GTI Research Report on 5G New Device Type

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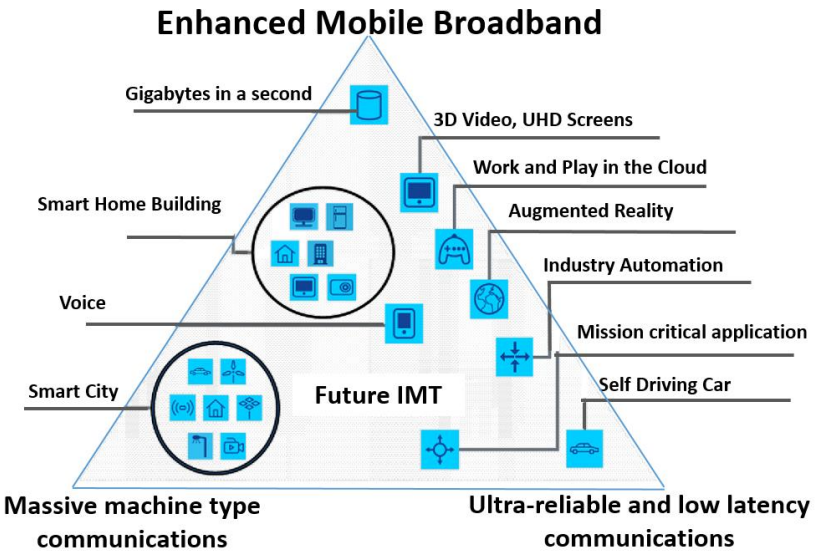
1 Introduction

From 2G, 3G to LTE generation of cellular communication, these wireless mobile systems have established the great value of mobile data to human society; moving the internet and all its associated services from a fixed abode to on-the-go anywhere. We are on the verge of the 5th generation (5G) of communication systems. It is expected to be an inflection point to further differentiate the data for an increasing number of applications, by offering increased data rate, lower end-to-end latency, and a more reliable and larger capacity system. Three broad use cases have been defined as the baseline in ITU-R for 5G, which contains enhanced mobile broadband (eMBB), massive machine type communications (mMTC) and ultra-reliable and low latency communications (URLLC).



As for initial stage of NR development eMBB is the expected primary focus, which will bring a revolution of user experience, by increasing the opportunity for devices, services and businesses with increased capacity, bandwidth and fast minimum connectivity speeds, even at the edge of networks.

For mMTC, NB-IoT or LTE Cat.M technologies are considered front-runners to sufficiently fulfill the demand, therefore an NR-based IoT evolution maybe considered in a future standard after 3GPP Release-16.

When it comes to URLLC, some of the technical requirements and user scenarios overlap with eMBB, since there is a need in part for both and there are not yet clear definitions between the dimensions of peak bandwidth and latency for each category. Therefore in a broader design we may cover both user scenarios for various applications.

Considering some of the typical cases of mission critical MTC this also requires an URLLC network, so the demand for a wide coverage deployment will benefit all broad types of communication. Leveraging eMBB infrastructure allows us to naturally diverge towards URLLC and MTC, which in turn allows exploration of new business. This potential new business opportunity justifies the investment, so therefore we believe new business and applications which require URLLC communication should first be validated by an eMBB network.

From a user equipment (UE) perspective the complexity is impacted by both the data rate and latency parameters. In this research report we focus on discussing potential new devise types and services enabled by eMBB applications, and we summarize the findings that numerous applications each requires, to some ratio, extremely high throughput (>5Gbps) and/or extremely low latency (<1ms), but not to need both at the same time, which provides the guidance for communication system design.

2 Innovative eMBB Applications

There are three main classes of new 5G applications: Enhanced Mobile Broadband (eMBB), Ultra-Reliable Low Latency Communications (URLLC) and Massive Machine Type Communication (mMTC). mMTC can mostly be fulfilled by modification and optimization of existing cellular technologies, however URLLC and eMBB require new technologies to break new bandwidth and latency boundaries. These will unlock new, potential applications and services that require 5G infrastructure. In this research report we focus on potential use cases and applications of eMBB devices, however use of URLLC applications may also be required as well.

5G infrastructure has significant implications for a number of applications that are already limited in some capacity by existing 4G services. However this is only the beginning, as every generational shift that grants more capacity and speed always grants unforeseen and unpredictable applications that will only be realized later.

Known applications that will benefit demand high bandwidth and/or ultra-low latency include

1. Augmented reality (AR), Mixed Reality (MR) and Virtual Reality devices
2. Autonomous driving
3. Infotainment services for public and private transportation
4. Mobile Media: 360-degree, 4K/8K resolution live entertainment and sports
5. Tele-education services
6. Tele-office services such as thin/zero client for mobile devices
7. Tele-health services such as remote surgeries
8. Tele-industrial applications such as remote robotics
9. Fixed Wireless Access (FWA) alternative to fixed-landline fiber services
10. Game-streaming services

1. Augmented Reality (AR), Mixed Reality (MR) and Virtual Reality (VR) devices

One of the biggest upcoming technological revolutions is AR, MR or VR devices. ABI Research forecasts that the AR smart glasses installed base will reach 48 million units in 2021, with the VR device installed base numbering over 200 million units globally.

Each reality-mode has its own unique applications and opportunities, and while basic implementations of these formats can be delivered through 4G networks, expected large-scale adoption will soon congest 4G LTE infrastructure and render the user experience intolerable. 5G eMMB will help meet this need and unlock new opportunities for these formats.

As smartphone performance increases, they are transforming into devices that can be used with VR/AR headsets. Currently, Google's Tango technology uses a Visual Positioning Service[1] (VPS) for in-door navigation, but it relies heavily on local Wi-Fi networks to define its location and the spaces it maps out. Using 5G technologies will enable more consistent signal coverage allowing VPS to be mapped via a combination of camera(s), cellular location and GPS.

Potential Requirements to 5G Device

While VR devices now operate at 1200 x 1080 @ 90fps resolution (per eye) next generation devices with 4K and even 8K @90-120fps displays (per eye) are being developed to increase fidelity and immersiveness. This amplifies the required video data bandwidth by several magnitudes (depending if any lossless-compression is used).

Generally speaking, AR/MR/VR are all performance hungry, which translates to power and battery limitations in smartphones and wearable devices (for example: Samsung Gear VR[2] or Microsoft Hololens[3]). A revolutionary 5G use-case could instead offload the AR/MR/VR sensor inputs and graphics rendering to a Cloud server, which would require only a much simpler, low power user-device that acts only as sensor recorder, 5G cellular transmitter and video decoder. This design would significantly lower the cost of ownership, enabling a much greater market potential and service-style models based on Cloud-server use time.

To enable next generation AR/MR/VR devices and 6DoF video it's expected that 200Mbps-1Gbps steaming bandwidth and sub-10ms motion-to-photon latency are required to avoid motion sickness.

Possible Device Types

Smartphone, Glasses, Headset, Helmet

2. Autonomous driving[45]

Autonomous driving will greatly depend on ultra-reliable wireless connectivity.

Scenarios such as truck platooning would enable an entry-point to autonomous transportation. This will require ultra-low latency and high reliability with sufficient safety and security implementations.

Inevitably the data-generated will become an increasing asset to transportation services, which in turn will require more bandwidth per vehicle. With a fleet of vehicles producing a constant stream of data for business' or governments, based on their internal status, telemetry, traffic, weather, road conditions etc each.

Further, enabling vehicles to communicate directly with each other could result in considerably more efficient and safer use of existing road infrastructure. If all the road-using vehicles were connected to a reliable network incorporating a traffic management system, they could potentially travel at much higher speeds and within greater proximity of each other without risk of accident. Potential dangers spotted by the increasing number of vehicular sensors could immediately be relayed to other vehicles in the vicinity.

Potential Requirements to 5G Device

At 100kmph, a reaction latency of the typical 25ms round-trip would be just 70cm whereas a typical human driver reaction latency is around 1.5 seconds: 6x longer, over 4 meters.

While individually, vehicular systems are expected to not require very high data bandwidth (~100Mbps download/upload), to enable data-connections for potentially millions of currently unconnected vehicles will require a far more extensive bandwidth infrastructure than current technologies offer. 5G provides a basis of reliable infrastructure with an ultra-low response time would be crucial for their safe operation.

Possible Device Types

Car, Bus, Truck

3. Infotainment services for public and private transport

Source: Retrieved Jan 29, 2018, from https://www.mediatek.com/products/autus-automotive/infotainment

While currently personal media needs are mostly being serviced by smartphones and tablets, private vehicles increasingly have infotainment functions built in[6] as natural extension to the legacy of radio, CD and DVD. While air travel has embraced in-seat infotainment for many years and subscription based services for private vehicles is gaining traction[7], public ground transportation services could also provide in-seat infotainment as a source of additional revenue.

Potential Requirements to 5G Device

The bandwidth requirement is not only dictated by the number of people serviced (5 people per car, 50 per coach or 500 per train for example) but also the quality and resolution of streaming media: Full HD, UltraHD 4K and potentially future 8K. Streaming 8K@60fps to 100 people would require 40Gbps of bandwidth.

Possible Device Types

In-vehicle infotainment (IVI) system, Dashboard, Tablet, Electronic Signage

4. Mobile Media: 360-degree, or 4K/8K resolution live entertainment and sports

Major sporting and entertainment events are both big value investments and have historic president. The potential market is very significant, with regular events in the hundreds of millions of viewers: the 2017 American Super Bowl had 111.3 million people watching[8], F1 motorsport has 425 million fans globally[9], and Manchester United soccer club alone has over 650 million global fans[10].

They are also frequently the perfect opportunity by the host to showcase the latest technologies. For example, the Tokyo Olympics is already set to become the first sporting event to broadcast in 8K[11], and one of the first to have 5G network coverage[12].

Smartphones displays are moving towards ever higher resolutions with HDR quality (for example: Sony Xperia XZ Premium[13], LG G6[14], Samsung Galaxy S8[15]), with video streaming services such as Netflix following as sufficient devices reach the hands of consumers. NTT Docomo President has already committed to the 2020 Olympics streamed over 5G to VR devices[16], which will let users feel like they are actually in the stadium with the athletes.

Current 360 degree video experiences are from a three degrees of freedom position (3DoF) that allows the user to rotationally look around from a fixed position. Future experiences will migrate to 6DoF, allowing the watcher to move around.

Potential Requirements to 5G Device

While 4K streaming requires typically only 25-75Mbps, 8K expectations range from anywhere between 100Mbps to 500Mbps, depending on the encoding choice and multi-channel sound mix. 6DoF, 360-degree video is expected to require even more bandwidth at 400-600+Mbps with a latency of just 20ms, depending on factors such as the resolution, compression, user feedback performance expectations (fast/slow movement) and field of movement available.

Possible Device Types

360-degree Camera with 4K/8K recording capability, Smartphone with 4K/8K display resolution

5. Tele-education services

While tele-education services are not a new concept, the increasing use of mobile devices and their native use by young people offers a way to encourage education services at all levels (basic, supplementary or further study). It's especially useful to deliver tele-education services to remote and rural areas, where students getting to school can be more difficult and teaching staff are sometimes not available for all ages.

5G mobile services can offer fast connectivity to remote and rural areas (see FWA), where streaming high quality (4K UltraHD) video will allow teachers to express a full whiteboard of text and diagrams without fine details being lost to compression or low resolution. It will allow students to zoom into areas and still read them clearly.

VR-style services (where smartphone devices are strapped into headsets) will give a native classroom style immersive experience, allowing students and teachers to interact naturally and effectively.

Potential Requirements to 5G Device

These services will require 100-200Mbps streaming data and low-latency (sub-20ms) to each user to ensure there is comfortable real-time interaction without delay.

Possible Device Types

TV, Tablet, Smartphone, VR/AR/MR Headset

6. Tele-offices services such as thin/zero client for mobile devices[21]

Source: https://www.samsung.com/us/mobile/mobile-accessories/phones/dex-station---black-ee-mg950tbegus/

Thin or zero clients have specific advantages in device cost and data security. With little to no locally stored user files corporate devices can be very efficiently managed and monitored. 5G eMMB could potentially provide users their apps and data, or even an entire OS state, every-time they turned on their device with little delay.

This is attractive if data-security and corporate device control is an essential consideration, as lost or stolen devices are simply locked out of the network with no local data risk.

Potential Requirements to 5G Device

The most demanding use of 5G data is expected to be the high bandwidth bursts when loading the client and/or OS and program data. Keeping this time to a minimum ensures maintaining productivity. Upwards of 1Gbps burst performance will be ideal, with reliable high throughput – even at the edges of connectivity - from 300-500Mbps will be essential for instilling confidence to business use.

Possible Device Types

Tablet, Smartphone, Computer Stick

7. Tele-health services[17]

5G technologies have a number of potential use cases not only in entertainment, but also practical scenarios such as tele-health services.

According to Grand View Research's report[23], the mobile health market is expected to scale to 49 Billion USD by 2020. Mobile devices are now being used regularly by medical professionals all around the world. According to a survey of 15,000 people across 15 countries, undertaken by the Mobile Ecosystem Forum[24], 44% those surveyed have seen a medical professional use a mobile device during treatment or diagnosis.

Examples of tele-health applications include surgical operations that could be performed by a remotely controlled robot across the country. This is useful where there are only a few professionals with the skills to perform certain surgeries, or in disaster zones where wireless connectivity can be established but highly trained medical personnel cannot easily or frequently reach.

Potential Requirements to 5G Device

This user scenario would require not only robot control but sensor and audio-visual data to be transmitted from the robot itself and on-site support staff. This would require Mbps-to-Gbps throughput, depending on specific application, with a focus on high reliability and a low latency that's as near real-time as possible.

Remote Healthcare

With countries of aging populations, remote healthcare is also an important step forward to alleviate the pressure and cost on health services. Medical AI, supported by remote professional services can support the needs of the elderly far faster and without them having to leave their homes.

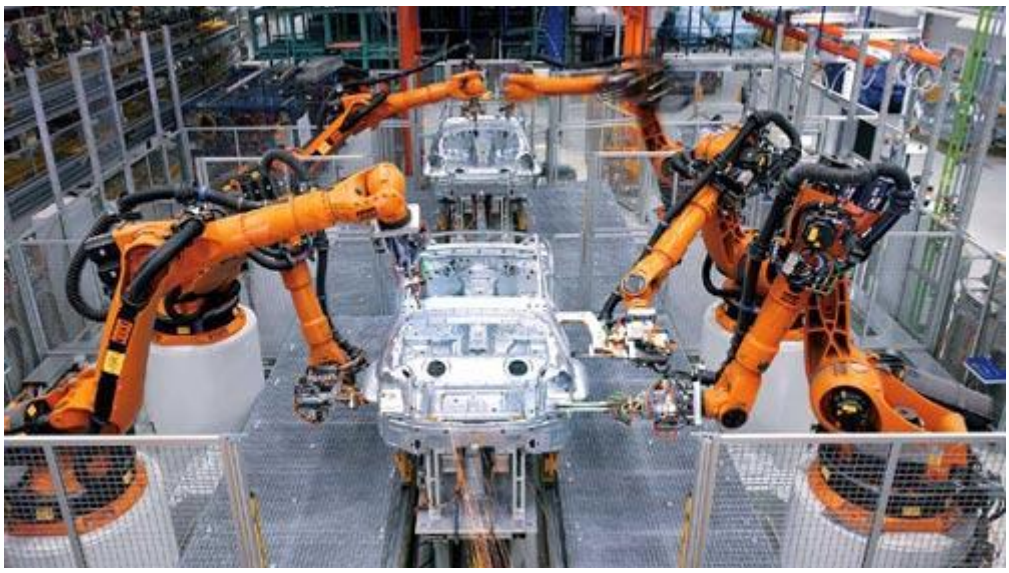
Potential Requirements to 5G Device

This requires audio-visual interaction and sensor data from the patient to be transmitted from a mobile device or in-home equipment with Mbps-to-Gbps streaming bandwidth and reliably low (sub 40ms) latency for effective and fluid real-time video calling.

Possible Device Types

Surgical Robotic Arm, Tablet, Bio Sensors for Vital Signs Monitoring System, Connected Diabetes Monitor

8. Tele-industrial applications[18]



Source: https://upload.wikimedia.org/wikipedia/commons/7/7d/Industrial-robots.jpg

The use of (semi/autonomous) robotics is an increasing industrial trend. While most industrial robots are currently controlled by local servers, the increasing use of IoT infrastructure to remotely monitor industrial processes pushes the onus of control towards a central department and server infrastructure. However, IoT is limited to only a monitoring and feedback infrastructure. Interconnecting the entire production and supply chain will be an important step to controlling quality, speed and effective distribution of mass market products. Production flexibility and efficiency will improve.

Potential Requirements to 5G Device

For more operational remote control, process update and optimization etc, 5G technologies are required that reliable ~500Mbps-to-3Gbps of data bandwidth (higher 10+Gbps for industrial backhaul operations such as inter-building communication) and strict low latency (1-10ms) requirements with low jitter (1µs), when processes are time critical.

Possible Device Types

Industrial Robotic Arm, 3D Printer, Wireless Surveillance Camera

9. Fixed Wireless Access (FWA) alternative to landline fiber services[19]

Source: https://www.networkworld.com/article/3155046/cellular-networks/atts-next-5g-wireless-trial-will-shoot-directv-now-to-users-homes.html

Fixed Wireless Access (FWA) can be an attractive alternative to fixed fiber roll-out. Fiber services can be a significant cost with a long roll-out time; they are simply unviable due to environmental, regulatory or other economic factors such as small subscriber numbers (small/remote towns and villages); or factors such as fixed infrastructure where it's too difficult to retrofit such as tall, inner-city apartment blocks or commercial buildings.

Since there is already ongoing investment in worldwide cellular services to increase coverage and reliability, the use 5G eMMB will provide an FWA alternative to fiber giving these locations fast multi-Gigabit download/upload connectivity for home and office use; enabled by low-cost, fixed antenna to the apartment or as a service for the whole building.

Potential Requirements to 5G Device

High-bandwidth and reliable internet services can allow for more efficient remote-working and inter-office collaboration tools; which is an attractive investment for local or national governments looking to stimulate business and job opportunities outside of cities.

FWA to an apartment block of 50 families would require ~10-40Gbps (@200-800Mbps each) giving enough capacity for the expectations of next-gen applications.

Possible Device Types

CPE, Router

10. Gaming as a Service (GAAS)

Source: http://kr.nvidia.com/object/cloud-gaming-geforce-grid-press-20120517-kr.html

For consumer devices, video games are a rare use case of high power computing. The video game industry has consistently pushed of performance for premium PCs, games consoles and premium mobile products.

Game streaming services (GAAS), however, moves the core processing onus from the user device into the Cloud. The user input/action is recorded and sent to the remote Cloud-server, where the game environment is rendered and only the display and audio output – essentially a livestream video feed – is sent to the user device. This means the user device requires only state of the art connectivity and simple AV decoding.

This type of service model is very attractive to many game publishers, infrastructure operators and users as it greatly lowers the ownership cost to a regular service fee, but previous attempts of services such as Sony PSNow[19] and Nvidia GeForce GRID[20] have only achieved limited success. A user experience that mirrors a local gaming device has not yet been met, often due to latency and bandwidth limitations even when using fixed line connections.

Potential Requirements to 5G Device

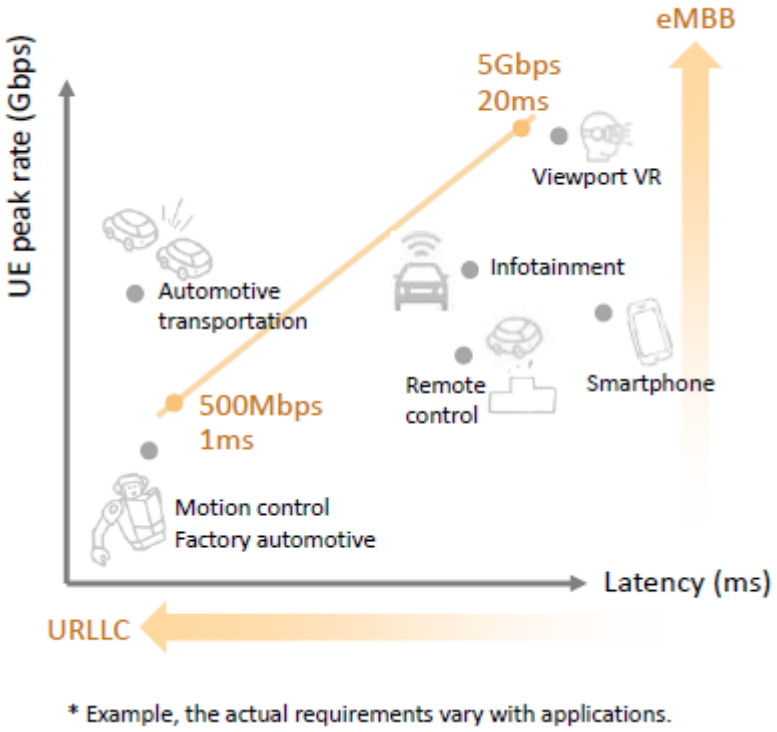
Round-trip latencies of sub-10ms and 200M-500Mbps streaming bandwidth, finally unlocking their market potential.

Possible Device Types

Gaming laptop, Smartphone for gaming, Router

3 Potential Requirements to 5G Device

In this research report we summarize that, for various applications, each has different throughput or latency requirements. An NR system design allows reasonable user equipment (UE) implementation flexibility. The processing functions within the UE device can either focus on achieving maximum throughput (data rate) or minimum (stringent) latency parameters. This aspect is already under 3GPP discussion.



* Example, the actual requirements vary with applications.

Opportunity	Use Cases	Potential Requirements to 5G UE
Personal	1. Augmented reality (AR), Mixed Reality (MR) and Virtual Reality devices	200Mbps to 1Gbps streaming bandwidth depending on compression and device resolution, with reliable sub-20ms motion-to-photon latency for VR
Vehicular	2. Autonomous driving	Ultra-low latency with very high reliability for safety and security. 100Mbps per vehicle; very high capacity for fleet (10Gbps+)
Vehicular	3. Infotainment services for public and private transportation	Extreme capacity up to 40Gbps DL (ex: 500 people per train) with low latency for VR/AR

		(reliable sub-20ms motion-to-photon)
Personal	4. Mobile Media: 360-degree, 4K/8K resolution live entertainment and sports	100-500Mbps streaming bandwidth for 8K with sub-20ms latency; 360-degree 6DoF 400-600Mbps streaming bandwidth with sub-10ms latency to avoid motion sickness
Education	5. Tele-education services	100-200Mbps reliable streaming bandwidth with low latency (sub-20ms)
Business	6. Tele-office services such as thin/zero client for mobile devices	A minimum of 300-500MBps with up to 1Gbps burst performance
Health	7. Tele-health services such as remote surgeries	Ultra-reliable throughput and strict low e2e latency (1-10ms) requirements with low jitter (1µs).
Health	7-2. Remote healthcare services	Reliable 100sMbps-1Gbps bandwidth and reliably low latency (sub-20ms)
Industrial	8. Tele-industrial applications such as remote robotics	~500Mbps-to-3Gbps of data bandwidth (higher 10+Gbps for industrial backhaul operations such as inter-building communication) and strict low latency (1-10ms) requirements with low jitter (1µs), when processes are time critical.
Business	9. Fixed Wireless Access (FWA) alternative to fixed-landline fiber services	Fiber+ like speeds (10-40Gbps) to multiple households within one site or apartment
Personal	10. Game-streaming services	200-500Mbps streaming bandwidth with sub-10ms latency for best user experience

4 References

5G use cases demonstrated by SoftBank and Huawei

https://www.itwire.com/telecoms-and-nbn/79837-5g-use-cases-demonstrated-by-softbank-and-huawei.html

1. Google VPS

   https://twitter.com/Google/status/864915561540669441

2. Samsung Gear VR

   http://www.samsung.com/global/galaxy/gear-vr/

3. Microsoft Hololens

   https://www.microsoft.com/en-us/hololens

4. Reliable and efficient autonomous driving: the need for heterogeneous vehicular networks
   http://ieeexplore.ieee.org/abstract/document/7355569/

5. IEEE COMSOC MMTC E-Letter

   http://mmc.committees.comsoc.org/files/2016/04/E-Letter-July2015.pdf#page=35

6. IHS: Primary Automotive Display Systems Market Valued at $11.6 Billion Globally in 2017, Will Grow to Nearly $21 Billion in 2022

   http://news.ihsmarkit.com/press-release/automotive/primary-automotive-display-systems-market-valued-116-billion-globally-2017-

7. Connected Cars: The future of Infotainment

   https://www.smallworldsocial.com/connected-cars-future-of-infotainment/

8. Here's How Many People Watched the Super Bowl

   http://fortune.com/2017/02/06/super-bowl-111-million-viewers/

9. F1's TV audience decline stopped in 2016

   http://www.f1fanatic.co.uk/2017/01/24/f1s-tv-audience-decline-stopped-2016/

10. Kantar / Manchester United

    http://www.manutd.com/en/News-And-Features/Club-News/2012/May/manchester-united-global-following-confirmed-as-659million.aspx

11. NHK Super Hi-Vision

    http://www.nhk.or.jp/8k/index_e.html

12. Japan gears up for 2020 Olympics with further 5G trials at 4.5GHz and 28GHz
    http://www.telecomtv.com/articles/5g/japan-gears-up-for-2020-olympics-with-further-5g-trials-at-4-5ghz-and-28ghz-14133/

13. Sony XZ Premium

    https://www.sonymobile.com/global-en/products/phones/xperia-xz-premium/

14. LG G6

    http://www.lg.com/us/mobile-phones/g6

15. Samsung Galaxy S8

http://www.samsung.com/global/galaxy/galaxy-s8/

16. Tokyo 2020 events to be live-streamed in VR over 5G network: NTT Docomo pres.

https://mainichi.jp/english/articles/20170526/p2a/00m/0na/012000c

17. A New Generation of e-Health Systems Powered by 5G

http://www.wwrf.ch/files/wwrf/content/files/publications/outlook/Outlook17.pdf

18. Industrial remote operation: 5G rises to the challenge

https://www.ericsson.com/en/publications/ericsson-technology-review/archive/2015/industrial-remote-operation-5g-rises-to-the-challenge

19. Ericsson CTO Prioritizes Non-Consumer 5G

http://www.lightreading.com/mobile/5g/ericsson-cto-prioritizes-non-consumer-5g/d/d-id/735723

20. PSNow service

https://www.playstation.com/en-us/explore/playstationnow/

21. GeForce GRID Cloud Gaming

http://www.nvidia.com/object/cloud-gaming.html

22. Fog for 5G and IoT (Securing the Internet of Things)

John Wiley & Sons Inc., 2017.

23. Grand View Research, mHealth Market Analysis By Service (Monitoring Services, Diagnosis Services, Healthcare System Strengthening), By Participants (Mobile Operators, Device Vendors, Content Players, Healthcare Providers) And Segment Forecasts To 2020.
http://www.grandviewresearch.com/industry-analysis/mhealth-market

24. Mobile Ecosystem Forum, 2015.
http://www.mobileecosystemforum.com/solutions/analytics/mef-global-mhealth-andwearables-report-2015/