ideal communications environment," NTT DOCOMO says. "We broadcast 180 degrees of live video from six 4K cameras placed on the observation deck, to three large LCD monitors set up as a viewing space in the east yard of Tokyo Solamachi." The operator found the 5G network delivered smooth, lag-free video at 16 times the resolution of HDTV.

'Better than office' virtual meetings

Using 5G, video conferencing will be able to deliver immersive meetings in home, regional offices, head offices and even remote locations. Virtual reality headsets, virtual offices, virtual productivity tools and meeting participants represented by avatars will all help to make virtual conferencing highly engaging.

Virtual presence

By remotely controlling a drone, people could be virtually present in remote locations, enabling them to make virtual visits to friends and relatives or take virtual vacations. The drone would use 5G to transmit live 360-degree images and audio from its location to a virtual reality headset worn by the user.

"5G will enable virtual presence or remote presence - taking yourself and being present in a place that is remote and you can't actually get to physically," says Bryan Fries, Vice President, 5G Product and Marketing Strategy and International Services at Sprint. "Your presence is there via a drone and you have a VR experience. Consider an example where a grandma has a condition that keeps her housebound and her grandson is playing little league baseball. A drone could be hovering over the game, providing her with a VR experience, so she can see the boy playing and interact with his Mum and Dad in the crowd. There are a lot of interesting things you can do when you pair 5G connectivity with VR and a drone."

ENTERTAINMENT EVERYWHERE

A game changer for entertainment, 5G promises to deliver 4K and 8K ultra high-definition video, 3D video, holograms, augmented reality (AR) and virtual reality (VR) applications for gaming and immersive TV, as well as digital services and content for connected stadia. Live sports coverage could be broadcast with a 360-degree view from the athlete's perspective via 5G.

In early February 2018, Verizon used a prototype 5G network to stream live, 180-degree stereoscopic video from the Super Bowl field in Minneapolis directly to VR headsets in New York City, together with a virtual in-stadium experience, including high-resolution replays on secondary screens, that employed multiple 4K and HD video streams.

In Japan, NTT DOCOMO has hosted "new sensory music live events," employing a range of image technologies such as head-mounted displays, 3D hologram displays and holographic image projection technology, to give remote viewers the sense of a live performance taking place before their eyes. "8K video transmission is ideal for customers who want more realistic live images of sports and music," DOCOMO noted. "In combination with technologies like augmented reality and virtual reality, it has the potential to change the way we enjoy these things in the future."

Connected screens everywhere

Although smartphones will still be widely used, 5G will be able to deliver video streams to many different displays. Indeed, every wall, surface and screen could become an entertainment window, enabling consumers to enjoy ultra HD video without expensive hardware: Low cost slim-line screens could remotely access interactive entertainment from cloud-based servers. Foxconn, for example, plans to produce 5G connected displays, supporting ultra-sharp 8K definition, from 2020. Hollywood is beginning to produce movies in 8K, and Japanese public TV company, NHK, plans to broadcast the 2020 Tokyo Olympics in 8K. Meanwhile, personal 8K video cameras are already available from manufacturers, such as GoPro.

"The quality of the content can increase dramatically and be magnified in much higher definition, both pre-produced content and live," says Bryan Fries, Vice President, 5G Product and Marketing Strategy and International Services at Sprint. "There is such huge demand for video, it is driving capacity constraints for many carriers: 75%-80% of traffic on the networks is video content. The pressure is growing and 5G will provide a massive relief valve that can rebalance supply and demand. Folks will be able to enjoy ultra HD and will be able to self-produce and stream ultra HD video."

"We will have bigger and better screens, which can be ported around," adds Simon Weeden, a former financial analyst and telecoms industry expert. "Every car will have a TV in the back, streaming live television or Netflix or another service. If you have every car and every truck with video, you can't do that with 4G."

Highly immersive gaming without the expensive hardware

Gaming will become more immersive with VR, more social with multiple players and more realistic with HD graphics. Fast, responsiveness access to the Internet will enable gamers to enjoy new VR games anywhere without the cost or inconvenience of carrying specialised hardware. As the computing capability moves entirely into the cloud, consumers could enjoy the latest games through lightweight 5G connected glasses. AI assisted games platforms will tailor games and improve the experience for specific players and groups of players.

Players will also enjoy a more exciting, gaming experience with more freedom of movement, player orientation and interaction within the game and the real world. Machine learning and remote gaming platforms will intelligently alter games by improving a player's online experience based on previous and real time data.

"Today, device form factors have to cater for a lot of stuff inside them to do all the hard work, but with 5G and edge computing you can take the processing out of the device, as the connectivity becomes fast enough," says Bryan Fries, Vice President, 5G Product and Marketing Strategy and International Services at Sprint. "That will change the form factor of the device: it will have a smaller size."

Currently, the most avid gamers still rely on specialist kit connected to a fixed-line in their home. "With 5G you will get a comparable or even better experience than you have with the wired scenario," adds Bryan Fries of Sprint. "5G will enable much better quality content on the go and will also enable new kinds of game. With 5G in there, you will be able to do things in VR and AR. That kind of experience is okay today, but can be much, much better as the hardware and connectivity improves."

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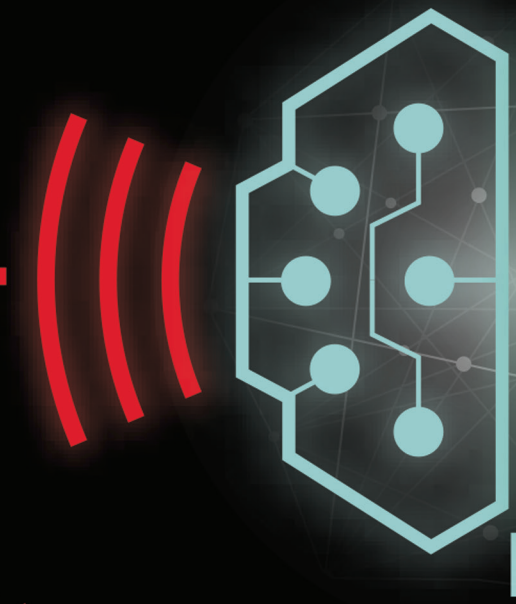
The Fusion of

INTELLIGENTLY CONNECTING EVERYONE



TOMORROW

5G ERA: INTEROPERABLE NETWORKS

5G / 4G / 3G / MOBILE IoT / WIFI / FIXED BROADBAND / SATELLITE

Flexible, reliable, high-speed, low latency, high capacity networks

ARTIFICIAL INTELLI

COMPUTER IQ: **10,0**

Smarter platforn decision makin

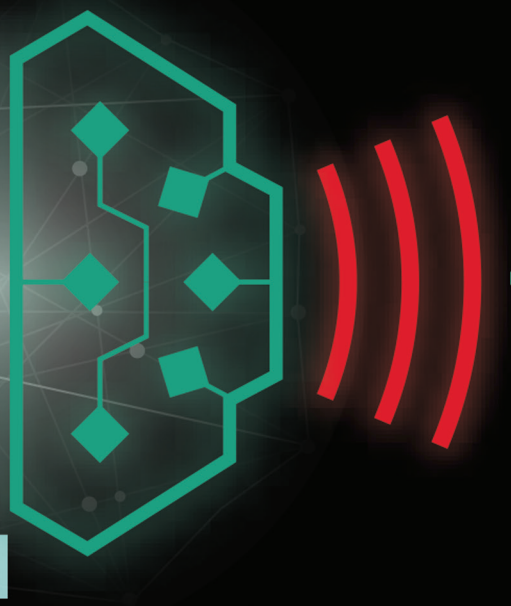
4G / 3G / MOBILE IoT

HUMAN GENIUS I

TODAY

CONNECTIVITY
5G, AI and IoT

AND EVERYTHING TO A BETTER FUTURE



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ms for enhanced
g & automation

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INTERNET OF THINGS
25 BILLION CONNECTED DEVICES

Everything will be securely connected
enabling rich new products & services

9 BILLION CONNECTED DEVICES

Sources: GSMA Intelligence, 2018 | Science Trends, 2018 | Softbank, 2017

SAFER AND SMOOTHER TRANSPORTATION

If every person and thing using the roads can communicate with everything else in the vicinity, then road transport will be much safer and more efficient. Vehicles, bikes and pedestrians could relay their position to other road users in real-time, enabling artificial intelligence systems to ensure there are no collisions. Indeed, recent research by Bosch found that connected cars will reduce traffic accident injuries by 350,000 every year and save approximately 11,000 lives by 2025[3]. Moreover, smart cities could deploy traffic control systems that use 5G connectivity to instruct vehicles when to slow down and when to accelerate, thereby removing the need for traffic lights, speed cameras and other systems.

Affordable personal driver

As 5G helps to enable self-driving vehicles, ride hailing will become more cost-effective than owning your own car. A self-driving taxi will be summoned by mobile phone to pick you up wherever you are located. Climb in, tell the car to take you home and you can have a snooze in the back seat. Vehicles with on-board sensors connected to 5G networks, providing reliable and very low latency connectivity, will enable the connected car to be responsive and intelligent enough to travel safely and efficiently.

But even before such self-driving cars are commonplace, 5G will make a major difference to the motoring experience, by relaying pertinent information from roadside infrastructure and other nearby vehicles. If vehicles ahead are braking hard, the 5G connection would relay that data to the car's on-board computer, which would automatically apply its brakes. In the case of an accident, vehicles can already summon assistance without human intervention using cellular-enabled eCall services.

AT&T has said that it expects "5G technologies will eventually allow future driverless vehicles to make real-time decisions based on information that goes beyond the individual sensors on-board the vehicle itself. Vehicles will be able to "see" around corners, through other vehicles, and at longer distances. This will enable vehicles to quickly make sense of their environment and help guide safe operations on the road."

In April 2018, Telefónica, which has operations across Latin America, demonstrated how 5G can support an autonomous driving electric minibus. "5G technology has much to contribute in the field of the connected vehicle," noted Javier Gutiérrez, Director of Strategy and Network Development at Telefónica Spain. "In addition to the download of multimedia content, autonomous vehicles generate up to 4TB of daily information from the information collected by the sensors, meaning that a high bandwidth is necessary for transferring this data in real time to the network's edge and also an extremely low latency. All in order to jointly process the data received by the vehicles of a certain area and to proceed with decision making, thus increasing the security in vehicular environments".

Connected cycling

In most cities around the world, cycling is enjoying a renaissance thanks to investment in cycle lanes, bike hire systems and the falling cost of electric bikes. But many potential cyclists still harbour safety concerns, which could be addressed by responsive, ubiquitous wireless connectivity. A cyclist's helmet could use a 5G network to connect to other road users and transport infrastructure, anonymously reporting speed, location, trajectory, and localised atmospheric data. Artificial intelligence in the cloud would mesh this data with other road and vehicular data, including weather and surface conditions, road works, congestion, the proximity of heavy goods vehicles or speeding motorists, giving the cyclist real-time advice on their route and when to take care, relayed through an ear piece in the helmet. The technical components of 5G, such as multi-access edge computing, low latency, network slicing and quality of service, are crucial to make such a scenario possible. To protect privacy, all road users' data would be anonymised and shared across secure mobile networks.

[3] *https://www.bosch-presse.de/pressportal/de/en/bosch-study-shows-more-safety-more-efficiency-more-free-time-with-connected-mobility-82818.html*

SLICK SUPPLY CHAINS

Industrial and agricultural goods tend to move through highly controlled environments, such as ports, aircraft terminals, warehouses and motorways, which lend themselves to automation. With a 5G network in place, elements of the supply chain could easily communicate with each other in real-time, coordinating their movements to optimise efficiency and keep wastage to a minimum.

Autonomous trucks on motorways

Connected to each other by 5G, trucks will be able to platoon on motorways – they will travel in convoys automatically keeping a safe distance between each other. Only the lead truck will need an alert driver – drivers in the preceding trucks will be able to get some rest, only actively taking the wheel when it is time to exit the motorway. Although drivers will be needed for loading, unloading and safety in towns and cities, long distance travel costs would be reduced if drivers can spend less time actively driving the vehicle.

Fast drone delivery

In locations with challenging terrain or congested roads, fleets of UAVs (Unmanned Aerial Vehicles) or drones will enable fast, low cost, secure delivery straight to customers' front or back doors. With 5G networks helping to coordinate their movements, large numbers of drones will be able to fly safely in the same locale, automatically avoiding collisions with tall buildings, street furniture and other drones. The mobile networks will provide secure connections, authentication and smart autonomous navigation with high-definition video backup and recovery location if something goes wrong. Drones are already being used to distribute essential medicines to remote medical centres in developing markets.

In its 2017 annual report, NTT DOCOMO, Japan's largest mobile operator, wrote: "We look forward to working with various partners to provide new added value with drones, believing that these efforts will contribute to solving social issues such as a declining labour force and aging infrastructure. After 2020, we will use the high-speed, large-capacity, and low-latency telecommunications made possible by 5G to further expand the range of applications for drones."

5G could also be used to support drone detection systems to help stop rogue devices from interfering with buildings such as power plants and prisons. Multinational operator Vodafone is already developing such a system, with plans to be fully operational by the fall of 2018. The system is based on software using CCTV cameras and sensors running on Vodafone's IoT network. The appearance of a drone will sound an alarm and alert Vodafone's customer, or its security provider, and could be used to locate the person operating the vehicle.

"The combination of 5G, AI and IoT could be used to automate supply chains, distributing intelligence, which can communicate with the control system," says Simon Weeden, a former financial analyst and telecoms industry expert. "It will require a balance between edge computing and cloud computing, which can be enabled by 5G. It will all work much more seamlessly and slickly than today. Today's smart monitors are not the end game. In future, they will be connected to the cloud to enable Alexa-type applications, which will get a big leg up from 5G."

REMOTE CONTROL OF ROBOTS IN REAL TIME

Once they can be controlled remotely via 5G, robots will perform tasks in inaccessible or inhospitable locations, such as repairing oil rigs, wind turbines and nuclear power plants. Remote operators will be able to see what the robot's on-board cameras are filming and make adjustments to the robot's actions in real-time. This kind of tactile Internet application relies on high-bandwidth, low latency and ultra-reliable connectivity.

The tactile Internet will enable haptic interaction with visual feedback, allowing for the perception and manipulation of objects using touch and proprioception - the sense of the relative positioning of the parts of one's body and the strength of effort used in movement. However, to be deployed at scale, the remote control of robots by humans (or artificial intelligence in the cloud) will require low cost edge computing, which will depend on 5G being underlying network infrastructure. Moreover, 5G will enable robots to be controlled and monitored as they move around relatively large areas beyond the reach of conventional wireless hotspots.

Businesses will also be able to use 5G to control remotely located machinery used in industrial production based on input from sensors and cameras located on-site. If necessary, specialist machines will be able to print 3D objects on-demand, enabling them to repair broken components. Over time, factories will become increasingly automated, enabling them to be controlled largely by operators in another location. With few employees needed on-site, businesses will have more flexibility about where to locate production plants, allowing them to prioritise other factors above the availability of skilled labour.

HOLISTIC WELLNESS AND HEALTHCARE

As 5G networks will be able to support large numbers of connections simultaneously, people will be able to routinely wear connected wellness and security monitors providing continuous information about heart rates, blood pressure, temperature, stress levels and location, while enabling emergency alerts in the event of a fall or an attack. All this information will help individuals to monitor their personal condition and take advantage of enhanced health insurance programmes, predictive healthcare and personal security solutions.

For the healthcare sector, the continuous connectivity provided by 5G will help managers to maximise the use of scarce resources and help ensure that clinics don't run out of critical medicines and equipment. Today, medical expertise is still largely confined to the location of the physician, but the advent of the tactile Internet will make it possible to get a diagnosis anywhere and at any time. The physician will be able to command a tele-robot at the patient's location, allowing remote physical examination with full audio-visual and haptic feedback. With 5G, surgeons could even carry out remote procedures using specialised robots. Although the first tele-surgical operation was carried out as early as 2001, telesurgery is still rare due to the limitations of robotics and the underlying communications technology.

STRONGER SECURITY, GREATER SAFETY

Mobile connectivity is already helping cities to become smarter, safer and more sustainable. The rollout of 5G will accelerate this trend, by supporting large numbers of continuously-connected cameras, sensors and alarms. These systems will make both private properties and public places more secure, while also enabling law enforcement to reduce so-called white-collar crimes. One of the most effective weapons in the battle with financial fraud, for example, is real-time information. Mobile networks can help banks and financial services firms to get the location and contextual awareness they need to more accurately detect fraudulent transactions and street crime.

More broadly, the combination of 5G and artificial intelligence could be used to implement instant analysis of location, video footage and any available biometric data, such as abnormal skin temperature and heart rates. Similarly, high resolution surveillance cameras either mounted in fixed locations or worn by police officers will be able to use cloud-based facial recognition systems to identify and spot offenders in real time. For these kinds of safety or security applications, the highly reliable quality of service and coverage made possible by 5G will be crucial to ensure that these tools are available when and where they are required.

Remote Area Safety – wide area security and safety monitoring

With 5G networks in place, connected high-definition cameras will be easy to install across many more outdoor locations and secure sites, such international borders, coastlines and along important infrastructure, such as train lines. Cameras could be mounted on solar-powered drones, which can achieve 14-day flight times, enabling constant "eye-in-the-sky detection" for key sites and at key times. All these cameras will be linked to intelligent control centres, where artificial intelligence systems can analyse the activities, body language and facial expressions of suspects, enabling more automated monitoring with fewer trained staff.

Indeed, key suspects can be digitally marked to assist with manual and auto surveillance, while security teams could wear connected clothing that will continually transmit their location and status and enable them to summon emergency assistance.

Connected cameras coordinate emergency management

In the 5G era, the emergency services will make extensive use of connected cameras to control and coordinate their operations. The police and fire brigade will wear body cameras, while drone-mounted cameras will conduct local area surveillance, and video cameras will be mounted on emergency service vehicles. This video footage, which will need to be very high quality, will be fed simultaneously into local sites and mobile control centres.

Controlling emergency service vehicles and robotics in hazardous environments

The emergency services will increasingly look to robotics to support their operations in hazardous environments. Robots will be able to check burnt out buildings at risk of collapse, drones will scan coastlines and mountainous terrain to detect smugglers, without risks to officers. These emergency service vehicles will require precise highly responsive remote control and high-definition video streaming delivered by reliable high-bandwidth mobile networks.

ENHANCED EDUCATION AND TRAINING

Already popular with some gamers, virtual reality (VR) and augmented reality (AR) headsets could also be used for education and training. For example, trainee engineers, mechanics and even medics could learn how to perform specific tasks by following instructions relayed via AR or by using VR simulations. Similarly these kinds of technologies could be used to teach biology and geography students about specific habitats and environments, either by superimposing digital information on images of the real world or by simulating the real world in virtual reality.

To date, the development of these kinds of interactive and immersive training applications has been limited by the high latency of most internet connections. 5G networks will remove these limitations, paving the way for a radical change in the way people approach education and training, which could take place almost anywhere and anytime.

In many cases, digital education and training courses will borrow techniques from video gaming to keep students engaged. Indeed, so-called serious games could be widely applied in fields, such as healthcare, engineering and the armed forces, where people need to learn hands-on skills. At the same time, highly reliable and responsive wireless connectivity will enable new forms of hands-on learning by enabling the haptic overlay of the learner and teacher. The teacher will be able to feel the learner's movements when they undertake a task involving fine motor skills, and correct as necessary. The learner will be able to see, hear and feel the exact movements their trainer has made, be they an engineer, pilot or surgeon.

RICHER RESOURCE MANAGEMENT

As the world's population climbs inexorably towards eight billion, the planet's resources – land, fresh water, fossil fuels and other minerals – are coming under increasing pressure. As policymakers, businesses and individuals seek to reduce waste, they are turning to connectivity to improve efficiency and better match supply and demand. By enabling large numbers of sensors to be connected in each cell, 5G will accelerate the deployment of such solutions. It will enable people to have real-time information on everything from soil acidity to water pollution to the availability of parking spaces.

"By 2035, 5G will enable $12.3 trillion of global economic output and support 22 million jobs worldwide," says Ronan Dunne, Executive Vice President and Group President, Verizon Wireless. "Much of that growth will come from the digitization of transportation, agriculture, manufacturing and other physical industries."

"It will be about creating solutions for real-life business challenges rather than selling pre-packaged solutions off-the-shelf," says Mishka Dehghan, Vice President of 5G Development at Sprint. "For example, the ambition of the mayor of New York City is to reduce CO2 emissions by 50% by 2020. We can help him do that with 5G. We have developed a precision-based location service, which is accurate down to the inch. What's the number one barrier to greater use of electric vehicles? Charging the battery of the car is a real pain. When I go to my lunch and I park my car, I can use my app to summon an autonomous robot that will come and charge the battery of my car while it is parked. This is not science fiction. We demonstrated it in one of the parking garages at LaGuardia Airport."

Smarter agriculture

With 5G, farmers will be able to boost yields and crop quality by precisely monitoring soil and weather conditions to tailor the use of pesticides and fertilisers. Connected vehicles could increase the efficiency of food distribution through optimal routing and monitoring of temperature control of food in transit. Better use of mobile refrigeration will lead to crops being delivered in better condition with longer market and shop lives.

"Large scale agriculture plants will deploy massive numbers of sensors across fields, supplemented by drones with high-definition, real-time video, which will enable automated crop management and harvesting," says Matthew Bloxham, Senior Analyst, Bloomberg Intelligence. "Being able to automate these processes will be compelling, given the low margins in farming."

Reducing environmental impact

By giving people fingertip control over their assets, 5G will help them to better manage their energy usage, reduce their greenhouse gas emissions and tap new, cleaner sources of power. With ubiquitous and reliable wireless connectivity, policymakers will be able to better incentivise citizens to select green options for transport, for running their home and for recycling of waste.

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CONCLUSIONS

By making high-speed connectivity ubiquitous, highly responsive and versatile, 5G, AI and IoT will transform the way we work and play. Many aspects of daily life, from the way we consume entertainment to the way in which we learn and interact with colleagues, will become much richer and more fulfilling. Individuals will always have the information and services they need at their fingertips, meaning both businesses and the public sector will become far more efficient and effective.

Behind the scenes, 5G will enable a vast expansion in the Internet of Things, which will collect the real-world data that machines need to learn and develop artificial intelligence. Advanced artificial intelligence will enable a huge range of compelling new services that will anticipate people's wants and needs, while helping them navigate life's challenges and setbacks.

Like artificial intelligence, 5G is one of the key building blocks of a sustainable future. By supporting large numbers of connections simultaneously, 5G will enable people to manage resources far better than has been possible in the past, while making transport both safer and more efficient. In time, the data collected by 5G networks will help humanity address some of its most pressing challenges, including climate change, an aging population and the spread of both chronic and infectious diseases.

About the GSMA
The GSMA represents the interests of mobile operators worldwide, uniting more than 750 operators with over 350 companies in the broader mobile ecosystem, including handset and device makers, software companies, equipment providers and internet companies, as well as organisations in adjacent industry sectors. The GSMA also produces industry-leading events such as Mobile World Congress, Mobile World Congress Shanghai, Mobile World Congress Americas and the Mobile 360 Series of conferences.

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