INTERNET OF THINGS IN THE 5G ERA

Opportunities and Benefits for Enterprises and Consumers

NB-IoT LTE-M 5G

NOVEMBER 2019

TABLE OF CONTENTS

1. Executive Summary

This paper explains how 5G mobile technology will impact the Internet of Things (IoT).

Initial deployments of commercial 5G cellular networks are now under way. Adoption of 5G and the IoT is being driven by a number of factors, including increased demand from consumers and enterprises and the availability of more affordable devices. Significant operator investment in 5G technology, spectrum and infrastructure, together with the implementation of global standards, are also helping to drive growth and increase market interest in the IoT.

The 5G mobile cellular networks being deployed today are evolving from existing 4G networks, which will continue to serve many use cases. Intended to last well into the future, 5G can cater for current requirements, such as smart energy applications, as well as anticipating use cases that are still some time away, such as self-driving cars. As they manage the technology evolution, mobile operators will need to ensure that their networks support both current and future use case requirements. Prudent operators will manage their investments to ensure customers are supported as networks transition to 5G.

Most 5G use cases can be grouped under three main categories - enhanced mobile broadband (eMBB), massive IoT and critical communications, each with its own speed, capacity and latency, requirements. Although 4G will continue to be used for many consumer and enterprise IoT use cases, 5G provides a range of benefits to the IoT which are not available with 4G or other technologies. These include 5G's ability to support a massive number of static and mobile IoT devices, which have a diverse range of speed, bandwidth and quality of service requirements. As the IoT evolves, the flexibility of 5G will become even more significant for enterprises seeking support for the rigorous requirements of critical communications. The ultra-reliability and low latency of 5G will allow self-driving cars, smart energy grids, enhanced factory automation and other demanding applications to become a reality.

Cloud computing, artificial intelligence and edge computing will all help to handle the data volumes generated by the IoT, as 5G boosts network capacity. Further 5G enhancements, such as network slicing, non-public networks and 5G core, will ultimately help to realise the vision of a global IoT network, supporting a massive number of connected devices.

2. Introduction

The first 5G networks are being deployed around the world today, amid expectations that this advanced mobile technology will play a significant part in the digital transformation and economic success of many countries.

The first commercial 5G mobile cellular networks, and the availability of more affordable devices, are driving demand and market interest among both consumers and enterprises. This paper looks at the impact of 5G on the IoT and examines some of the unique features and benefits of 5G, compared to other technologies. It also presents IoT use cases that can be supported using existing cellular technologies, such as 3G and 4G, and discusses use cases where 5G is essential. Focused on the deployment of cellular technologies for IoT applications, this paper is intended to be an educational document for non-technical users and procurers of communication systems within enterprises.

The number of IoT connections is set to surge over the next five years. The GSMA Intelligence forecasts the total number of IoT connections will grow to 25.2 billion by 2025. It estimates 3.1 billion of these will employ cellular technologies, including low power wide area Mobile IoT[1] networks.

IoT devices today use a wide variety of wireless technologies. These include short-range technologies, typically using unlicensed spectrum, such as WiFi, Bluetooth, ZigBee and Z-wave and wide area cellular technologies, using licensed spectrum, such as GSM, LTE and 5G. Alternative solutions are also available, such as low-power technologies operating in unlicensed spectrum, including LoRa and Sigfox. Cellular technologies operating in licensed spectrum offer a number of benefits for IoT devices, including enhanced provisioning, device management and service enablement. More significantly, cellular networks offer the global coverage and high levels of reliability, security and performance required by even the most demanding IoT applications.

Today's LTE or 4G networks will continue to co-exist with 5G, offering sufficient coverage and capacity for a wide range of use cases, as 5G coverage expands globally in the coming years[2].

However, 5G brings a range of benefits to the IoT which are not available with 4G or other technologies. These include 5G's ability to support a massive number of static and mobile IoT devices, which have a diverse range of speed, bandwidth and quality of service requirements. Most of these can be grouped under three main categories - enhanced mobile broadband (eMBB), massive IoT (known as mMTC) and critical communications. The 5G networks being deployed today are building on 4G networks, which employ both LTE for Machines (LTE-M) and Narrowband-IoT (NB-IoT) technologies, with 5G delivering the functionality required to support both existing and future use cases.

[1] https://www.gsma.com/iot/wp-content/uploads/2018/08/GSMA-IoT-infographic_18-19_2.png
[2] The Mobile Economy 2018, GSMA Intelligence

The GSMA expects 5G to deliver high-speed, low-latency, reliable and secure mobile broadband in its early deployments[3]. Over time, massive numbers of IoT devices will be connected to 5G networks, providing support for ultra-reliable and low latency communications. A combination of 5G and wireless edge technologies will support demanding use cases, such as autonomous driving, time-critical industrial IoT manufacturing processes and augmented and virtual reality (AR/VR).

Mobile IoT networks, using LTE-M or NB-IoT cellular technology, continue to gain traction for applications that require low power wide area (LPWA) connectivity. As of October 2019, mobile operators had launched 123 commercial LTE-M and NB-IoT networks[4]. These networks will continue to evolve and will operate seamlessly both with existing networks and 5G NR (New Radio) connectivity. From the core network perspective, both the existing LTE Core (Enhanced Packet Core/EPC) and the new 5G core (5GC) will continue to support the evolution of Mobile IoT into the future.

> “Over time, massive numbers of IoT devices will be connected to 5G networks, providing support for ultra-reliable and low latency communications”

[3] The 5G Era, GSMA Intelligence

[4] https://www.gsma.com/iot/mobile-iot-commercial-launches/

3. 5G Solutions for IoT

3.1 INTRODUCTION

Standards body 3GPP has made a number of enhancements to 5G network architecture and NR specifications to improve support for IoT devices used by consumers and enterprises.

3GPP Release 16, the second phase of the 5G specifications, is scheduled to be completed by December 2019. Release 16 will enhance the capabilities of the 5G NR and introduce support for key features such as:

- Ultra-Reliable Low Latency Communications (URLLC)
- Non-public networks

3.2 ULTRA-RELIABLE LOW LATENCY COMMUNICATION (URLLC)

Resilience will be key in the 5G era, as the mobile network is being explicitly asked to support ultra-reliable and critical systems, such as automatic control of industrial devices and autonomous self-driven vehicles. This is an important selling point for 5G and is reflected in the identification of URLLC as one of the key pillars of the 5G opportunity, according to the GSMA[5].

URLLC is critical for enterprise IoT use cases and in the consumer sector for smart city and smart home applications. For example, smart cities could use URLLC IoT devices to manage traffic more efficiently, prevent congestion and warn of accidents ahead, benefitting road-users. In smart homes, URLLC capabilities will bring a number of benefits, supporting online gaming and AR/VR devices. Faster response times and higher reliability will reduce transmission delays, providing a more immersive experience.

Low latency connectivity is important for machines that drive themselves, such as autonomous vehicles, or perform critical tasks, such as control of industrial devices. Low latency will allow a 5G network to be optimised to process huge volumes of changing data in real time, a capability not possible with other technologies.

In summary, the reliability and low latency required for critical IoT will be best served with 5G technology supported by global standards.

[5] The 5G Guide, A Reference for Operators, GSMA Intelligence

3.3 NON-PUBLIC NETWORKS

Industrial IoT applications often require a high level of security and reliability. These include

- Industrial robots
- Factory vehicles
- Predictive maintenance
- Connected tools
- Wearable technology[6]

Typical public networks may not meet the stringent requirements needed by enterprises for these applications.

3GPP Rel-16 defines non-public networks – often referred to as 'private networks' – as networks which serve the needs of enterprises. A number of independent spectrum options, including dedicated IoT frequency bands, shared bands and unlicensed bands, could be used to enable non-public networks. In addition, operators can allocate part of their spectrum assets to support these networks.

Non-public networks can connect to public networks or be restricted to a particular factory or site, depending on the requirements. Again, 5G technology gives enterprises the flexibility to serve their individual needs. Some potential use cases include campus networks in universities, hospitals or military bases, as well as maritime ports, manufacturing sites or transport hubs.

Network slicing technology could offer an alternative to a private network: the GSMA has published a document[7] introducing network slicing, showing how it can be utilised by business customers to meet their individual requirements in a similar manner to a private network.

[6] https://www.iotworldtoday.com/2017/09/20/top-20-industrial-iot-applications/
[7] https://www.gsma.com/futurenetworks/5g/introduction-to-5g-network-slicing/

4. 5G IoT Opportunities, Benefits and Use Cases

4.1 INTRODUCTION

Mobile operators have a clear opportunity to benefit from 5G: new use cases for cellular connectivity will provide additional revenue streams for operators and the broader telecommunications industry. A 2018 GSMA/TMG study[8] estimated that 5G will add more than US$2.2 trillion to global GDP and US$588 billion in worldwide tax revenues cumulatively over the period from 2020 to 2034.

Enterprise and consumers are both set to gain from the 5G evolution. This section looks at the opportunities, benefits and use cases related to deploying 5G IoT rather than other technologies.

4.2 OPPORTUNITIES AND BENEFITS FOR ENTERPRISES

The enterprise segment will be the biggest source of incremental 5G revenues for mobile operators. 5G will bring new capabilities and the flexibility to serve the specific needs of different enterprise customers, which the GSMA estimates could be worth up to US$400 billion per annum to operators by 2025[9].

Two further GSMA surveys underline the importance of the enterprise segment to mobile operators. In an October 2016 global survey of 750 CEOs, nearly 70% of respondents indicated that they view the enterprise segment as the most important opportunity for the mobile industry in the 5G era[10]. A more recent survey from April 2018 revealed that the industry aspires to generate 40% of its revenues from enterprises five years post-5G[11].

For enterprises, 5G cellular connections will bring a range of benefits compared to earlier cellular technologies, such as 4G. It builds on 4G in a number of key areas, including speed, capacity and latency. Although 4G is in use throughout the world, it will not be able to match 5G speeds nor will it be able to manage huge numbers of devices on the network. As discussed in the previous section, latency[12] is also a key differentiator for 5G. The low latency supported by 5G means that enterprises can enhance manufacturing processes in factories, for example, by increasing use of automated robotics and vehicles.

[8] https://www.gsma.com/spectrum/wp-content/uploads/2019/10/mmWave-5G-benefits.pdf
[9] The 5G Guide, A Reference for Operators, p.130, GSMA Intelligence
[10] The 5g era: Age of boundless connectivity and intelligent automation, p.23, GSMA Intelligence
[11] The 5G Guide: A Reference for Operators, p100, GSMA Intelligence
[12] Latency is the time taken for information to be sent from a device until it can be used by the receiver.

In cities, 5G will enable enhanced traffic management by supporting a massive number of IoT connections to traffic lights, cameras and traffic sensors. Smart meters - supported by 5G low cost IoT sensors and connections - will monitor energy usage and help reduce consumption.

A recent GSMA Intelligence market survey[13] revealed that most enterprises are already using IoT. It found that 65% of the surveyed enterprises had deployed an IoT solution. The majority of deployments are small, but the size of deployments will increase with the arrival of 5G.

The business and technical benefits of 5G for enterprises are summarised in the following pages, which outline use cases and business models enabled by 5G, together with key requirements and future potential roles for operators as 5G technology matures.

4.2.1 AUTOMOTIVE AND MOBILITY

ENTERPRISE USE CASES ENABLED BY 5G AND KEY BENEFITS

- High bandwidth connectivity to provide a seamless and high QoS for infotainment, navigation and other services.
- Low latency and high bandwidth connectivity can support platooning, which improves fuel efficiency and reduces the number of drivers required.
- In future, low latency, high bandwidth connections could support remote driving and remote support (e.g. vehicle maintenance), which can open up new services/cost savings.
- Network slicing provides road/infrastructure managers with the flexibility to better manage their infrastructure - slices can be allocated for specific functions.

NEW BUSINESS MODELS ENABLED

- Data-based business models become available to car manufacturers; they can monetise data assets (such as traffic information and driving patterns) with other stakeholders, such as insurance companies and fleet managers, who may value the information.

KEY REQUIREMENTS FROM MNOs

- MNO will need to provide clear service level agreements (SLAs) for network slices.
- Closer relationships between telcos and car manufacturers are needed.

POTENTIAL OPPORTUNITIES FOR MNOs

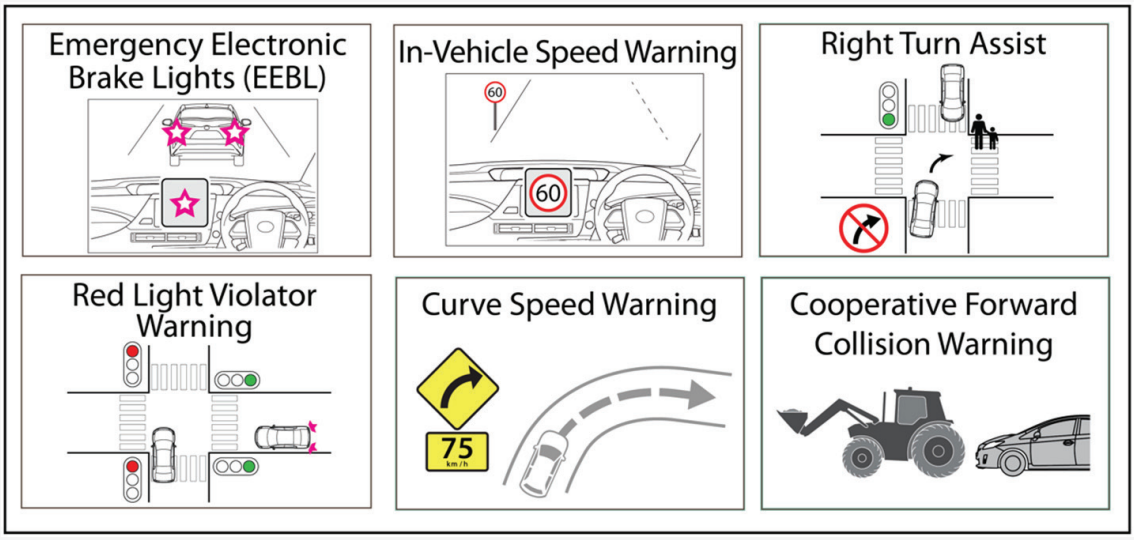
- Pan-regional networks.
- Public private partnerships (PPP) with governments/smart cities, but highly dependent on the market.

[13] https://www.gsmaintelligence.com/research/?file=1578f93f699691a8a2f6285042e0fab3&download

ADVANCED CONNECTED VEHICLE TRIAL

While the development of autonomous vehicles is drawing much attention, it is unlikely that there will be mass adoption of fully driverless vehicles on public roads for a number of years. As a step in the direction of a driverless future, however, connected & smart vehicles are seeing increased adoption. For example, 75% of cars shipped in 2020 in Australia are likely to be connectivity-capable[14] [15]. In the coming years, vehicles' connectivity will be used for more than streaming music and reporting weather: vehicles will be talking to road infrastructure, other vehicles on the road and even pedestrians – very near term possibilities that 5G & IoT can help enable.

In a connected vehicle trial in Australia, operator Telstra partnered with vehicle manufacturer Lexus Australia to deliver a cellular V2X (vehicle-to-everything) project that establishes the real-world impact of advanced connectivity technologies on improving road safety. Sponsored by road authority VicRoads and the Transport Accident Commission (TAC), the Advanced Connected Vehicles Victoria (ACV2) trial seeks to demonstrate six safety-enhancing use-cases. These use-cases (illustrated below) all involve a human machine interface (HMI) to give warnings of potential hazards to drivers of connected vehicles.



[14] Business Insider Intelligence Connected Car Report (https://www.businessinsider.com/connected-car-forecasts-top-manufacturers-leading-car-makers-2016-4-29/?r=AU&IR=T)

[15] 5GAA Forecast

These warnings are delivered over Telstra's 4G network, which has been adapted to provide a 5G-like service. As most of the above applications are time-critical (with timely collision warnings being particularly important in a potential life or death scenario), Telstra has built a low-latency service specifically for the trial. This service sits on top of the 4G network, and uses RAN software features (at 4G base stations) to provide reliable lower latency connectivity for vehicle-specific messaging, pre-empting the kind of quality of service 5G could deliver in the years to come. While this service works well for current purposes, 5G (and in particular URLLC) would help with the delivery of this kind of capability at scale.

Telstra has established a significant trial area across Melbourne, Australia, with coverage of both urban and rural roads. Trial activities have included both controlled and on-road testing, with a notable feature of the project being the 'virtualization' of roadside infrastructure. Rather than having to install physical boxes at intersections in order for vehicles to receive information about their local environment, mobile communication with a cloud platform linking vehicles to road authority-managed systems, such as SCATS (Sydney Coordinated Adaptive Traffic System,) bypasses the need for extensive fixed infrastructure. This not only demonstrates how the use of mobile networks can help reduce rollout costs, but highlights the kind of benefits that continual network improvement can bring. The handling of an entire ecosystem of interconnected vehicles and their virtual communications with the road network is one clear new use for the additional capacity provided by 5G.

The Lexus vehicles employed in the trial (see above) also utilize high-precision QZSS antennas (Quasi-Zenith Satellite System) to ensure the vehicles are able to report their location with lane-level accuracy. This enables safety systems, such as "right-turn assist", where a vehicle turning on a busy road is alerted that potentially-obscured pedestrians are crossing in front of it. This kind of use case, which requires both location accuracy and low latency connectivity, can make roads safer in the short term. Longer term, the kind of precise information sharing that a 5G cellular-V2X ecosystem could deliver should help give semi and fully-autonomous vehicles the eyes and ears they need for safe, at-scale usage on our roads.

http://www.acv2.com.au/

4.2.2 MEDIA AND CONTENT

ENTERPRISE USE CASES ENABLED BY 5G AND KEY BENEFITS

- Transmitting high volume, high definition video in real time requires the high bandwidth and low latency of 5G.
- Cloud gaming requires the low latency and high bandwidth of 5G. Edge computing can also help to process large volumes of data, meaning the AR/VR headset itself does not need to include advanced processing capabilities.
- Low latency and high bandwidth 5G can support live broadcasting using smartphones and interactive and immersive VR experiences.
- In the retail sector, 5G will enable the use of VR to enhance the customer experience for shopping/car parking etc.

NEW BUSINESS MODELS ENABLED

- Advertising opportunities for the media/content provider e.g. immersive retail.
- An enterprise could have its own private network. However, this could be very expensive, as it will require resources to manage and run.

KEY REQUIREMENTS FROM MNOs

- Live content requires low latency, high bandwidth and high reliability connectivity.
- Media and content players need operators to collaborate better and agree on common application programming interfaces (APIs) for developers.

POTENTIAL OPPORTUNITIES FOR MNOs

- Media and content players are willing to experiment with 5G use cases.
- Companies working within a smaller ecosystem value the reach and marketing spend that can be accessed through partnerships with mobile operators.
- Revenue share business models for new services with multiple parties involved.
- Proprietary platforms help operators diversify, improve revenues and move further up the value chain.
- Cloud computing is key to handling the large volumes of video traffic: operators could provide associated cloud delivery services for media and content.

HOW THE IoT IS CHANGING THE GAMING INDUSTRY

This report looks at how the IoT is helping to make games more immersive and engaging than ever before.

https://www.headstuff.org/entertainment/gaming/how-the-internet-of-things-is-changing-the-gaming-industry/

4.2.3 PUBLIC/SMART CITY

USE CASES ENABLED BY 5G AND KEY BENEFITS

- Connected vehicles for police, linked to traffic lights.
- Mass digitisation of some public services. For example, police officers with smartphones capable of transmitting high quality voice and video feeds from crime scenes.
- Smart city management. For example, city-wide air quality monitors to advise public on potential hazards.
- Network slicing to provide higher security and reliability for mission-critical services.

NEW BUSINESS MODELS ENABLED

- The public sector will value cost efficiencies, security and reliability.
- A municipality could have its own private network. However, this could be very expensive, as it will require resources to manage and run.

KEY REQUIREMENTS FROM MNOs

- Need guarantee of service.
- Need network prioritisation for emergency services.
- Need low cost and reliable connectivity from 5G.

POTENTIAL OPPORTUNITIES FOR MNOs

- Operators have the potential to re-sell services provided to the public sector to the private sector. For example, re-selling prioritisation services at a premium to enterprises.

SMART CITY

The city of Chicago is undergoing a transformation. By harnessing the power of big data and the IoT, the city is fundamentally improving its services and economy. 5G will further enhance the analysis of the vast amounts of data being generated by IoT devices, using edge computing to process the data in near real-time. In this short video, the city's administration and AT&T discuss how collaboration has been vital to the success of Chicago's various smart city initiatives.

https://www.gsma.com/iot/resources/smart-city-chicago/

4.2.4 HEALTHCARE

USE CASES ENABLED BY 5G AND KEY BENEFITS

- Training junior doctors for surgery using AR/VR delivered via low latency and high bandwidth 5G.
- Wired connections in operating theatres could be replaced with the low latency and secure wireless connections made possible by 5G.
- Enhancing remote real-time diagnostics by delivering high quality video over 5G.
- The use of robots for dispensing of pharmaceuticals, support diagnostics and ultimately perform surgery, with 5G providing the necessary low latency and high bandwidth connectivity.
- Data analytics across medical records, such as CT scans, can help with patient prioritisation.

NEW BUSINESS MODELS ENABLED

- More about cost optimisation than new business models. The focus will be on offering the best experience for patients and physicians.

KEY REQUIREMENTS FROM MNOs

- 5G has to offer the same latency as wired networks with no interruptions, as patient safety is of paramount importance.
- Low price for cellular connectivity for diagnostic devices, while offering a similar high performance to fibre connectivity.

POTENTIAL OPPORTUNITIES FOR MNOs

- Operators could provide cloud storage/data centres, outsourcing these assets to other parties that are not large enough to have their own.
- Diversification of revenue streams.
- Governments are looking for innovative partners and PPP models for healthcare use cases

SMART CITIES HEALTH

The dense population of cities can stretch healthcare services and can speed up the spread of disease. 5G and IoT technology can improve the monitoring of the health of a city's population, whilst giving emergency services new tools to improve their response times to emergencies. This use case describes how an operator provided the tools to effectively bring the outbreak of a deadly fever to an end.

https://www.gsma.com/iot/smart-cities-resources/smart-cities-health/

4.2.5 MANUFACTURING

USE CASES ENABLED BY 5G AND KEY BENEFITS

- Wirelessly connecting a large number of devices in a secure and cost-efficient way, as wired connections are expensive and inflexible.
- Enabling virtual control of machines with low latency 5G connectivity. This leads to cost optimisation as less CPUs (central processing units) are needed on one floor.
- Telemetry/information exchange between a large number of interconnected devices in real time. A combination of cloud computing, eMBB and mMTC can be used to transmit the information in real time in high resolution.
- Network slices can be reserved for specific functions.

NEW BUSINESS MODELS ENABLED

- Providing service capabilities to customers based on analytics of data generated by connected devices. For example, predictive maintenance or providing cloud computing.
- Product innovation based on networked equipment and machines.

KEY REQUIREMENTS FROM MNOs

- The minimum requirement for 5G is to deliver similar latency to a fixed network for mission-critical applications.
- Support for backward compatibility with earlier generation devices may be required.
- Communicate clearly that NB-IoT and LTE-M will continue to be supported as part of 5G and provide clear deployment and technology support timeframes.

POTENTIAL OPPORTUNITIES FOR MNOs

- Provision of cybersecurity services.
- Potential for operators to leverage their global reach and help provide 'out-of-the-box' connectivity to simplify device deployment.
- Potential for operators to become data platform providers.

5G SMART INDUSTRIAL FACTORY

This case study illustrates how Ericsson is utilising 5G Mobile IoT and other cellular networks to support a wide range of different manufacturing use cases, optimising manufacturing processes via a single communication system.

https://www.gsma.com/iot/resources/ericsson-smart-industrial-factory/

5G SMART PRODUCTION AND DEVELOPMENT

Deutsche Telekom is further expanding its partnerships to tap into smart production and development opportunities.

https://www.mobileeurope.co.uk/press-wire/deutsche-telekom-partners-up-for-smart-factory-push

4.2.6 ENERGY AND UTILITY

USE CASES ENABLED BY 5G AND KEY BENEFITS

- Edge computing will enable utilities to scale the number of connected devices and deploy platforms and analytics that can handle the resulting data volumes in real-time.
- 5G could be a flexible and cost-effective replacement for last mile fibre.
- Micro-robots could perform inspection of sensors and share information in real-time for fault prevention, helping to reduce costs.
- In the longer-term, management of complex virtual energy production plants.
- Cybersecurity services that protect the large volumes of data, delivered in collaboration with security partners.
- Running private networks that provide utilities with greater control.

NEW BUSINESS MODELS ENABLED

- Cybersecurity services that protect the large volumes of data, delivered in collaboration with security partners.
- Running private networks that provide utilities with greater control.

KEY REQUIREMENTS FROM MNOs

- Clear communication of how technologies will be supported once deployed.
- Support for backward compatibility with earlier generation devices may be required.
- Rigorous SLAs to encourage adoption of 5G.
- Managing cybersecurity is becoming more important as the volumes of data increase. The veracity of data from wireless networks needs to be established.
- Enterprises need to understand from operators the value proposition for technologies, such as network slicing and mobile edge computing.

POTENTIAL OPPORTUNITIES FOR MNOs

- Delivering cybersecurity and/or trusted data services.
- Where market conditions allow, deep collaboration with utilities in which operators provide platforms for energy management.
- Audit the certification of IoT devices.

SMART METERING

China Mobile's automated meter reading service for electric utilities, which consists of an NB-IoT connected smart meter and the cloud based OneNET management and application development platform, can be deployed by a utility or in industrial parks and intelligent buildings. The solution optimises the meter reading process and enables accurate billing for electricity consumption, which has been an issue in some parts of China.

https://www.gsma.com/iot/resources/china-mobile-electric-smart-metering-internet-of-things-case-study/

EMISSIONS REDUCTION

Telecom Italia has developed an analytical model that suggests that 5G could cut CO2 emissions by 8.2% a year at the port of Livorno.

https://www.mobileeurope.co.uk/press-wire/tim-demos-how-5g-could-reduce-port-emissions

4.3 OPPORTUNITIES AND BENEFITS FOR CONSUMERS

Early 5G networks are set to transform the mobile broadband experience for consumers by delivering download speeds of over 1Gbps to enable a consistently high-quality mobile broadband experience with reliable internet access at home, in the office and on the move. This enhanced, reliable and high-speed mobile broadband experience will be complemented by IoT devices and applications, facilitated by operators' Mobile IoT networks.

One of the ultimate tests for 5G will be to capture the vast amounts of data generated by consumer IoT devices. Here, 5G should excel thanks to its capacity, bandwidth and low latency capabilities which can support edge computing, machine learning and artificial intelligence to collect, analyse and respond to consumer demands in real time.

As discussed earlier, transportation is one important area where consumers should benefit, with 5G-connected IoT devices providing a range of enhanced safety measures for motorists. These include advanced warning capabilities, collision detection, vulnerable user detection, using on-board IoT sensors, and improved infotainment facilities.

In June 2017, 3GPP completed the standardisation of Cellular Vehicle-to-Everything (C-V2X) technology. Based on LTE, this cellular technology is designed to connect vehicles to each other, to roadside infrastructure, to other road users and to cloud-based services via the IoT[16]. A combination of 5G NR, URLLC, edge, cloud and network slicing technologies will enable applications that pave the way to assisted driving and fully autonomous vehicles. Motorists will benefit from fewer accidents, increased driving comfort and more cost-effective road transportation.

> "A combination of 5G NR, URLLC, edge, cloud and network slicing technologies will enable applications that pave the way to assisted driving and fully autonomous vehicles"

[16] https://www.gsma.com/iot/wp-content/uploads/2017/12/C-2VX-Enabling-Intelligent-Transport_2.pdf

4.3.1 ENHANCED MOBILE BROADBAND (EMBB)

The GSMA expects 5G to expand the consumer IoT market by delivering high-speed, low-latency, reliable and secure enhanced mobile broadband (eMBB) in its early deployments[17]. Enhanced MBB will support the delivery of high definition consumer video (e.g. TV and gaming), immersive communications, such as video calling and augmented and virtual reality, and smart city services, including IoT video cameras for surveillance.

The biggest benefit from 5G will be its capacity to support large volumes of data traffic and large numbers of users, including IoT devices. By some estimates, 5G will provide the capacity for at least 100GB per month per customer[18]. In addition, the cost per bit is set to decrease, potentially making "unlimited" data bundles feasible.

5G will also support low latency and high throughput IoT services for consumers. The "tactile Internet", providing fingertip control over remote assets, and "immersive communications", such as high definition video conferencing, are examples of consumer use cases that will benefit from 5G's lower latency capabilities, predicted to be as low as 1ms between the device and base station.

4.3.2 FIXED WIRELESS ACCESS (FWA)

Fixed Wireless Access (FWA) systems can be used to provide Internet access to homes using wireless technologies rather than fixed lines.

5G FWA enables home broadband services to be set up quickly and cost-effectively in areas that do not have access to fixed line home broadband. Consumer 5G FWA is likely to have a major impact in both developing and developed markets, bringing broadband availability to rural areas not served by fixed-line operators. The main benefit of FWA for consumers is performance: FWA will deliver speeds similar to fibre-based services. In addition, the cost per bit to connect a household to broadband using FWA can be 74% lower than wireline connections[19]. For customers, the advent of 5G means that previously unconnected households and communities will realise the benefits of higher speeds, capacity and bandwidth to support their increasing number of IoT devices.

[17] The 5G era: Age of boundless connectivity and intelligent automation, GSMA
[18] The 5G Guide, A Reference for Operators, p.115 eMBB Drivers, GSMA Intelligence
[19] https://www.gsma.com/futurenetworks/technology/understanding-5g/fixed-wireless-access/

FIXED WIRELESS ACCESS: ECONOMIC POTENTIAL & BEST PRACTICES

As customers demand high throughput and low latency connectivity everywhere, both mobile and fixed networks will need to be densified to serve consumer use cases as well as business use cases effectively.

FWA can provide an economic means to achieve network densification, bringing broadband connectivity to regions where wireline infrastructure is not present or only copper wireline infrastructure is in place. This GSMA document focuses on FWA based on 3GPP standards, including 4G LTE and 5G NR.

https://www.gsma.com/futurenetworks/5g/fixed-wireless-access-economic-potential-and-best-practices/

4.4 MOBILE IOT IS PART OF THE 5G STORY

Many IoT applications are well supported by existing 4G cellular networks, including those employing LTE-M and NB-IoT technologies. But 5G will further enhance these Mobile IoT networks.

Massive IoT connectivity based on low power wide area networks will become less expensive and less complex as the technology evolves, providing the foundation for energy-efficient smart services. 3GPP has incorporated LTE-M and NB-IoT into the 5G specifications, confirming their long-term status as part of future 5G standards.

The large-scale deployment of 5G will accelerate when IoT becomes embedded within enterprise and consumer applications, many of which are developed by small and medium-sized enterprises.

The case studies presented below show how Mobile IoT applications, using LTE-M and NB-IoT technologies, are being deployed to support a wide range of use cases.

HOW ASIA PACIFIC INTELLIGENTLY CONNECTS TO IoT

This report shows how LTE-M and NB-IoT are being deployed in the Asia Pacific region. Drawing on interviews with mobile operators and their partners, the report describes six very different Mobile IoT applications. These case studies highlight how Mobile IoT networks can be used to support a very wide variety of use cases.

https://www.gsma.com/iot/resources/mobile-iot-asia-pacific-case-study/

ENABLING MILLIONS OF IOT DEVICES IN CHINA

In China, the leading mobile operators are using Mobile IoT technologies to connect millions of consumer devices, appliances and machines.

Designed to connect devices with low bandwidth requirements, NB-IoT significantly improves the power consumption of user devices, system capacity and spectrum efficiency, compared with other wireless technologies, especially deep indoors and other hard-to-reach locations. A device battery life of more than 10 years is feasible for a wide range of use cases.

https://www.gsma.com/iot/wp-content/uploads/2019/08/201902_GSMA_NB-IoT_Commercialisation_CaseStudy.pdf

5. Conclusion

The first 5G networks are being deployed around the world today, amid expectations that this advanced mobile technology will play a significant part in the digital transformation and economic success of many countries.

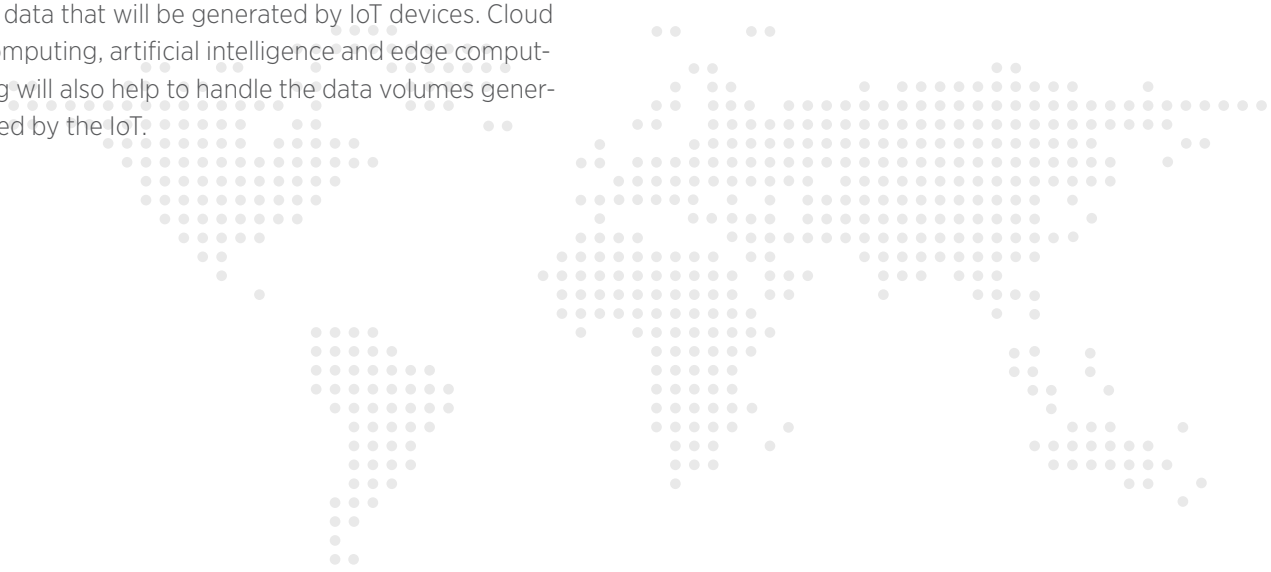
5G provides a range of benefits which are not available with other technologies. These include 5G's flexibility to support a massive number of static and mobile IoT devices, which have a diverse range of speed, bandwidth and quality of service requirements.

As the IoT evolves, the flexibility of 5G will become even more significant for enterprises. 5G will support critical communications with even more rigorous performance requirements. 5G's ultra-reliability and low latency could help make self-driving cars, smart energy grids, enhanced factory automation and other advanced applications a reality.

As well as being able to serve a very wide range of devices and their diverse service requirements, 5G networks can also securely handle the vast volume of data that will be generated by IoT devices. Cloud computing, artificial intelligence and edge computing will also help to handle the data volumes generated by the IoT.

A global technology, 5G is being implemented consistently using 3GPP international standards. It has been developed to ensure support for the IoT and it continues to evolve with ongoing enhancements to agreed standards. Building on 4G's support for IoT, Release 15 and 16 of the 3GPP specifications will provide further support for IoT devices with 5G features, including ultra-reliability and low latency.

Further 5G enhancements, such as network slicing, non-public networks and 5G core, are ultimately set to help realise the vision of a global IoT network, supporting a massive number of connected devices with diverse mobility and accessibility requirements.



TERM	DESCRIPTION
3G	3rd Generation of Mobile Telecommunications Networks
3GPP	3rd Generation Partnership Project
4G	4th Generation of Mobile Telecommunications Networks
5G	5th Generation of Mobile Telecommunications Networks
5G NR	5G New Radio
AI	Artificial Intelligence
AR	Augmented Reality
CPU	Central Processing Unit
C-V2X	Cellular Vehicle-to-Everything
eMBB	Enhanced Mobile Broadband
IoT	Internet of Things
LPWA	Low Power Wide Area
LTE	Long-Term Evolution
LTE-M	Long-Term Evolution Machine Type Communications
MCC	Mission Critical Communications
MIoT	Mobile IoT
mMTC	Massive Machine Type Communications
NB-IoT	Narrowband IoT
URLLC	Ultra-reliable low latency communications
VR	Virtual Reality

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 the industry leading MWC events held annually in Barcelona, Los Angeles and Shanghai, as well as the Mobile 360 Series of regional conferences.

For more information, please visit the GSMA corporate website at www.gsma.com.

Follow the GSMA on Twitter: @GSMA.

For more information please visit:
www.gsma.com/IoT

GSMA HEAD OFFICE
Floor 2
The Walbrook Building
25 Walbrook
London EC4N 8AF
United Kingdom
Tel: +44 (0)20 7356 0600
Fax: +44 (0)20 7356 0601