HUAWEI

5G UNLOCKS A WORLD OF OPPORTUNITIES

TOP TEN 5G USE CASES

XLabs Wireless

5G networks will offer an unprecedented leap in bandwidth speeds in comparison to previous mobile networks. For example, downlink peak data throughput could reach 20 Gbps, while uplink peak data rates could be as high as 10 Gbps. 5G will also reduce latency and improve overall network efficiency. Streamlining network architectures will deliver end-to-end latency requirements of less than 5 ms. This will allow 5G to offer ultra-reliable low-latency communication for machine-to-machine and public safety applications.

As it delivers new infrastructure solutions, 5G will depend on an end-to-end digital service transformation, which will minimise OPEX, deliver efficiencies, and drive revenue growth. For 5G to deliver an attractive business model to mobile network operators and their customers, the network must enable efficient provisioning of a wide variety of new services for varied customers with different service level needs and performance requirements. Not only will operators need to provide services to customers across enterprise verticals efficiently, but they will need to commercialize those services rapidly and effectively.

This whitepaper explores the top 10 applications that will harness the versatile capabilities of 5G.

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Preface

Data services emerged in the 2G era, grew in the 3G era, and diversified in the 4G era. 5G, featuring superior user experience and massively greater capacity, is poised to usher in a new era of mobile communications. 5G will connect everything, and benefit all walks of life. It will combine big data, cloud computing, artificial intelligence (AI), and many other innovative technologies to accelerate the arrival of a golden age of information over the next 10 years.

Digital technologies enable continuous innovation across a diverse range of industries. The ICT, media, finance, and insurance sectors are the current leaders in digital transformation. But this digitalization is also accelerating in the retail, automobile, oil and gas, chemical engineering, healthcare, mining, and agriculture sectors.

Key technologies that underpin digitalization include software-defined devices, big data, cloud computing, block chain technology, network security, latency-sensitive networks, virtual reality (VR), and augmented reality (AR). Communication networks are the key to connectivity of everything.

There is unprecedented buzz around 5G, because it can create a world boasting services and products like "Mobile Beyond Giga", "Real-Time World", and "All-Online Everywhere". Mobile networks have emerged as fundamental to productivity, enabling digital transformation throughout all industries.

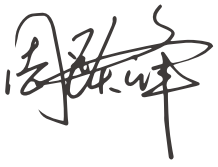
To support a wide enough range of different services, continuous and long-term network development is absolutely necessary. We can see from the applications we use in our daily lives that they are always changing and evolving. The single biggest change is the improvement in online video. According to research findings from Huawei Wireless X Labs, if you take all of the possible viewing angles, average arm length, and expected comfort levels into consideration, the maximum possible display resolution for a handheld mobile device is 5K. This will only generate a top data rate of over 20 Mbps. But 5G WTTx can deliver 8K video streaming to your living room TV, and this is expected to drive a 6-fold increase in demand for bandwidth.

Cloud services are developing rapidly, with continuous improvements being made to their storage, computing, and rendering capabilities. Many services can be processed over the cloud to reduce the cost of the terminals, and to allow for complex inter-platform coordination. We believe that a combination of VR and the cloud can significantly increase the ubiquity of service access. VR gaming, modeling, and other services can be rendered over the cloud, and then transmitted to terminals in real time, via reliable high-speed 5G networks. This will increase service accessibility and improve user experience.

Another key development in 5G video: the viewer can be either a person or a machine. For example, a cloud AI machine can enable drones to identify license plates or gas leakage in real time. Wireless industrial cameras can make real-time product positioning and error detection possible. A machine can stream video 24/7, non-stop.

Mobile networks are designed to create a super connected world, in which the generated data is contextualized, constructed and processed over the cloud, continuously creating value. Connected cars, smart manufacturing, global logistics tracking, smart agriculture, smart metering, and other applications are some of the first, most promising areas for IoT to focus on. These applications are poised to rapidly develop in the 5G era.

We have selected 10 use cases for in-depth analysis, to help us better understand the market opportunities introduced by these new network capabilities. We hope that this will help a wide range of diverse industries understand wireless progress, and proactively embrace digital transformation and industry trends.



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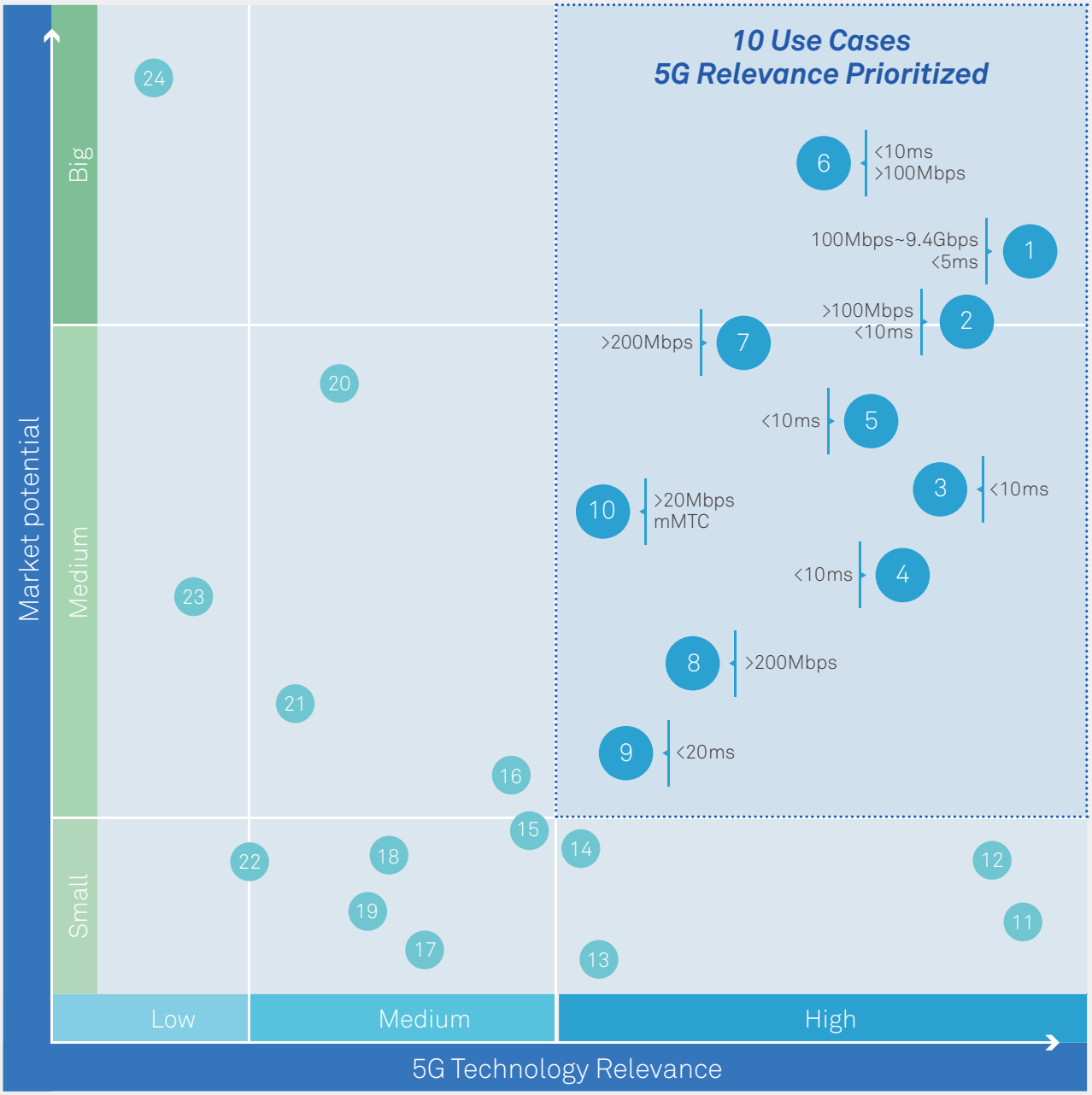
TOP TEN 5G USE CASES



Index Definitions

1. Cloud Virtual & Augmented Reality – Real-time Computer Rendering Gaming/Modeling
2. Connected Automotive – ToD, Platooning, Autonomous Driving
3. Smart Manufacturing – Cloud Based Wireless Robot Control
4. Connected Energy – Feeder Automation
5. Wireless eHealth – Remote Diagnosis With Force-Feedback
6. Wireless Home Entertainment – UHD 8K Video & Cloud Gaming
7. Connected Drones – Professional Inspection & Security
8. Social Networks – UHD/Panoramic Live Broadcasting
9. Personal AI Assistant – AI Assisted Smart Helmet
10. Smart City – AI-enabled Video Surveillance

11. Hologram 12. Wireless eHealth – Remote Surgery
13. Wireless eHealth – Ambulance Communication
14. Smart manufacturing – Industrial Sensors
15. Wearable – UHD Body Camera
16. Drone – Media 17. Smart manufacturing – Cloud Based AGV
18. Home – Service Robotics (Cloud AI Assisted)
19. Drone – Logistics 20. Drone – Fly Taxi
21. Wireless eHealth – Hospital Nursing Robot
22. Home – Home Surveillance
23. Smart Manufacturing – Logistics & Inventory Monitoring
24. Smart City – Trash Bin, Parking, Lighting, Traffic Light, Meters

Cloud Virtual & Augmented Reality

> The bandwidth requirements for VR/AR to work effectively are substantial, as most VR/AR applications are very data intensive. Advanced VR/AR content will depend on cloud servers to meet growing demands for realistic experiences provided to consumers at affordable prices. While an average throughput of 100 Mbps might be possible over existing 4G network, some premium VR/AR applications will demand even higher speeds and lower latency.

Real-time Computer Rendering Gaming/Modeling

Virtual reality (VR) and augmented reality (AR) are transformative technologies poised to revolutionize the consumption of content in both the consumer and the enterprise sectors.

VR/AR require significant data transfer, storage, and compute capabilities. These data- and compute-intensive tasks will therefore move to the cloud, which provides abundant data storage and can provide the necessary high-speed computing capability.

1. This will greatly reduce device costs – making consoles or devices affordable for end users.
2. The cloud market is growing rapidly at 18% YoY. In the next 10 years, homes and offices will increasingly dispense with PCs and laptops, and switch instead to cloud-connected display screens and a variety of human/machine interfaces activated by voice command and/or touch. 5G will significantly improve access to these cloud-based services.

Cloud VR/AR Evolution and Connectivity Requirements

	Stage 0/1		Stage 2	Stage 3/4
	PC VR	Mobile VR	Cloud Assisted VR	Cloud VR
VR Applications & Technical Features	 Gaming, simulation (motion processing and rendering in a local computer)	 360° video, education (panoramic video download and motion processing in smartphone)	  Immersive content, interactive simulation, visualization/design (cloud-based motion processing, FOV(+) video streaming)	  Gaming / modeling premium experience (cloud-based motion processing and real-time CG rendering, FOV(+) video streaming)
	2D AR		3D AR/Mixed Reality	Cloud MR
AR Applications & Technical Features	  Assembly instructions, gaming, location-based, remote work, visualization for retail/marketing (Local images and text overlay)		 Holographic visualization with increasing universe size. Highly connected public safety AR applications (Image upload, cloud-based multimedia response)	  Cloud-based mixed and merged reality applications Increased user density and connectivity (Image upload, cloud-based image re-rendering)
Connectivity Requirement	Primarily Wi-Fi Connectivity	4G and Wi-Fi Streaming to 20 Mbps 50 ms latency	4.5G Streaming to 40 Mbps 20 ms latency	5G Streaming to 100 Mbps - 9.4 Gbps 2-10 ms latency

Figure 1: VR/AR Connectivity Requirements and Evolutionary Stages (Source: Wireless X Labs)

1.1 Business Model and Use Case Examples

The more extensively the mobile telco operator engages in the ecosystem, the more revenue the operator is likely to gain. In the B2B market, the priority target segments are broadcasting companies, social networking companies, and SME content developers. A number of these companies have expressed interest in VR as a "live broadcast" platform.

The three main charging models in the VR ecosystem will be the advertisement model, the subscription-based model, and the usage-based model, as described in Figure 2.

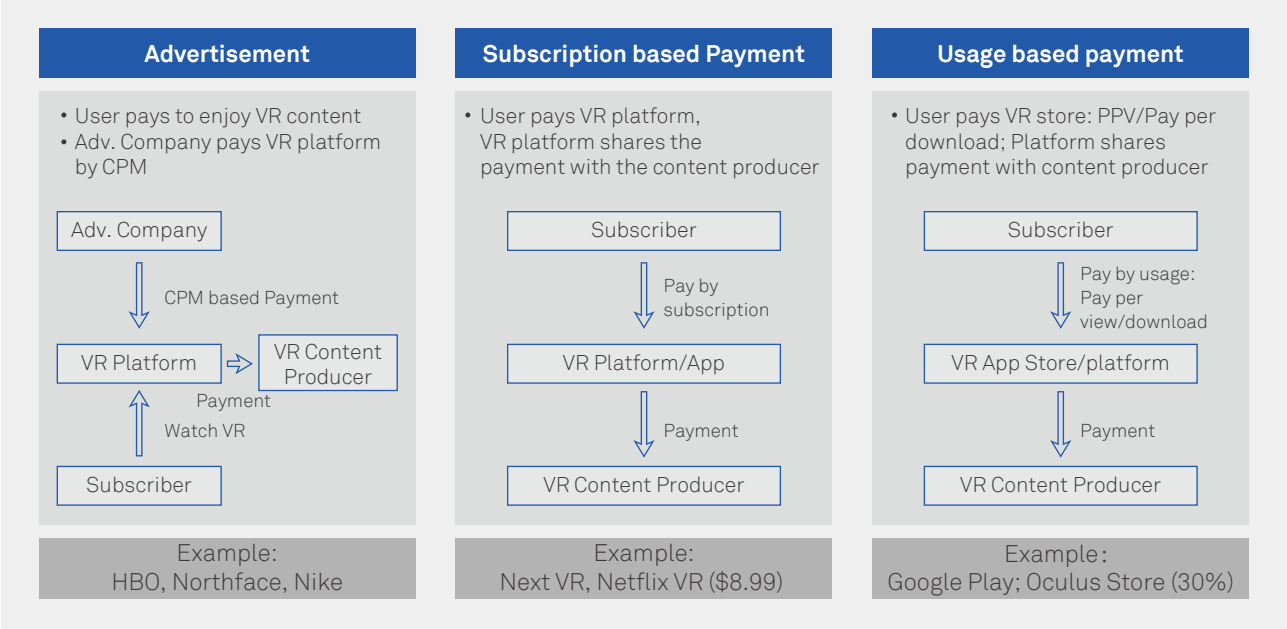
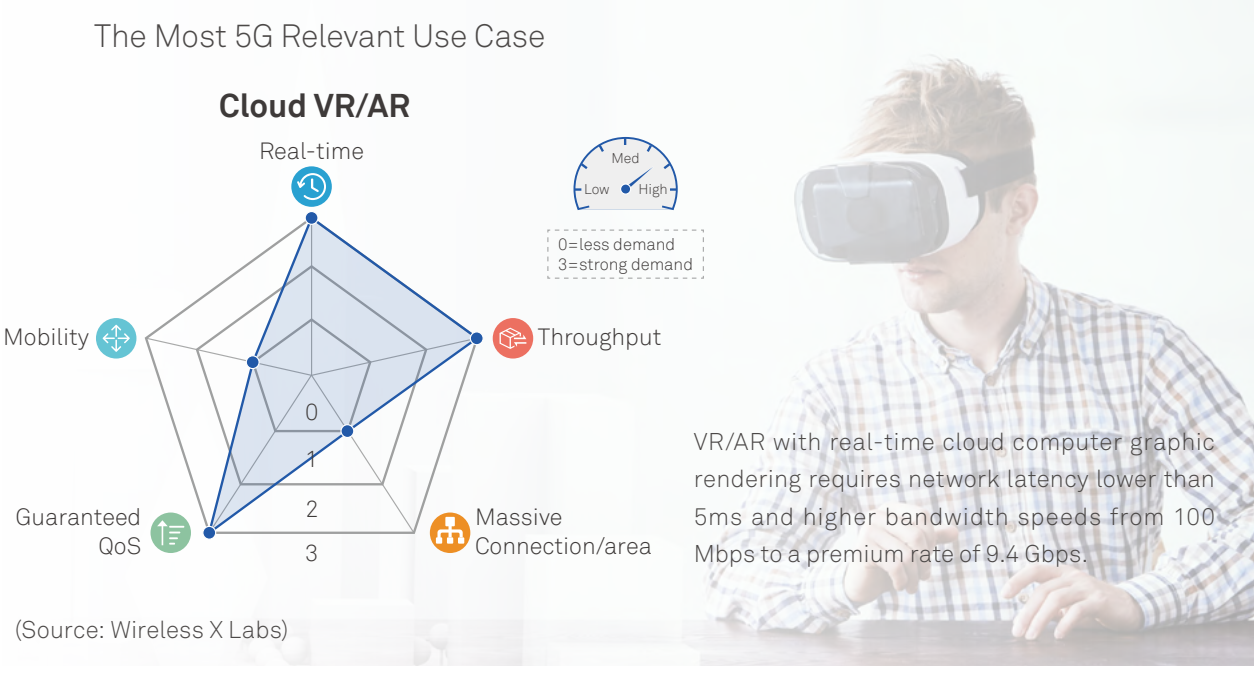


Figure 2: VR Service Charging Model Summary (Source: Huawei Consulting)

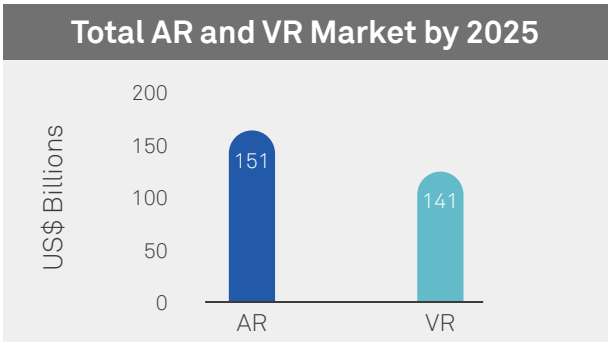


The VR market today is largely oriented around the gaming and video/advertising segments. Sponsorship models and VR experiences created to promote other premium content/events have predominated in the video market, although select experiences such as sporting events (e.g., Intel True VR) and live events (e.g., NextVR) have helped VR develop beyond these early lifecycle short-form experiences.

Orange has released a mobile-dependent head mounted display (HMD) unit for Android and iOS smartphones, priced at €50 to support its Orange VR 360° application. SK Telecom unveiled its "360 Adaptive VR Live Streaming Platform" at MWC 2017 and is planning to show 360º views in the upcoming 2018 Winter Olympics. SK Telecom has also selected three companies, Looxid Labs, Red Bird, and ELROIS to develop 5G VR/AR services, by the means of a "5G Realistic Media & Convergence Service Exhibition" that is hosted with mobile game developer UnityKorea.

1.2 Key Takeaways

- ABI Research estimates the total AR and VR market will reach US$292 billion by 2025 (US$151 billion for AR and US$141 billion for VR).
- In order for telcos to develop cloud VR/AR services with realistic charging models, they must adapt their business models and product offerings to essentially become full cloud service providers.
- The carrier serviceable addressable market opportunity in VR/AR is significant and, by 2025, is expected to reach more than US$93 billion, ~ 30% of the total VR/AR opportunity.



> Key players in the autonomous car value chain include: vehicle vendors, software vendors, platform providers, and telco operators. Telcos have the potential to explore alternative business models in the value chain, e.g., platform development, advertising, Big Data, and vertical enterprise services.

Connected Automotive

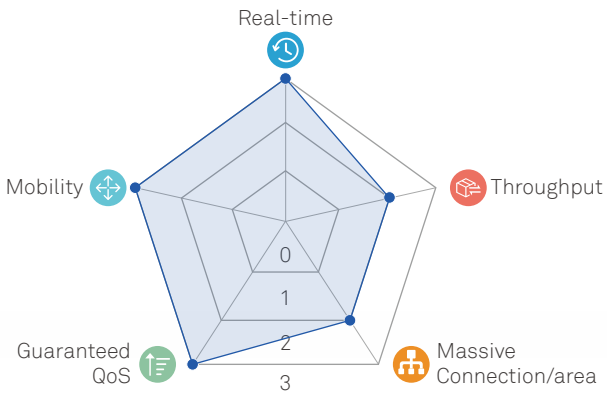
ToD, Platooning, Autonomous Driving

The Connected Car market is set for a radical transformation, as the role of connectivity grows beyond legacy entertainment and convenience functions, developing into a critical enabler of safer, more sustainable mobility.

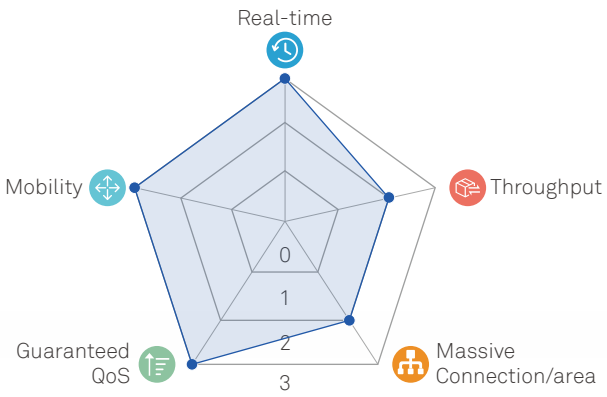
Key technology trends driving the mobility revolution - autonomous driving, cooperative mobility, vehicle life-cycle maintenance and sensor data crowdsourcing require secure, reliable, low-latency and high-bandwidth connectivity. These attributes are essential for delivering the necessary performance both at highway speeds and in dense urban environments. Only 5G can satisfy all of these rigorous connectivity requirements.

The Most 5G Relevant Use Case

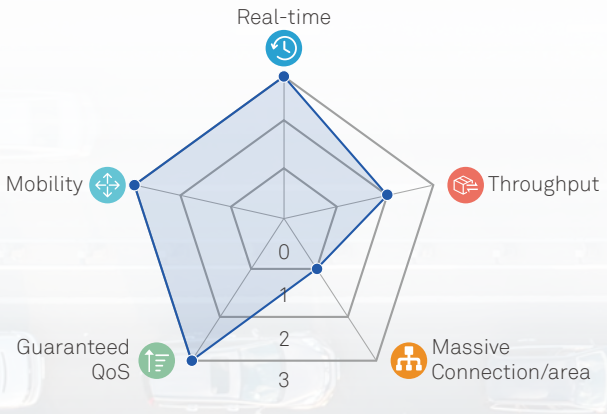
Autonomous driving



Platooning



Tele-operated Driving



In the example of Tele-operated Driving (ToD), when E2E latency can be controlled to within 10ms, the emergency remote brake's distortion can be limited to within 25 cm at speeds of up to 90kph.

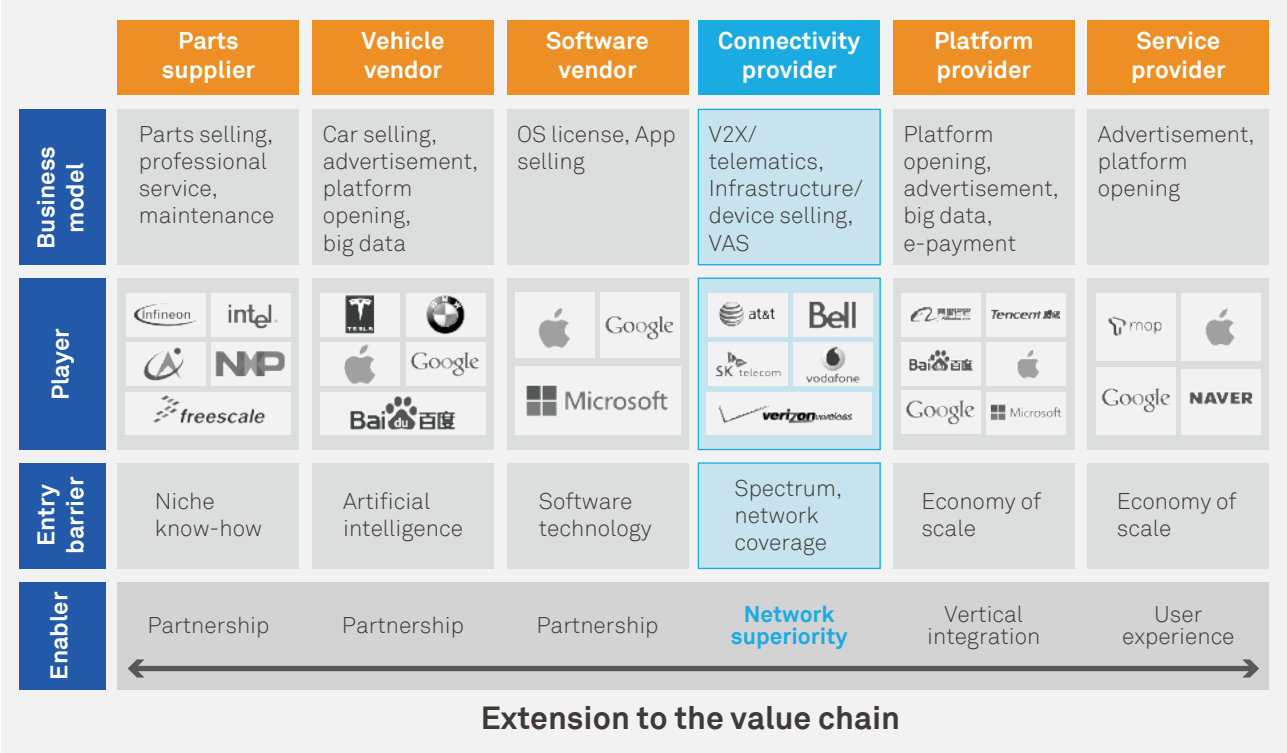


Figure 3: Autonomous Vehicle Value Chain (Source: Huawei Consulting)

2.1 Business Model and Use Case Examples

In the autonomous driving era, full wireless connectivity will allow add-on services such as navigation systems to be embedded into vehicles. Reduced direct human intervention will demand a greater need for frequent information exchange between the vehicle's control system and cloud-based backend systems.

The 5G operator's business model in the autonomous car can be divided into B2C and B2B, as shown in Figure 4 below.

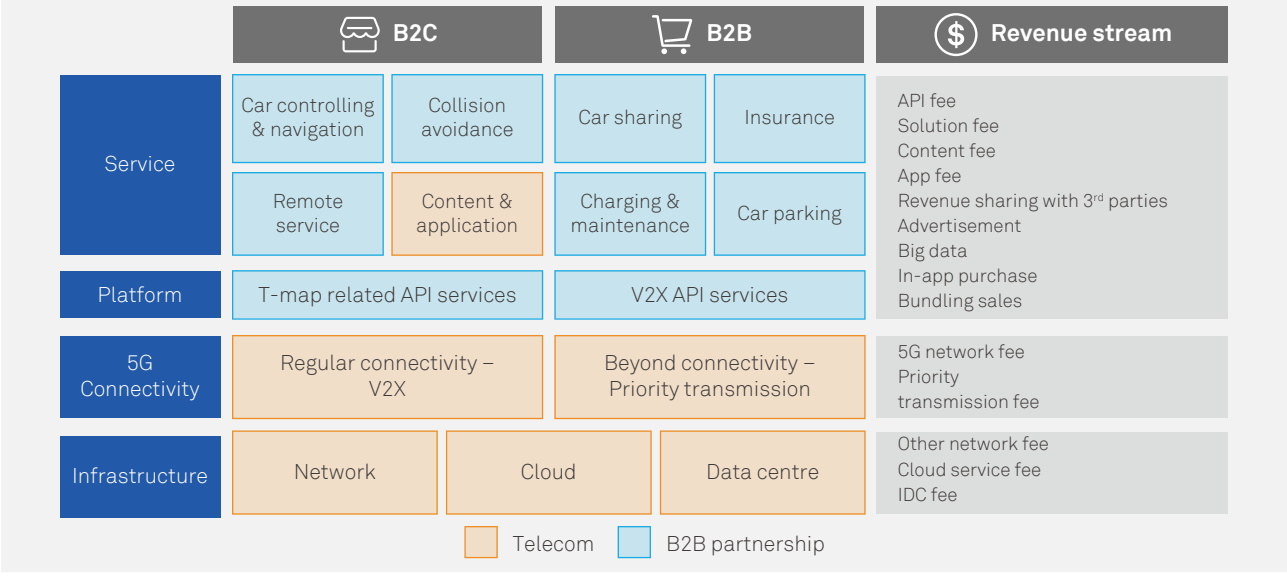


Figure 4: Autonomous Vehicle/Telco Business Model (Source: Huawei Consulting)

5G has the potential to be a unifying connectivity technology addressing all major requirements of the future connected, shared, tele-operated, autonomous, and cooperative vehicle. 5G can replace, or at least complement, alternative connectivity technologies (for example, 5.9 GHz DSRC currently in the process of being mandated for V2V technology in the United States). Should ADAS or DSRC V2X fail, 5G can take over. Specifically, in the early stage before vehicles are fully autonomous, 5G will also support the following use cases which requires more reliable technology:

Use Case	Description	Network Requirements
Platooning	Linking trucks or cars automatically in a convoy of vehicles that are much closer together than can be safely achieved with human drivers, to save fuel and make the transport of goods more efficient. Platoons are expected to be flexible – being established on motorways, then broken up when a vehicle leaves the motorway.	Platoons of 2 or 3 vehicles can be established using sensors and direct communication between immediate neighbors. For longer platoons, propagation of messages takes too long. Braking must be synchronous, requiring low-latency network communications. For platoons of more than 3 cars, 5G will be needed.
Tele-operated / Remote Driving	A vehicle is driven by someone in a remote location, rather than someone in the vehicle. The vehicle is still driven by a person – it is not automated. This could potentially be used to deliver a premium concierge service to enable someone to participate in a conference or to work while on a journey, or to support a taxi service, or to help a person without a driving license, or when they are ill, intoxicated, or otherwise unfit to drive.	Requires a high-reliability radio link with full round trip delay below 10 ms. This is fast enough that instructions can be received and acted upon by the systems just as quickly as the human eye can perceive change. This will require 5G.

In Feb. 2017, Before the Mobile World Congress, Huawei and DLR (Deutsches Zentrum für Luft- und Raumfahrt) have tested 5G for cooperative automated driving in Munich. The results show the practical applicability of 5G V2X to achieve a reliable and ultra-low-latency connection between vehicles for collision avoidance.

In June 2017, China Mobile, SAIC Motor, and Huawei jointly demonstrated the first 5G remote driving vehicle. SAIC Motor's smart concept car, the iGS, was set up with Huawei's 5G solution and China Mobile providing the connectivity. Control signals for steering, acceleration, and braking were also transmitted over 5G in real time using 5G's ultra-low-latency capabilities (less than 10 ms).

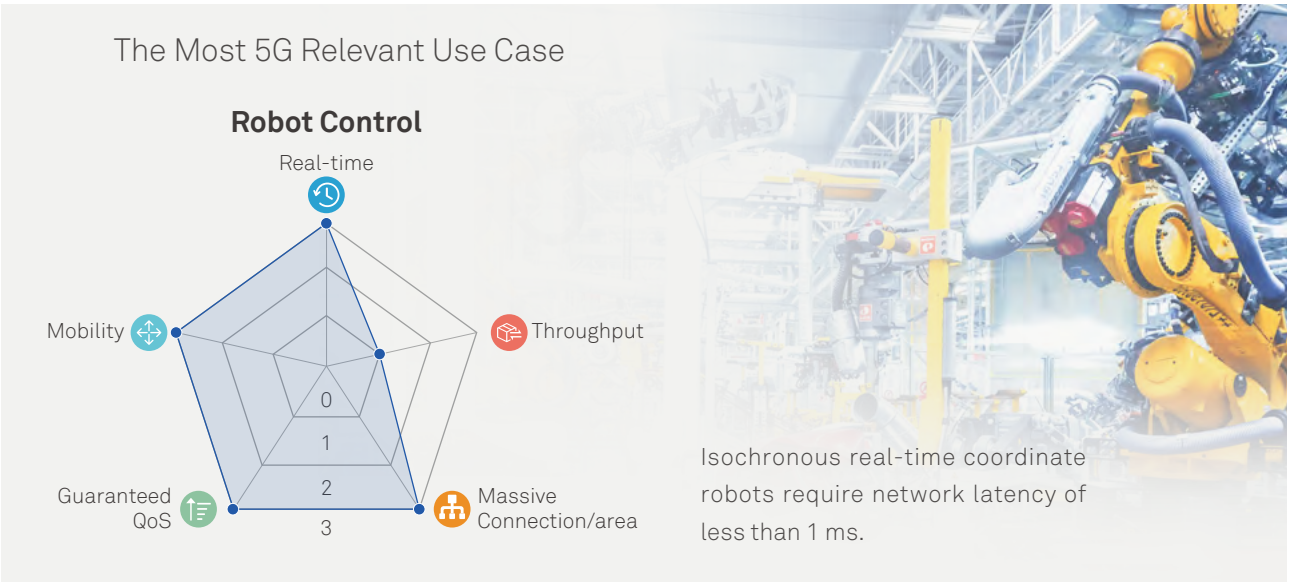
2.2 Key Takeaways

- 5G will provide enhanced situational awareness and high precision navigation through high bandwidth, low latency streams from other vehicles, and roadside infrastructure.
- ABI Research estimates there will be 60.3 million 5G-connected vehicle subscriptions in place by 2025. Growth will pick up between 2025 and 2030 as the typical 7- to 10-year vehicular replacement cycles have their impact.

60.3 million 5G-connected vehicle subscriptions by 2025

Cloud Based Wireless Robot Control

Innovation is at the heart of manufacturing. Major developments include the moves toward lean manufacturing, digitalization, and greater flexibility in work processes and production. Recent times have also seen a strong shift in favor of the industrial Internet of things (IoT). Historically, manufacturers have relied on wired technologies for their connected applications. However, wireless solutions, such as Wi-Fi, Bluetooth, and WirelessHART have taken a foothold in the manufacturing workplace, but these wireless solutions face limitations in security and reliable bandwidth.



eMBB	mMTC	uRLLC
Wireless Industry Camera	Status Monitoring	Wireless Cloud PLC
Industrial Sensors	Asset Tracking	
Remote Control	Cloud Based AGV	Synchronized Robotics
Edge Computing Analytics	Logistics & Inventory Monitoring	

Figure 5: Smart Manufacturing (Source: ABI Research)

Recent cutting-edge connected applications demand flexible, mobile, high bandwidth, ultra-reliable low-latency communications (uRLLC) as a fundamental requirement.

3.1 Business Model and Use Case Examples

The underlying business rationale for implementing smart manufacturing is to bring higher-quality products to market faster with more flexible and efficient production systems. Key benefits include:

- Increased productivity through collaborative robotics and AR smart glasses that assist workers throughout assembly processes. Collaborative robots exchange analytics to synchronize and coordinate automated processes. Smart glasses empower workers to do their jobs quicker and more accurately.
- Reduced down-time and maintenance costs through condition-based monitoring, machine learning, physical-based digital simulations, and digital twins that can accurately forecast future performance, optimize the maintenance schedule, and automatically order replacement parts.
- Reduced costs for inventory and logistics by optimizing accessibility and transparency of data internally and externally with suppliers. Cloud-based network management solutions are smart manufacturing offerings that share data in a secured environment.

Mobile telcos can assist manufacturers and logistics centers with their smart manufacturing transformations. 5G network slicing and MEC enable mobile telcos to offer a variety of value-added services on top. They already offer control centers to handle large numbers of remote devices and send over-the-air software updates to these devices, as well as data stream management tool sets.

- KUKA: At MWC 2017, Huawei and KUKA demonstrated 5G collaborative robotics in the form of two robot arms drumming together in synchronized patterns. The KUKA innovation lab reported latency as low as 1 ms and 99.999% reliability.
- Bosch predicts significant demand for real-time meshing of data and analytics from different types of sources. In June 2017, Bosch demonstrated its wireless Programmable Logic Controller (PLC) software on its mPad mobile control unit. The mPad used a 5G connection to control a Bosch APAS collaborative robot. Users could configure and monitor the robot from the mPad; Bosch believes Wi-Fi is not reliable enough for these operations. Moreover, Bosch has plans for active assist intelligent laser-guided work stations to communicate with AR headsets and collaborative robotics. Sensors on the wearables, headsets, and robots will send alerts to slow down the robots when a worker approaches and stops them if necessary, preventing safety threats to the workers. This communication between the active assist, AR, and robots requires wireless technologies, and 5G provides the necessary bandwidth and ultra-reliable low-level connectivity.

Wireless cloud PLC meets the openness and flexible requirements of industrial automation control. MNO's cloud infrastructure can host PLC.

Phase	Data Rate	Latency
Phase1: Soft real-time	<10 Mbps	10~100 ms
Phase2: Hard real-time	<10 Mbps	1~10 ms
Phase3: Isochronous real-time (IRT)	<10 Mbps	<1 ms

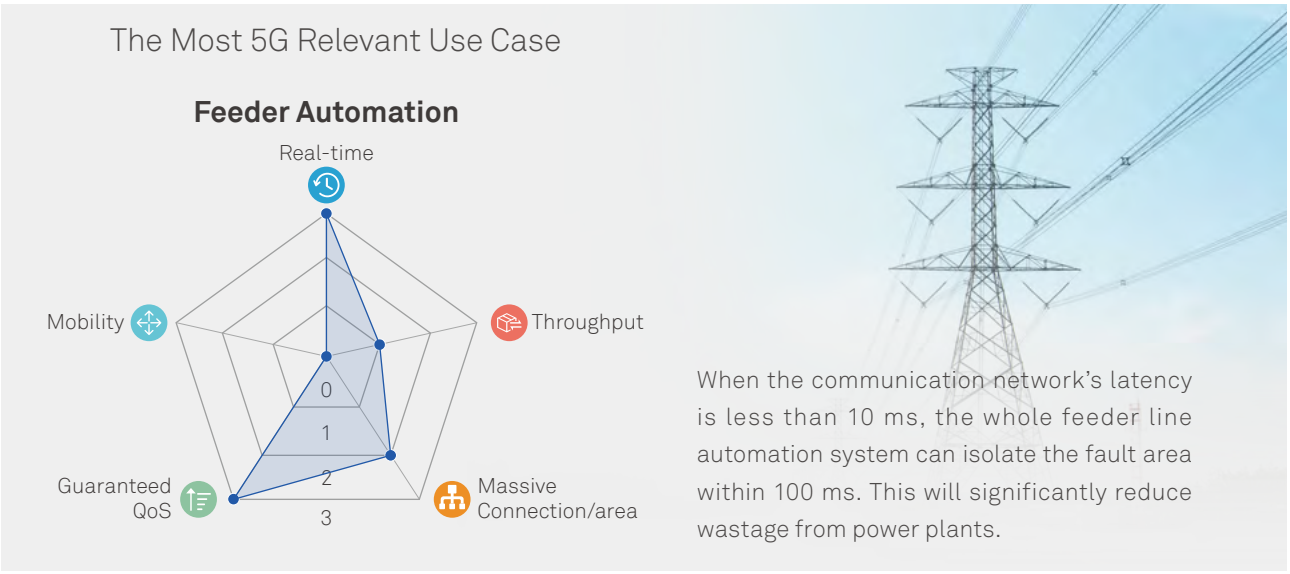
3.2 Key Takeaways

- If manufacturing enterprises are to take full advantage of the industrial IoT opportunity, they need to implement an end-to-end solution that covers the supply chain, the manufacturing shop floor, and the entire product life cycle.
- At the end of 2017 there were 18 million condition-based monitoring connections world-wide, by 2025, the figure will rise to 88 million. The number of industrial robots shipped world-wide will similarly grow from 360,000 to 1.05 million.
- Fixed-line dominates in terms of the number of industrial IoT connections. But 5G should see a CAGR of 464% from 2022 to 2026.

5G IIoT: CAGR of 464%, 2022-2026

Feeder Automation

Many energy management companies, in Developed markets and Emerging Markets, are starting to rely on Distributed Feeder Line Automation Systems. Feeder line automation systems are particularly invaluable for integrating renewable energy generation into energy grid operations. Benefits include reduced O&M costs and improved reliability. It is necessary for the feeder line automation system to have access to very low latency communications, such as 5G. Mobile telcos can play a complementary role to the energy companies by offer a dedicated network slice for energy vendors for their intelligent distributed feeder power systems. This allows them to perform intelligent analysis and respond in real time to abnormal consumption information, enabling more rapid and accurate power control across the grid.



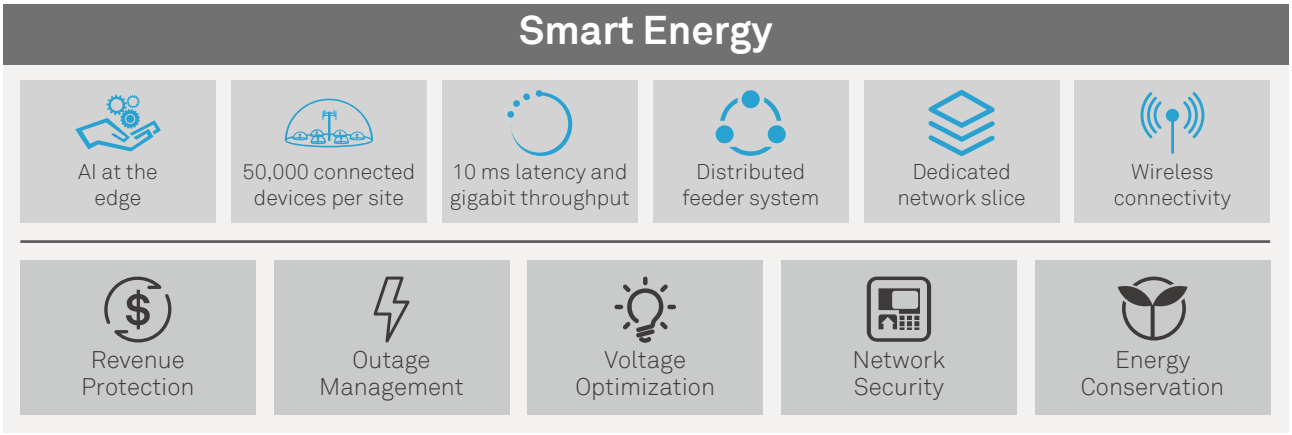


Figure 6: 5G Making Energy Smarter (Source: ABI Research)

4.1 Business Model and Use Case Examples

Energy companies are moving toward intelligent distributed feeder systems. In developed markets, the power supply reliability is expected to be at 99.999%, which translates into an annual outage duration of less than 5 minutes. In emerging markets, solar power, wind turbine, and hydro-electric power can place varying loads on the grid. This means the current centralized feeder system can struggle to meet demand requirements, as fault location and isolation can take approximately 2 minutes.

Freed from a centralized fault notification system, a distributed feeder system can respond to an outage, run topology calculations, and implement the fault location and isolation in rapid fashion. Currently, intelligent distributed feeder systems require fiber-optic cabling to provide connectivity. As 5G can offer network latency of 10 ms and gigabit throughput, a wireless distributed feeder system can serve as an alternative approach.

As 5G technology works on licensed bands only, mobile network operators stand to benefit from the adoption of smart metering based on 5G. On top of a service-level agreement, mobile network operators can offer authentication and core network signaling security.

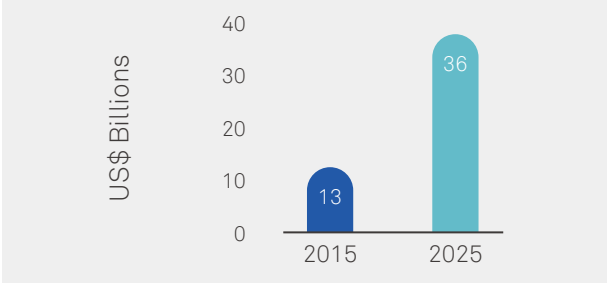
NARI Technology in China has implemented several intelligent distributed FA terminal portfolios using a fiber-based solution. The pilot is in Shanghai Pudong Area, where power supply reliability has increased from 99.99% to 99.999%. Companies such as GE and Eaton are also promoting intelligent distributed FA terminals, and indicate a preference for wireless-solutions to reduce communication costs.

5G not only offers very low latency response times (10ms) in this case, it also lowers the barrier to entry for many energy companies in emerging markets to establish smart grids. As these markets lack legacy grid and power generation infrastructure, it is likely that many energy companies will adopt renewable energy as their primary source of power. However, power generation via renewable sources lacks stability, resulting in energy level fluctuation in the transmission grid. In order to mitigate this failure, the energy generated must be adjusted against the energy consumed.

4.2 Key Takeaways

- According to ABI Research, the global distribution automation system market will increase from $13 billion in 2015 to $36 billion in 2025.
- 5G can replace current fiber infrastructure in power distribution automation. The technology offers network latency < 10ms and gigabit throughput, enabling a wireless distributed control model.
- 5G also lowers the barrier to entry for many energy providers in emerging markets. 5G's low latency, wide coverage, and quick deployment allows rapid information exchange to occur within a smart grid, which is very useful where renewable energy is the primary power source.

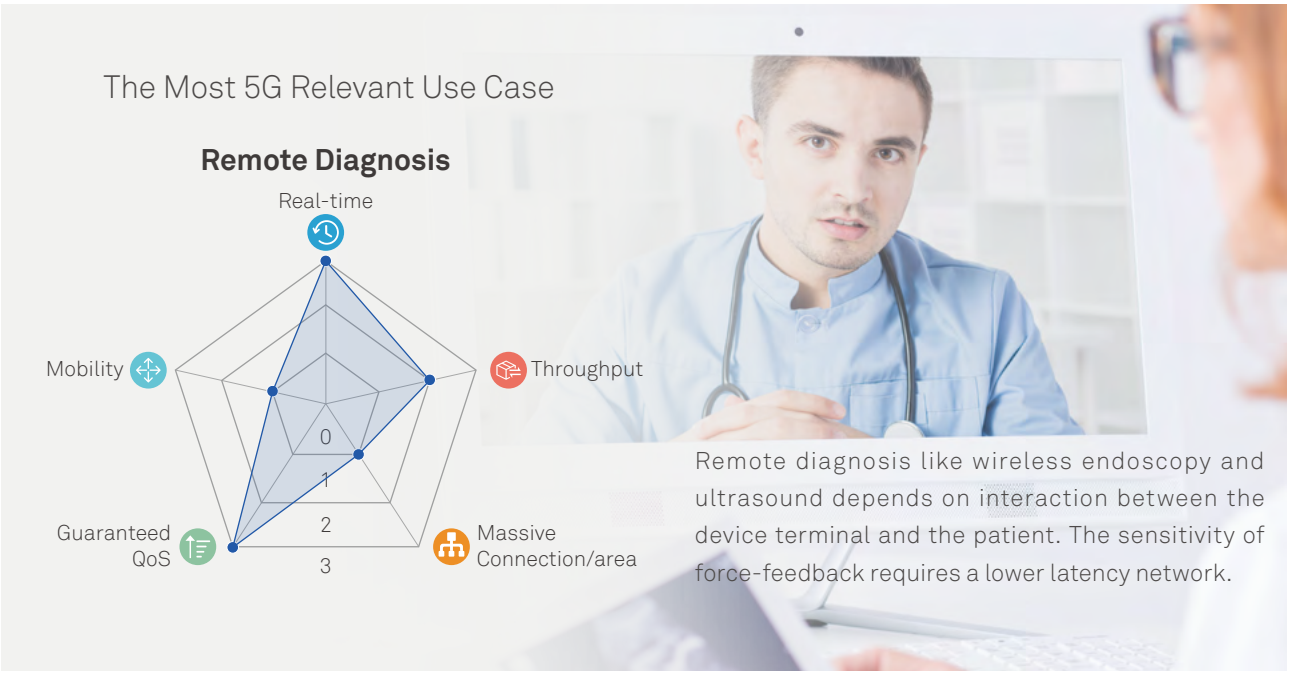
Global Distribution Automation System Market Scale



Remote Diagnosis With Force-Feedback

Both in the West and in Asia, populations are rapidly aging. The percentage of the world population that is 55 years and older will almost double between 2000 and 2030 from 12% to 20%. Moody's Analytics, based on UN data, has reported that some countries (the United Kingdom, Japan, Germany, Italy, the United States, and France) will become "super-aged," where 20% or more of the population is 65 years or older.

Over the past 5 years, there has been increasing adoption of wireless Internet in medical devices. Healthcare professionals have begun to integrate solutions such as remote audio/video diagnosis, remote surgery, resource databases, and remote health monitoring using wearables/portable devices.



5.1 Business Model and Use Case Examples

The healthcare industry has the opportunity to develop a fully personalized medical advisory service that is complemented by doctor-driven AI medical systems connected by 5G. These AI medical systems can be embedded into hospital call-in centers, home medical advisory assistants, local doctor clinics, and even traveling out-station clinics that lack on-site medical staff. Tasks include:

- Real-time health management systems that track patients, their medical records, recommend treatments and appropriate medicines, and set up follow-up appointments
- Taking contextual information into account, such as genetic information, patient lifestyle assumptions and the current physical condition of the patient, when developing medical prognoses
- Proactive monitoring of patients by AI models that can suggest changes to treatment plans

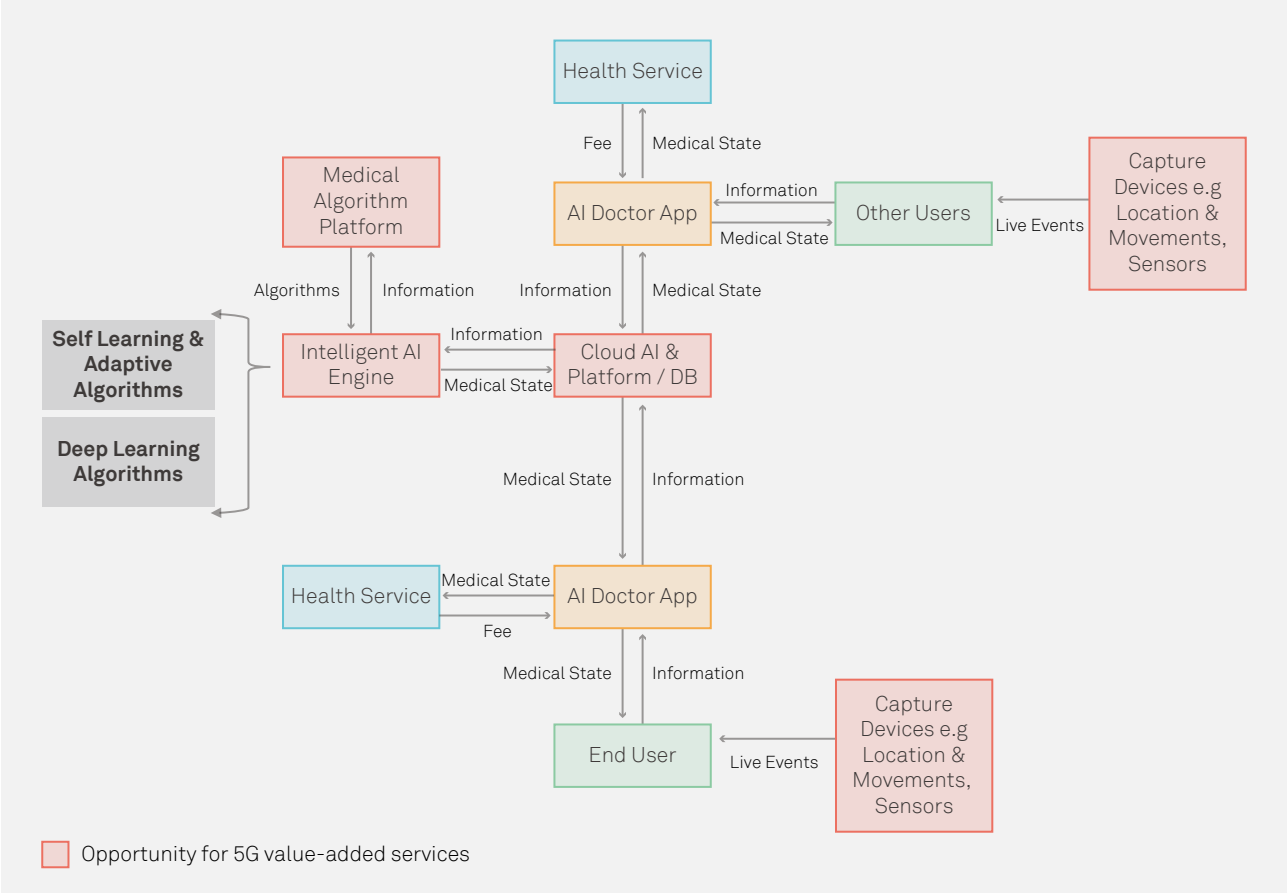


Figure 7: Role of 5G-Enabled Devices, AI, and Cloud Analytics in Future Healthcare (Source: SPO LAB)

Other advanced use cases include medical robotics and medical cognitive computing. They outline uninterrupted connectivity requirements for high-end applications, such as biotelemetry, VR-based medical procedure training, ambulance drones, bioinformatics, and real-time data transmission.

Mobile telcos can actively partner with the healthcare industry, medical system integrators, and the community at large to create a favorable ecosystem, providing IoMT connectivity and related services, such as analytics and cloud services, to support various technology deployment initiatives.

In 2016, Sweden's Umea University has demonstrated the use of remote ultrasonic robots, wearables, and tele-ECG devices to monitor patients more than 100 miles away.

One specific use case – remote diagnosis – is particularly dependent on the lower latency and higher QoS offered by 5G networks.

For example, a tele-ultrasound robot in the Hospital of Belle Île en Mer (a French island off the coast of Brittany) ensures proper healthcare is attainable in this remote location, and allows for advanced consultations to be provided by doctors and clinicians on the mainland while reducing the costs of medical transport and transfers.

Such tele-ultrasound robots are already available commercially. They implement force feedback functions – an example of the "tactile internet" – to engage with patients with more precision to minimise pain during examinations. 10ms E2E latency is required.

Wireless endoscopy

Phase	Data Rate	Latency
Phase1: Light endoscope	12 Mbps	35 ms
Phase2: 360˚ 4K+tactile	50 Mbps	5 ms

Wireless ultrasound

Phase	Data Rate	Latency
Phase1: Semi-automatic, tactile	15 Mbps	10 ms
Phase2: AI-assisted vision, tactile	23 Mbps	10 ms

5.2 Key Takeaways

- Investment in the smart healthcare market is expected to eclipse US$230 billion by 2025. 5G will provide the connectivity for an increasing proportion of that investment.
- Technological evolution in the healthcare domain is being spearheaded in North America, as well as in the German and North Asian markets. Emerging applications include cloud-based data analytics, AI medical assistants, 5G-enabled ambulance communications and remote diagnosis.
- In a recent B2B survey, ABI Research found that 42% of respondents in this sector have in place solid plans for 5G deployments and are convinced of its role as an enabler of advanced healthcare solutions.

Smart healthcare to eclipse $230 billion By 2025

Wireless Home Entertainment

> One of the very first commercial use cases for 5G is fixed wireless access, which is an established means of providing internet access to homes using wireless mobile network technology rather than fixed lines. Fixed wireless access, or WTTx ("wireless-to-the-x"), can often prove more convenient to set up as it accesses existing tower sites and spectrum.

UHD 8K Video & Cloud Gaming

By August 2016, there were nearly 10 million 4K/UHD TV service users worldwide. 4K/UHD TVs already make up more than 40% of the global market and 8K TVs will soon be available. According to forecasts, lower prices and new subscription-based UHD TV services will attract half of TV watchers worldwide to use 4K/8K TVs by 2020. 8K video using data rates of over 100 Mbps will require the high bandwidth 5G WTTx provides.

Other video-based applications, such as home surveillance, content streaming, and cloud gaming, will also benefit from 5G WTTx. For example, current cloud game platforms do not generally provide levels of image quality greater than 720p, but 5G is expected to offer responsive and immersive 4K gaming experience at 90 fps, which requires data rates greater than 75 Mbps and less than 10ms latency.

Cloud gaming requires less from end-user devices – all the processing will be on the cloud. Users' interactions will be transmitted to and processed in the cloud in real-time to ensure high-quality game streaming experiences.

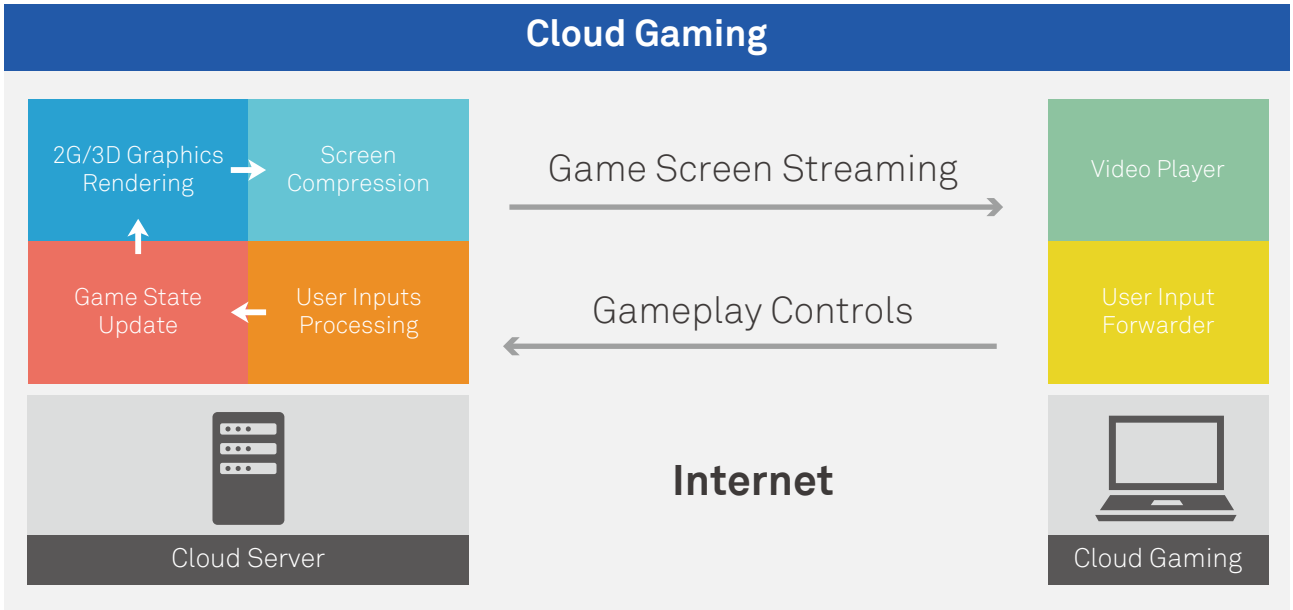
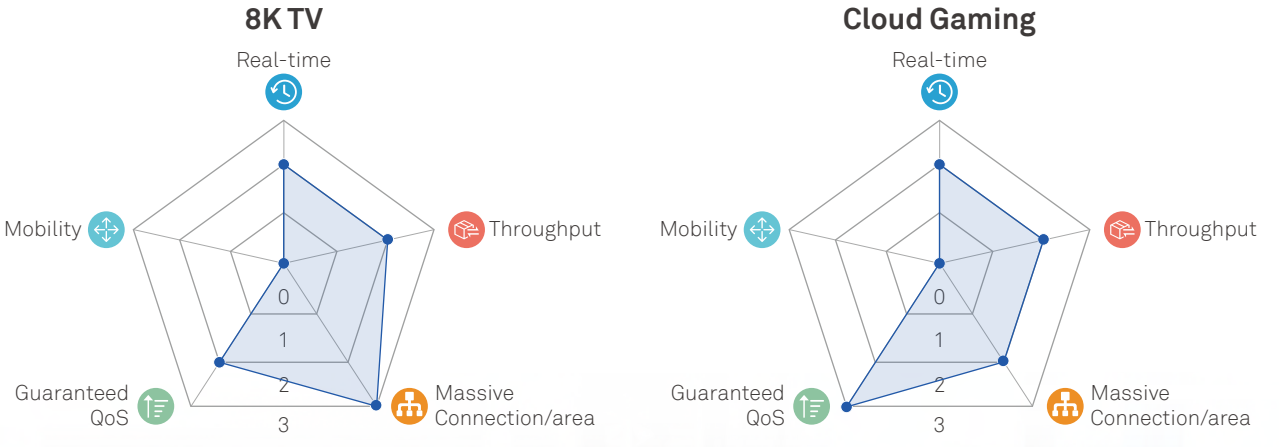
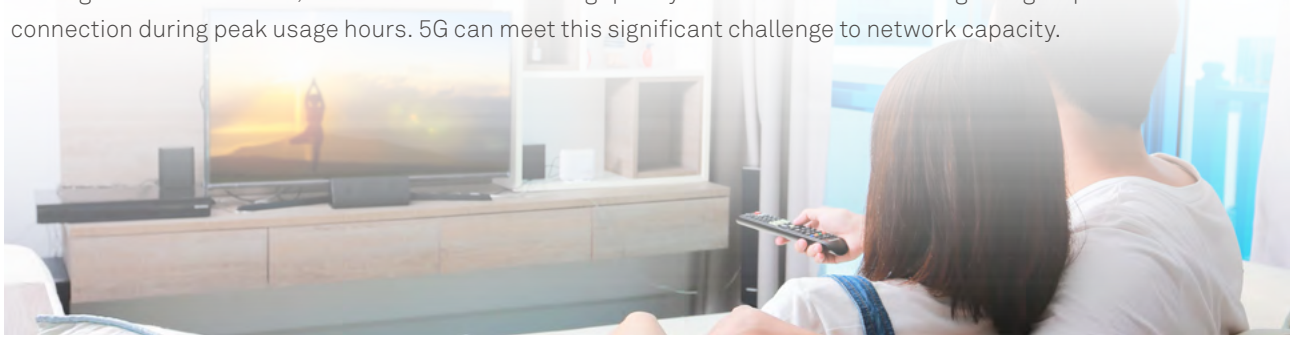


Figure 8: Cloud Gaming Processing Diagram (Source: Wireless X Labs)

The Most 5G Relevant Use Case



The higher the bandwidth, the better UHD streaming quality. TV and TV based cloud gaming requires ultra reliable connection during peak usage hours. 5G can meet this significant challenge to network capacity.



6.1 Business Model and Use Case Examples

The capital expenditure required to implement WTTx is much lower compared to other technologies. According to Australia company NBN, fixed wireless deployment is 30% to 50% lower than fiber-to-the-premise. WTTx saves mobile network operators from the necessity of laying fibre to every household and significantly reduces the amount of capital expenditure spent on poles, cabling and trenches.

TV, gaming and home applications place the telco at the center of the smart home. With WTTx, the telco can provide a platform for a number of smart home value-added services that can be enhanced by AI digital assistant integration, data aggregation analysis, and software app development.

This WTTx-enabled smart home ecosystem allows telcos to offer:

- Unified family packages, integrated broadband, and video services at competitive prices
- Very low latency immersive HD and higher video and gaming content at competitive prices
- Integrated third-party smart home applications that leverage the telco gateway
- Assured carrier-class privacy and security

Prototype WTTx deployments include AT&T and Verizon aiming to launch 5G for fixed wireless residential broadband in 2018. Google's acquisition of high-speed wireless Internet service provider Webpass in June 2017 shows its interest in the wireless broadband business. The web giant dropped its plan to deploy a fiber-optic broadband network across the United States, in favor of 5G.

The world's first 8K live broadcast was used during the 2016 Rio Olympic Games. On August 1, Japan's public broadcaster NHK, began testing 8K TV broadcasting and broadcasted the opening and closing ceremonies, swimming events, and track and field events the games. Additionally, NHK plans to broadcast during the 2020 Tokyo Olympic Games. South Korea also plans to broadcast the 2018 PyeongChang Winter Olympics in 8K.

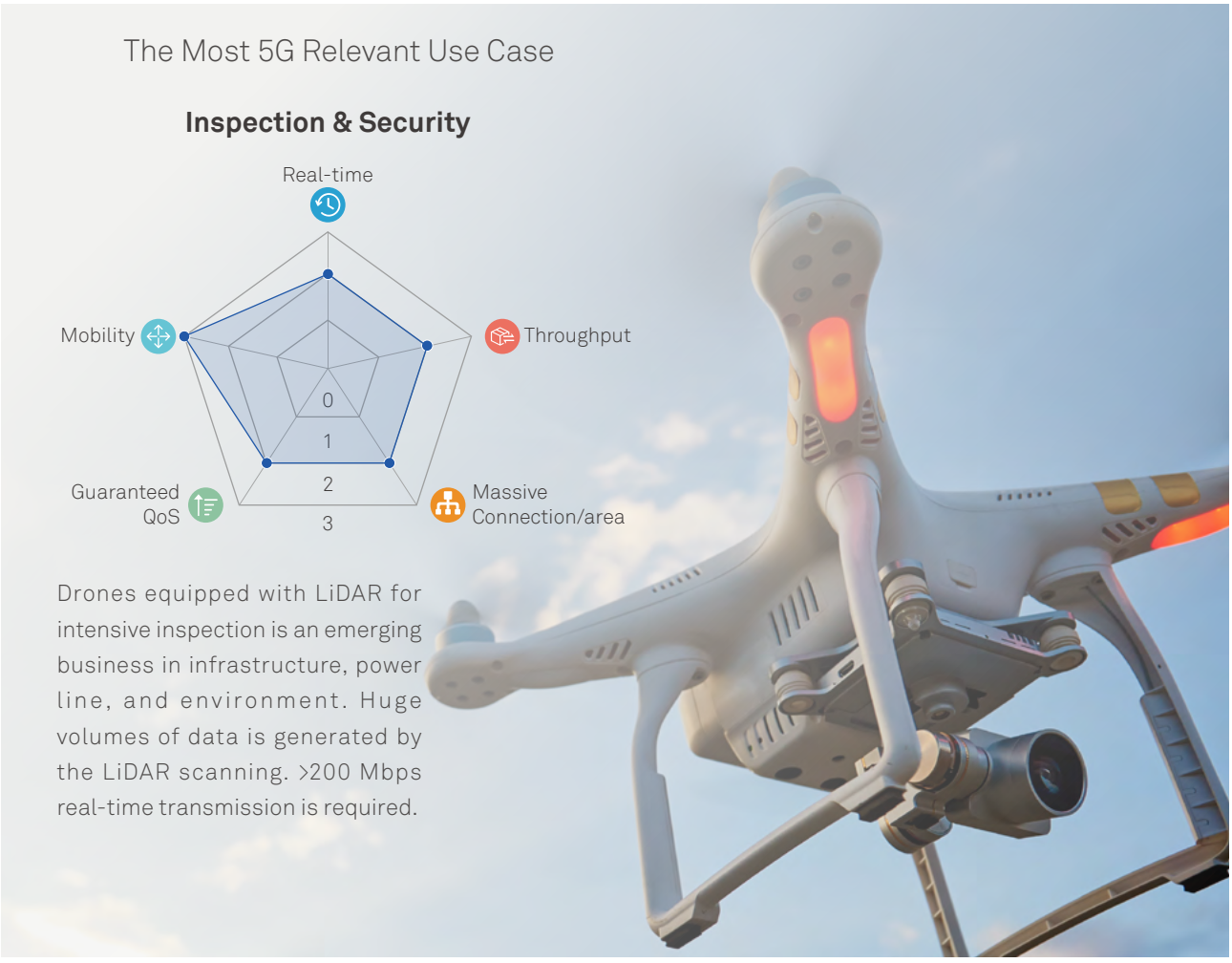
6.2 Key Takeaways

- With no need to dig trenches, lay fiber cables, or install poles, WTTx can greatly shorten the period of network deployment.
- At the end of 2017, fixed broadband subscriptions will reach 854 million households, which equates to only 44% of global residences. According to the forecast, 350 million households could potentially afford WTTx services by 2020.
- 5G is expected to support responsive and immersive 4K gaming experience at 90 fps, with end-to-end latency of 10ms in general and end-to-end latency of 1ms for use cases that demand extremely low latency.

350 million households could potentially afford WTTx services by 2020

Professional Inspection & Security

The global market for unmanned aerial vehicles (UAVs) has grown significantly over the last decade. UAVs, also known as drones, are now established delivery platforms for a diverse set of commercial, government, and consumer applications.



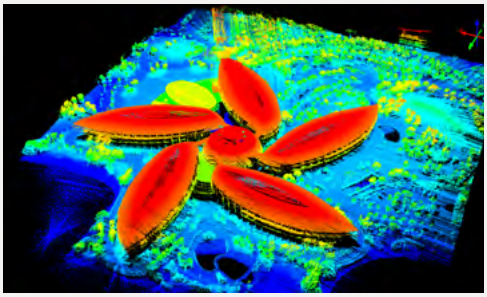
7.1 Business Model and Use Case Examples

Significant efficiency gains and safety improvements can be rapidly achieved through the deployment of drone platforms. 5G networks will allow new levels of automation and enable analytic solutions that will have a transformative impact across multiple industries. For example, rather than live visual inspection of potential rotor blade damage on a wind turbine by a trained human drone operator, an autonomous drone fleet deployed across a wind turbine farm could capture video. Similar vertical solutions may help protect essential property and key resources, such as oil & gas pipelines and installations, or increase productivity in the agricultural sector, for example. Drone use and applications are also accelerating in the security and transport fields.

Drone operators are tapping into the on-demand, "as-a-service" economy, delivering their services to end users in a similar manner to the cloud-consumption model. For example, in the agricultural sector, a farmer can access crop monitoring services on a PAYG basis, or a monthly contract. Meanwhile, drone operators are building an increasing number of partnerships to create drone service marketplaces and app stores, furthering the enterprise and consumer appeal of their services.

Further, drone operators and their marketplace partners can aggregate and anonymize the data that they collect from customers in order to improve their services and tap into the data analytics monetization market. Aggregated and anonymized industry sector data may provide financial services organizations with an indication of commodity/input cost future price trends, or may potentially be useful to logistics/shipping companies and government agencies for forward planning.

Drone LiDAR Scan of Buildings



Drones equipped with LiDAR for intensive inspection is an emerging business in infrastructure, power line, and environment. Huge volumes of data is generated by the LiDAR scanning. >200 Mbps real-time transmission is required.

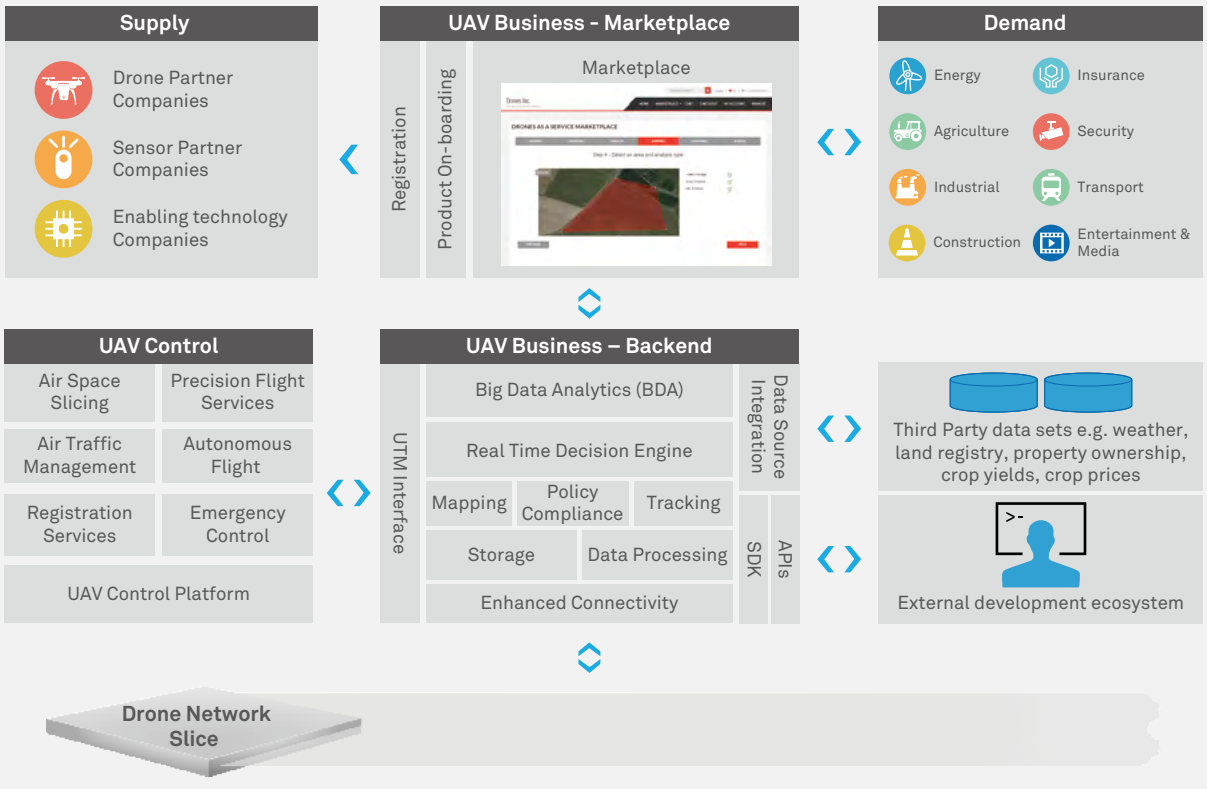
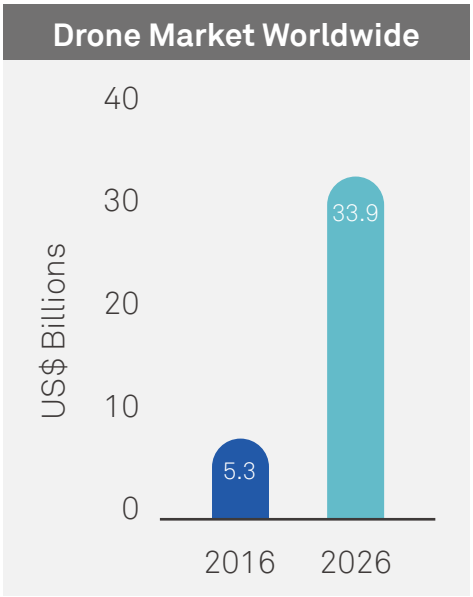


Figure 9: Demand-Supply Business Model for Drones (Source: SPO LAB)

At the moment, the main traction for drone usage comes from the civil construction industry. Drones are deployed to monitor buildings and cell towers for mobile network operators. Drones equipped with LIDAR technology and thermal imaging technology can conduct aerial surveillance. At Huawei's X Labs, drones with thermal imaging are used to perform gas leakage inspection and surveillance.

7.2 Key Takeaways

- Drones have the potential to be scalable support solutions. They can address application use cases from construction, oil/gas, energy/utilities, and agriculture.
- 5G technology will enable drone operators to enhance their offerings through the ubiquitous availability of high-bandwidth networks that enable significant data volumes with minimal latency.
- Based on ABI Research's estimate, the market for small drones will increase rapidly, from US$5.3 billion in 2016 to more than US$33.9 billion in 2026. This includes revenue from software platforms, hardware accessories, services, and application services.
- Drone service providers are leveraging cloud technology and partnerships to offer apps and marketplaces. These technologies open business opportunities for telcos and their partners.



Social Networks

> Mobile video has developed from the provision of on-demand content on mobile devices to new modes of content creation and consumption. Two of the most prominent recent trends are social video and mobile live video:
>
> - Live video is being increasingly carried on leading social networks, e.g. Facebook and Twitter
> - The social aspect of live video, including interaction between broadcasters and viewers as well as between viewers, is driving the fast adoption and direct monetization of mobile live video.

UHD/Panoramic Live Broadcasting

As of the end of 3Q-2017, there were approximately 10 billion monthly active users (MAUs) on the top 10 social networks. The top 3 social networks were Facebook with 2 billion monthly active users, YouTube 1.5 billion and WeChat with 963 million.

The smartphone has been a lynchpin technology for social networking. Approximately 60% of MAUs access Facebook via their mobiles. However, consumers are increasingly updating their family and friend social networks via personal wearables that can communicate live video, even 360° video, sports performance, step-counts, even their mood on a real-time basis.

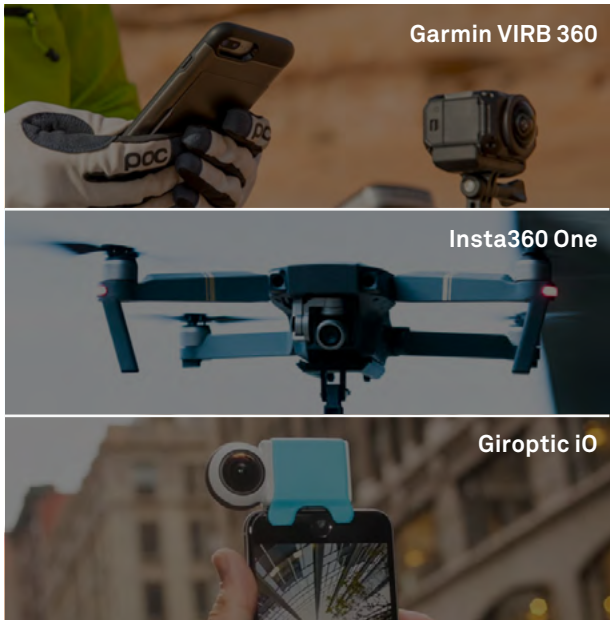
The popularity of social networks indicates that its users are becoming increasingly comfortable at sharing content, including live video. By definition, live video streaming does not need the content captured by the host to be stored on the device then uploaded to a hosting platform afterwards. Instead, the content is transmitted directly to the streaming platform and viewed almost instantly.

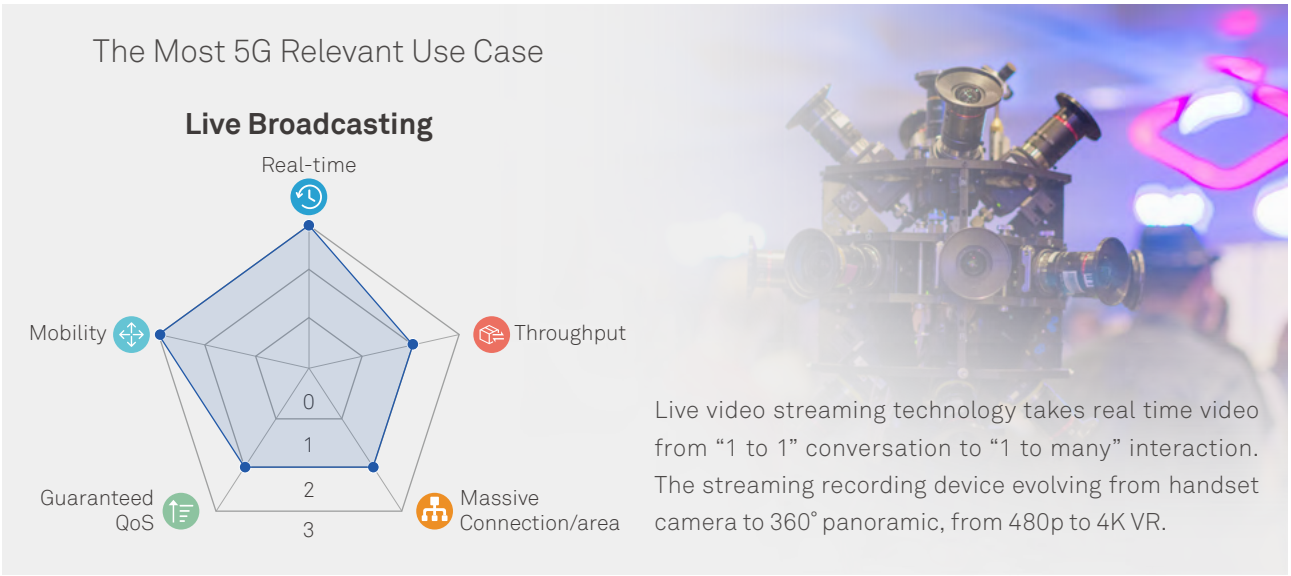
The real-time feedback nature of a conversation is built in on smartphones and enabled by mobile video live streaming platforms, making this new type of "one to many" communication much more interactive and social. With the capability of interaction between viewers added to the experience, there is also a "many to many" social dimension to live video streaming.

Immersive video recordings are expected to be enthusiastically adopted by social networkers, extreme sport, fashion bloggers and trendsetters. Facebook launched its 360° live video platform in 1Q-2017. The company has updated the platform to make it more accessible to both creators and viewers. Bloggers can now stream live 360° video on Facebook in up to 4K resolution.

Viewers can view the content in virtual reality. Commercial live stream video cameras that are compliant with Facebook include Garmin VIRB 360, Giroptic iO, three Insta360 models and Nokia's Ozo Orah 4i. As the streaming cameras continue to shrink we will see an increasing number of sport activities livestream "in-person" video content. Want to see your friend cross the finish line of a marathon? Or Or should your friends the grandeur and scale of the Grand Canyon?

Total Freedom, 360X Live Broadcast





8.1 Business Model and Use Case Examples

The business models for live video streaming are still evolving. There are regional differences in the underlying business model. In China, individual broadcasters are playing a very prominent role whereas in the US, Mass media broadcasters have adopted the media to reach millennials and other end-users interested in real-time content. Advertisers are keen to interleave their advertisements into a community of users with notable discretionary spending.

		China		US	
		Level of importance	Examples	Level of importance	Examples
Streamers	Individual live streaming hosts	Extremely active	Hosts on Douyu, Inke, etc.	Active	Gamers on Twitch
	Mass media broadcasters	Non existent	n.a.	Active	New York Times on Facebook Live
Monetisation	In-app purchase	Dominant model	All live streaming platforms	Level of importance	
	Advertising	Less important	Xiaomi showcasing battery life on Bilibili	Nascent but dominant model	Ads on Twitter’s live streaming of NFL games
	Subscription	Little presence		Niche	Twitch’s subscription packages
	No direct monetisation: ecosystem play	Gaining importance	Alibaba’s fashion show with direct purchase feature	Very important	Celebrities on Facebook Live

Figure 10: The 2 Typical Live Video Markets Comparison of China and US (Source: Wireless X Labs)

Live broadcasting is supported by LTE but 5G will address its challenges in 3 key ways:

- End-to-end network latency will decline from 60~80 ms to less than 10 ms;
- HD video feeds will typically require 50 Mbps but that figure could go up to 100 Mbps due to 4K, more fields of vision, and/or data analytics overlay;
- Massive UL throughput of 10 Gbps will allow the upload of high-definition images and videos.

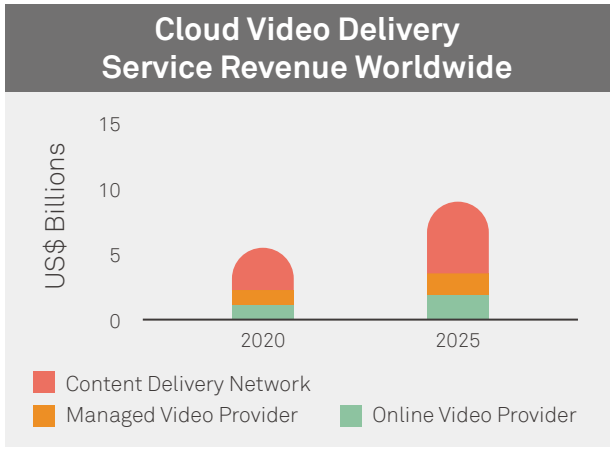
Sports broadcast is proving to a pioneer of this novel live 360X streaming service. Examples include:

- Multi-view streaming - In Formula One Shanghai 2016 competition, China Mobile realized the first live multi-view streaming service from the race track - which gave its users a unique point of view perspective. The audience can switch from commentators booth to embedded immersive 360° camera angles in an instant.
- Athletes' in-person video streaming – In March 2017, South Korea operator, Korea Telecom, tested wireless network based player view video service at the training day of the International Bobsleigh & Skeleton Federation (IBSF). Ultra-compact cameras and location sensors were used to transmit real-time 4K video from the player's own point of view. Audience watched the live matches from the perspective of players. The Bobsleighs reached speeds of 120 -150 Km/h and viewers can select from a number of multiple-angle cameras.

Mountain Cyclist Live Video Stream

8.2 Key Takeaways

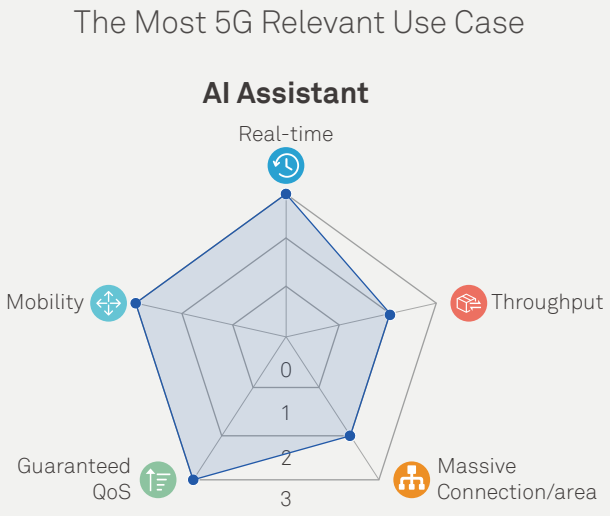
- In 3Q-2017, there were 10 billion monthly active users on the Top 10 Social Networks. 2 billion were on Facebook.
- Mobile broadcasting is evolving from handset camera to 360˚ panoramic; from 480p to 4K VR.
- In Developed Markets, approximately 50% of mobile data traffic is sourced from live video uploads.
- Cloud video providers are not only managing live video streams but also monetizing the revenue. By 2025, CDNs, MVPs and OVPs should capture almost US$ 10 billion, up from US$ 6 billion in 2020.



AI Assisted Smart Helmet

Following the maturation of the smartphone market, personal wearables and assistant were expected to lead the next wave of smart gadget adoption. Due to limited battery life, network latency, and bandwidth limitation, personal wearables often resort to Wi-Fi or Bluetooth for connectivity and need to be constantly paired with computers and smartphones, and as a result are failing to exist as independent devices.

5G is expected to offer prime opportunities for both the consumer and enterprise sectors. Wearable devices offer manufacturing and warehouse workers hands-free access to information. AI software located in the cloud allows existing wearables to have AI functionality and the ability to search for certain objects or people.



The visual impairment guiding helmet relies on cloud intelligence to assist people's daily lives; guaranteed network availability is essential.

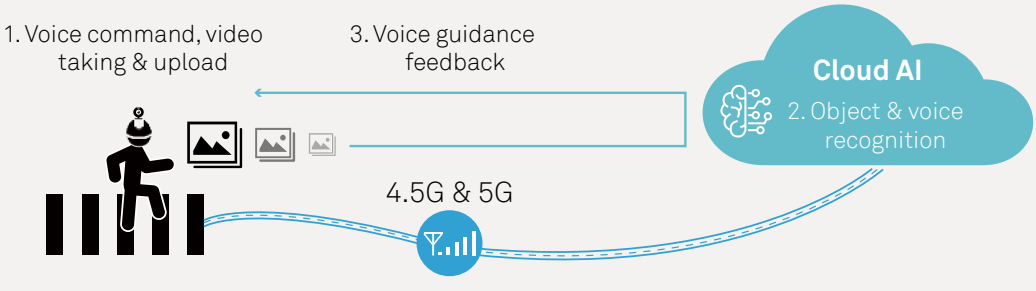


Figure 11: Visual Impairment Guiding Helmets

In the consumer sector, visual impairment guiding helmets can harness computer vision, 3D modeling, real-time navigation, and positioning technology to provide “eyes” for the blind.

Phase	Data Rate	Latency
Phase1: 1 FOV, man assisted	> 6 Mbps	50 ms
Phase2: 4 FOV, AI navigation	> 30 Mbps	< 20 ms

Human neural network delay	Network latency requirement	AI process time is expected to decrease from 180 ms to
100 ms	**< 20** ms	**80** ms

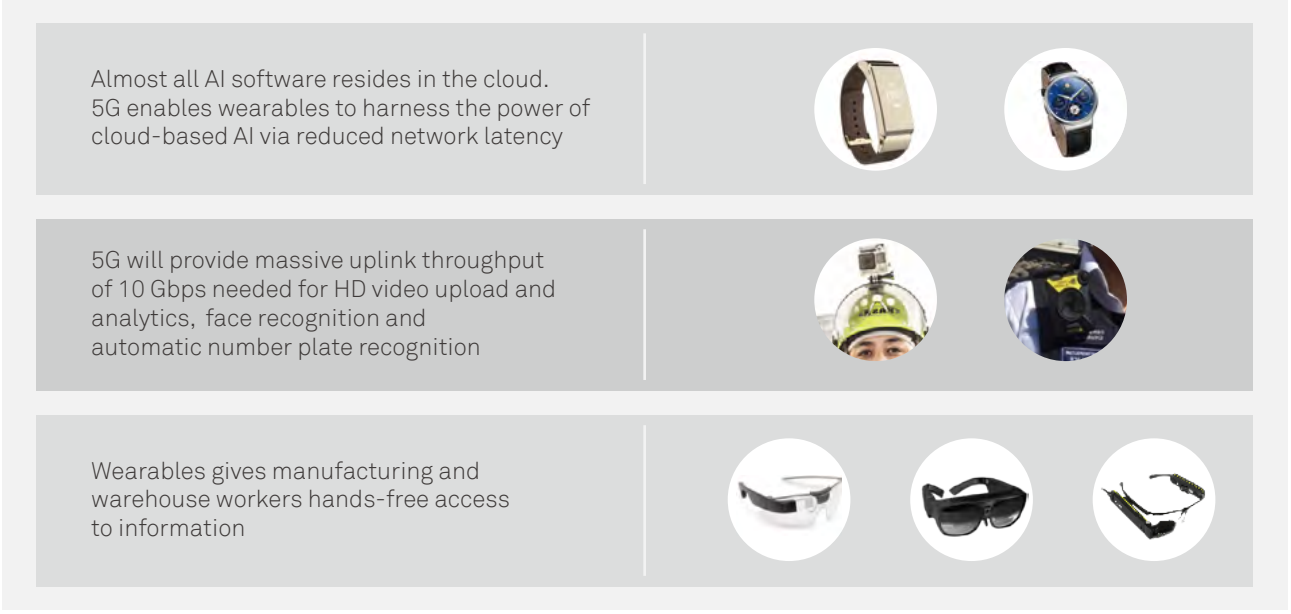


Figure 12: 5G-Enabled Wearables (Source: ABI Research)

9.1 Business Model and Use Case Examples

5G will address this challenge in three key ways. End-to-end network latency will decline from 60~80 ms to less than 10 ms. Massive UL throughput of 10 Gbps will allow the massive upload of high-definition images and videos at a high speed. In addition, caching and computing capabilities at the network edge will drastically improve response time and battery efficiency, promoting a better user experience.

As higher quality content drives higher data consumption, mobile network operators can offer competitive enterprise packages, encompassing basic connectivity with other VAS, such as Big Data, MEC, and caching.

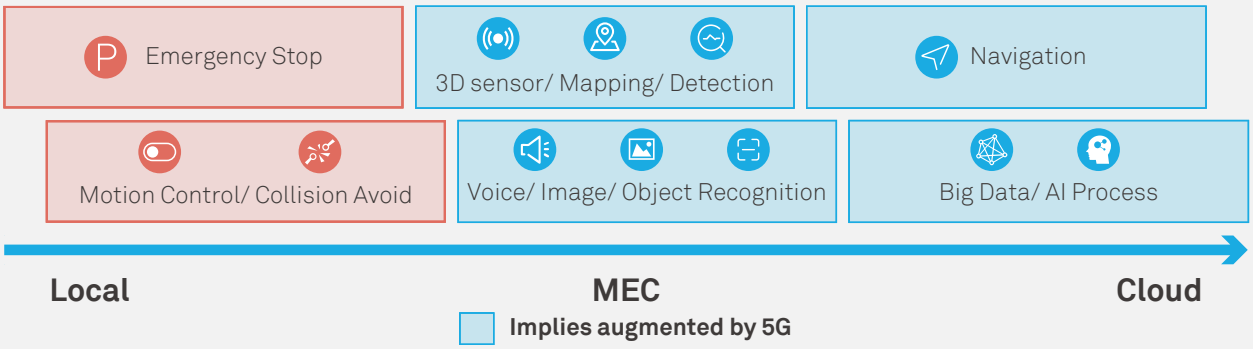
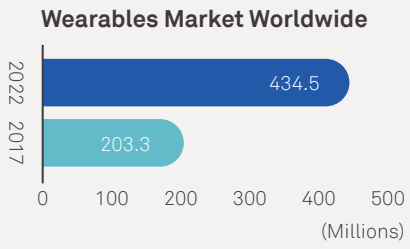


Figure 13: 5G Telco Can Underpin Personal Wearables (Source: Wireless X Labs)

9.2 Key Takeaways

- ABI Research estimates the wearable device market will grow at a CAGR of 16.4% from 2017 to 2022, from 203.3 million shipments in 2017 to 434.5 million shipments in 2022.
- Sport, fitness, and wellness trackers remain the key segment by 2022, accounting for 36% of the shipments; with smartwatches (19%), wearable cameras (11%), and healthcare (9%) following behind.



- Coupled with 5G's ubiquitous coverage, higher data rate, and lower latency, personal wearables could be deployed in mission-critical and business-critical scenarios, such as public safety, mining, and remote healthcare.

Smart City

> A smart city holds a competitive advantage in that it can be proactive rather than reactive to the needs of its residents and businesses. To become a smart city, civic authorities not only need to invest in data sensors that can take the pulse of the city but video surveillance cameras that can monitor the flow of traffic and the safety of its neighborhoods.

AI-enabled Video Surveillance

City video surveillance is an invaluable tool that not only enhances security but also energize the productivity of businesses and civic institutions. Video surveillance systems are invaluable for monitoring:

- Busy public places (squares, activity centers, schools, hospitals)
- Business areas (banks, shopping centers, plazas)
- Transportation centers (stations, docks)
- Major intersections
- High-crime areas
- Institutions and residential areas
- Flood prevention (canals, rivers)
- Critical infrastructure (energy grid, telecom data centers, pumping stations)

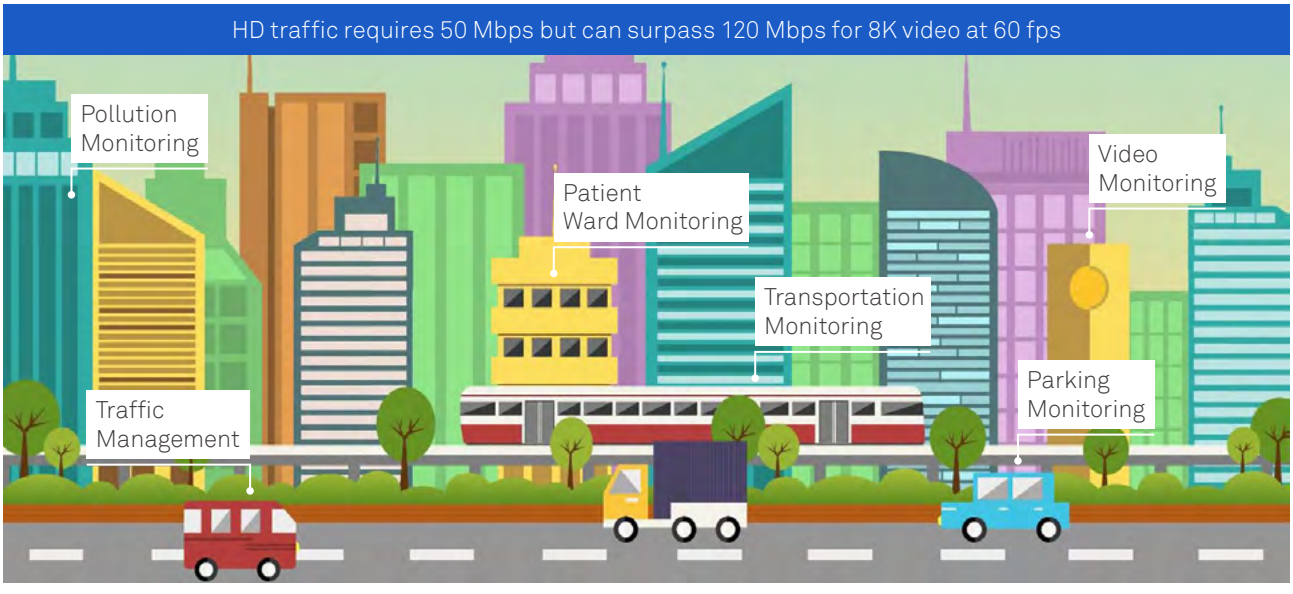
Demand for video surveillance is primed by the innovation in video camera technology, the cloud storage that supports data collection and analytics and by price competition.

Notable video camera innovations include:

1. 4 megapixel IP cameras (IPC) which currently dominate the market, and 6mp and 8mp cameras with 4K capability which will gain traction from 2020;
2. Novel application scenarios such as body-worn cameras, and in-vehicle cameras which are used by Emergency First Responders and also individual car owners.

The enhanced features of the latest video surveillance cameras such as high frame rates, HD video and WDR (Wide Dynamic Range, which allows for imaging even in challenging lighting conditions) will contribute to significant new data traffic being generated.

Video Monitoring Services Play an Essential Role in the Smart City



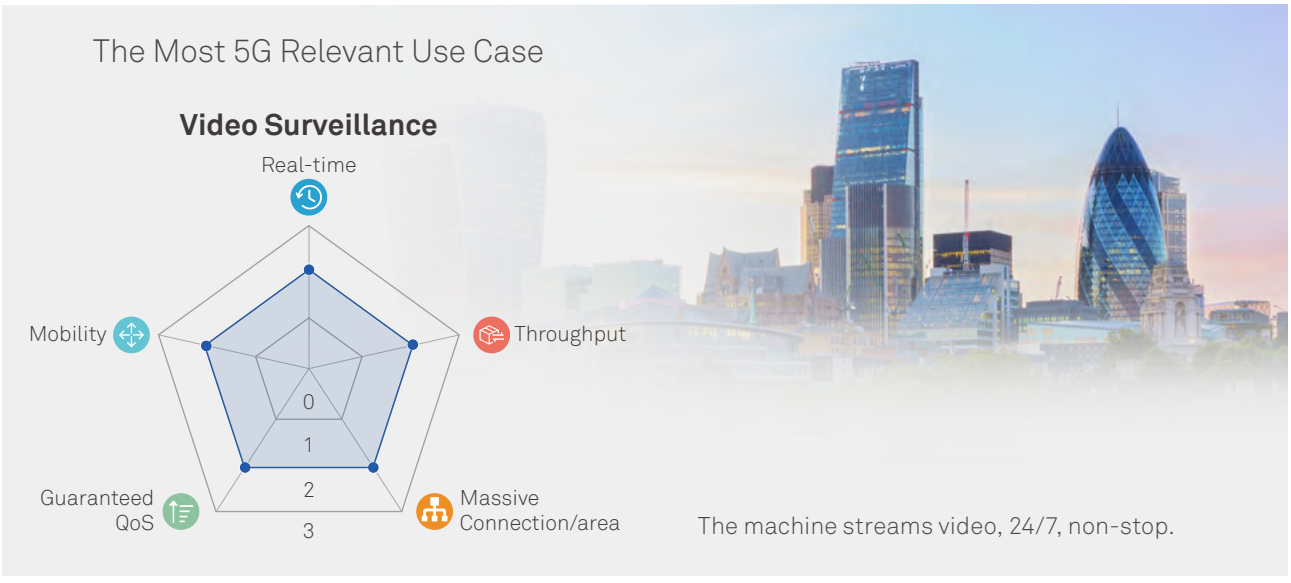
10.1 Business Model and Use Case Examples

For the next generation of video monitoring services, the smart city will need to move away from the traditional business model based on the concept of "building the system and walking away". Instead smart cities will migrate to a Video Surveillance as a Service (VSaaS) model. In VSaaS video recording and storage, management, and hardware and services monitoring are provided to the users via cloud-based delivery and managed by the service provider.

Enhanced Video Surveillance Deployment Models & Video Analytics

	Hosted Video Model	Managed Video Model	Hybrid Hosted/ Managed Model
Data Center	A 100% cloud-based model. Videos generated on-site by cameras transferred to the SP's data center	Video surveillance system components are located on-premise, from the video recorder and storage system to the VMS and servers	A combination. The most critical data and functionalities closer to their source, while sending everything else off to the cloud
Edge-Based Video Analytics (VA algorithms & software in the camera but basic functionality. E.g. fire or motion)			
Server-based Video Analytics (can perform metadata extraction, AI can monitor and learn from viewed data, query large databases)			

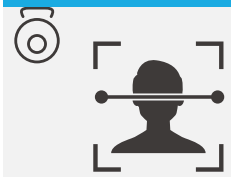
The cloud provides flexible data storage as well as the Data Analytics/Artificial Intelligence layer. Standalone storage systems for a video surveillance system owner have significant upfront capex and ongoing opex costs that will be ameliorated by economies of scale. Cloud storage may be priced dynamically according to need. In peak retail seasons, the video cameras may be configured to a higher resolution while at other times, the resolution is scaled back to reduce cloud storage costs.



Telcos can create an advantage in offering Artificial Intelligence to enhance their cloud services. AI can enable computers to interpret large amounts of data in the form of images, sound, and text. AI will enable face recognition, vehicles, license plate recognition or other video analyses. For example, the detection of an intruder by the video surveillance system could trigger the automatic locking of all the adjacent doors, confining the intruder until the arrival of law enforcement personnel. Alternatively, the video surveillance system could be triggered by another system. For example, a POS system could notify the video surveillance system every time a transaction is made and alert a camera to record the scene before and after the action.

Single wireless cameras do not consume much bandwidth at the present time. But along with the introduction of central cloud and mobile edge computing, telco cloud infrastructure could support more AI assisted surveillance applications, where cameras stream video, 24/7, non-stop.

AI assisted wireless surveillance camera

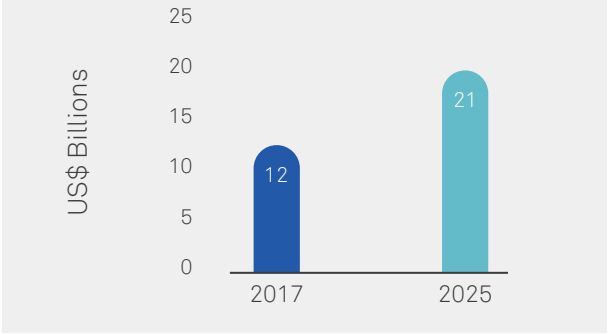


Phase	Data Rate	Resolution
Phase1: Single sensor camera	20 Mbps	4K
Phase2: Multiple sensors AI camera	> 60 Mbps	360° 4K+

10.2 Key Takeaways

- Wireless surveillance cameras will extend the useful application scenarios as well as simplify deployment.
- The UK has deployed 6 million video cameras. Other countries are stepping up the deployment of video monitoring equipment. In Beijing, the density of surveillance cameras is 59 per 1,000 people.
- Surveillance cameras are evolving to 4K full HD in 5G era.
- The estimated VAS revenue in the Non-consumer Video Surveillance Market was US$ 12 billion in 2017 and are expected to grow to US$ 21 billion by 2025.

Non-consumer Video Surveillance VAS Revenue World-wide



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Wireless X Labs is a brand-new platform designed to get together telecom operators, technical vendors and partners from vertical sectors to explore future mobile application scenarios, drive business and technical innovations and build an open ecosystem. Wireless X Labs have set up three laboratories, which aim to explore three major areas: people-to-people connectivity, applications for vertical sectors and applications in household.

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