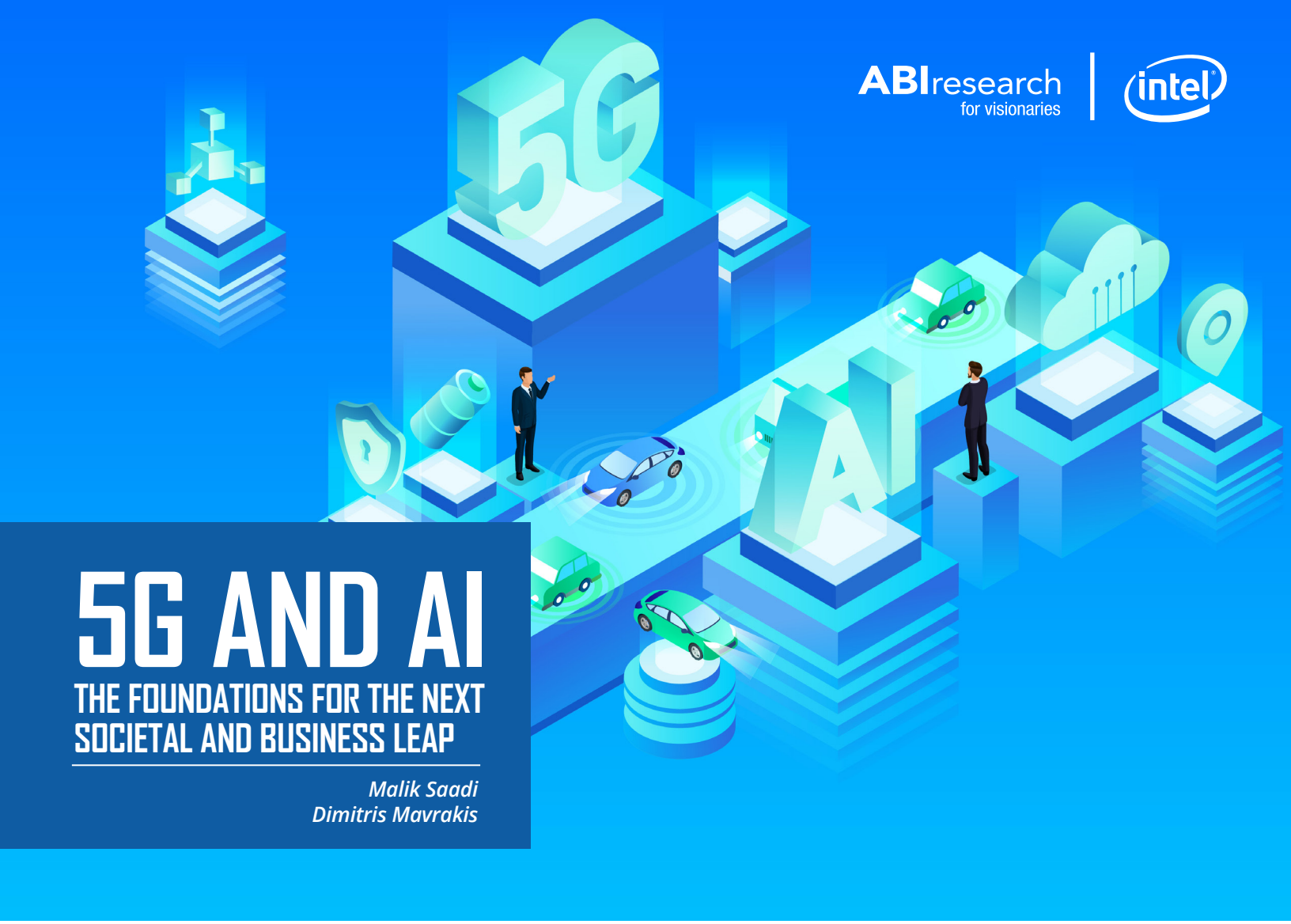

5G AND AI

THE FOUNDATIONS FOR THE NEXT SOCIETAL AND BUSINESS LEAP

Malik Saadi
Dimitris Mavrakis

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EXECUTIVE SUMMARY

5G and Artificial Intelligence (AI) are the breakthrough technologies of this decade. The two technologies, each in its own way, are bringing thousands of the most influential and innovative companies together to build one of the strongest ecosystems likely to transform the way we live and work. The combination of these technologies will serve as a catalyst to many other emerging technologies and will pave the way for a variety of new business opportunities in the consumer and enterprise segments, otherwise not possible with existing technologies.

5G is more than just an access technology evolution to Long-Term Evolution (LTE), designed for extending the network capacity and lowering its latency. Thanks to network slicing and service orchestration capabilities, 5G and network transformation create the foundation for building intelligent, secure, and reliable infrastructure capable of accommodating new services, use cases, and applications with different resources and service requirements on demand.

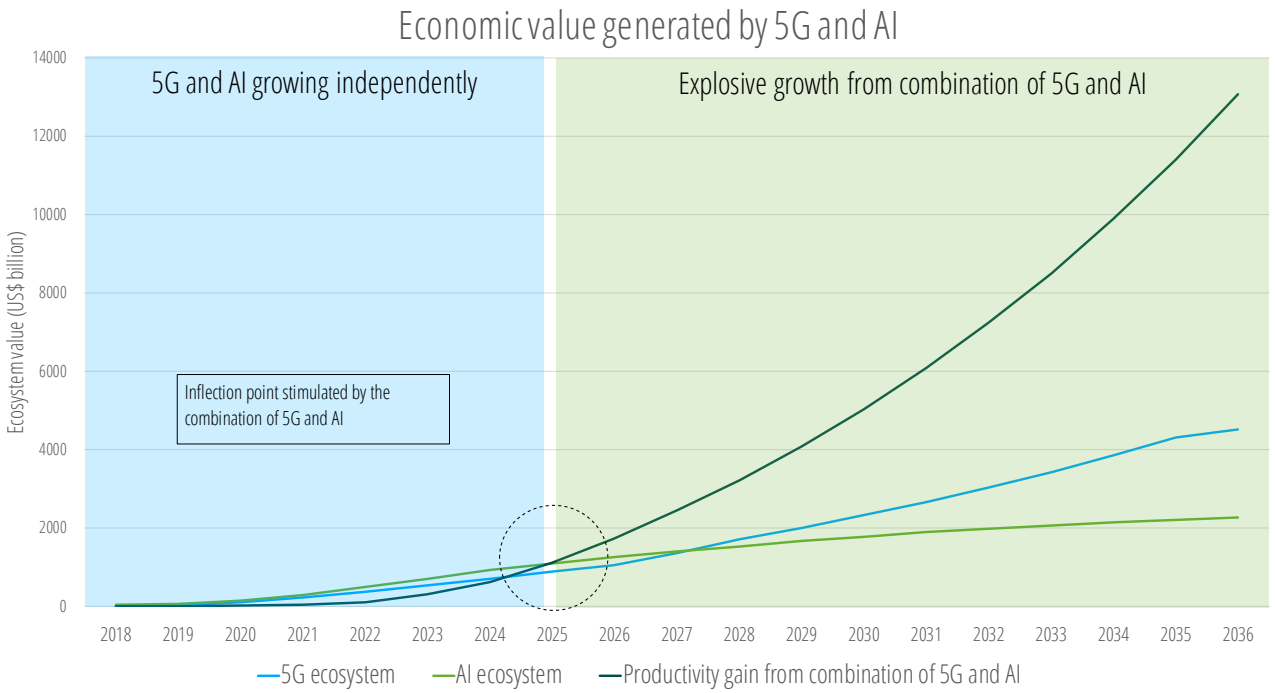
5G will create a fabric of processing capabilities at the edge of the network, coupled with high-bandwidth and reliable low-latency connectivity. 5G networks and corresponding use cases will require a higher level of flexibility and adaptability that current network design paradigms cannot provide. The requirement for such features will also increase exponentially when enterprise vertical use cases become mainstream, and Mobile Service Providers (MSPs) will need to adapt their networks in ways beyond what might currently be envisioned. The transformation of society, consumer experiences, and business workflows will not happen overnight, and more importantly, it cannot be driven by MSPs alone. Therefore, networks need to be flexible and adaptive to accommodate new features and cater to new use cases and, at the same time, be open to stimulate innovation from third parties.

On the other hand, AI is now enabling a host of new applications, augmented experiences, and efficient processes for several use cases across different verticals. Current AI implementations are largely public cloud-centric. The migration of more powerful processing capabilities to the edge, combined with 5G's low-latency performance will likely create an infrastructure that will thrive in a private and secure way.

Network transformation will be necessary to achieve these steps. There will be a need for cloud-native platforms, network orchestration, network Application Programming Interfaces (APIs), and third-party access, as well as a considerable level of flexibility in terms of network components and traffic control. This transition will not be an easy feat, but a necessary one for service providers to take full advantage of business opportunities that the combination of 5G and AI will create.

For this report, ABI Research interviewed leading MSPs, technology suppliers, and technology implementers about the role 5G and AI will play in accelerating the economic growth of key industry sectors. Most companies interviewed agreed that enabling distributed intelligence is the most important asset that the combination of AI and 5G offers, with the goals of bringing computing capabilities, AI in particular, close to the end customer, improving the end-to-end service latency, and minimizing risks related to data privacy and cybersecurity attacks.

Based on the guidance of industry leaders, ABI Research has compiled market forecasts to illustrate the impact that the combination of AI and 5G will have on business productivity across many industry segments and the overall global economic growth. Market data indicate that this combination will create US$3.1 trillion worth of value in 2025, 41% of which will be driven by direct revenue in the 5G value chain, including consumer subscriptions and equipment sales. This will change radically when both technologies reach maturity. ABI Research forecasts that 5G and AI will create value worth 9.2% of the global Gross Domestic Product (GDP) in 2035.



Source: ABI Research

MARKET IMPACT OF 5G AND AI

5G AND AI MARKET TRANSFORMATION

While the combination of transistor technology and the Internet revolutionized the way we capture, process, transmit, and share information, 5G and AI are likely to extend this revolution to enable fully automated and digitized processes across many industries. This combination will serve as a catalyst to many other technologies and business models capable of generating great economic value to developed and developing economies and at the same time, aiming to lower the carbon footprint of many technologies.

The move to 5G is forcing the entire telecommunications industry to evolve. 5G is not just a network evolution of LTE or an extension of LTE use cases that primarily target consumers. 5G has a lot more to offer than just enhancing the network bandwidth or lowering its latency:

- **Scale and Scalability**: Thanks to network slicing and service orchestration capabilities, 5G can support a variety of service types, use cases, and applications with different technologies and quality of service requirements. These capabilities will also allow MSPs to react to market demand in a timely fashion by enabling the launch of new services and use cases in a matter of days, not months or even years, as is the case with today's existing networks. For example, with 5G, mobile operators will be able to create a network slice for healthcare applications, giving it the utmost priority amongst all other network use cases.
- **Decentralized Intelligence**: Once mature, 5G is expected to operate in highly densified deployments. Under this environment, macrocells, microcells, and small cells will see their capabilities extended from cellular access points to edge compute nodes capable of bringing cloud computing and data warehousing close to the end user. This will not only turn MSPs to edge cloud service providers, but it will help them dramatically improve performance for many services and use cases, while enabling intelligence to be more distributed across different parts of the ecosystem between the cloud and the edge of the network.

- **Catalyst for Many Other Technologies and Business Models**: A number of burgeoning technologies, such as Augmented Reality (AR)/Virtual Reality (VR), unmanned automated machines (aerial, ground, or underwater), autonomous vehicles, AI, machine vision, light-field technologies, and the decentralized web, are promising to create new business opportunities across various industries and verticals. Although these technologies can be handled by existing networks, they are unlikely to achieve their full potential and performance without the support of 5G.

The combination of 5G and AI will be the infrastructure that permeates autonomous decision-making processes across industries and applications. The combination of AI and 5G will enable:

- More **Distributed Intelligence**: This allows computing functions to be distributed across the entire infrastructure from the cloud to the edge. The goal here is to deploy computing resources and AI on demand to transform the way information is collected, rendered, transmitted, and analyzed, thereby simplifying technology complexity, enhancing service experiences, and improving the overall infrastructure operation efficiency.
- **Greater Efficiency**: Both AI and 5G technologies have the ability to handle a large amount of information in a short time frame — 5G by transmitting this information at very high speeds and low latency, and AI by using efficient algorithms, reducing operational complexity.
- **Cost Effectiveness and Operation Efficiency through Automated Systems**: Thanks to the combination of 5G and AI, many processes and infrastructure functions will be automated, enabling a number of industries to reduce the amount of unnecessary interfacing equipment deployed, making smarter decisions in a timely fashion, increasing operation and production efficiency, and reducing human errors.

5G will play a key role in democratizing the use of AI, as virtually all applications and services will rely on some level of AI capabilities in the future. Both technologies will benefit from each other, but their combination will create new experiences and will redefine how we live, work, and play. 5G will also play a key role in the way AI will be deployed, enabling the development of new AI paradigms based on the combination of distributed, collaborative, and personalized AI approaches.

In this section, ABI Research draws on our interviews with technology decision-makers across many enterprise verticals, including automotive, cloud services, healthcare, manufacturing, smart cities, retail, and telco, to describe a few of the many values the combination of 5G and AI bring to the table beyond just a technology designed to enhance the network access bandwidth or its latency. Particular interest is dedicated to the impact of the combination of 5G and AI on productivity and global economic growth across many verticals and adjacencies.

METHODOLOGY

The value of the combination of 5G and AI technologies could be captured across three main dimensions: direct value from the 5G and AI ecosystems; indirect value from third-party technologies and services; and the impact that these two technologies will have on the overall productivity across different industries and markets.

DIRECT VALUE FROM THE 5G AND AI ECOSYSTEMS

Direct value of 5G to the GDP refers to direct contributions, which are currently dominated by consumer subscription revenue. Arguably, the 5G revenue mix will start to include enterprise vertical revenue, especially

when use cases combine the new cellular generation with AI. According to ABI Research's forecasts, direct revenue from 5G services will be nearly US$4 trillion in 2035, driven by Enhanced Mobile Broadband (eMBB), Massive Machine Type Communications (mMTC), and Ultra-Reliable Low-Latency Communication (URLLC) use cases.

According to this report, AI's direct contribution to the GDP represents the value created by the AI ecosystem, including cloud companies providing AI services, AI computing infrastructure vendors, and AI application vendors.[1] The direct contribution of the AI ecosystem to the GDP is expected to grow massively over the coming years to reach US$1.5 trillion by 2035 or 0.75% of the global GDP that year. By 2035, 55% of the AI impact on the GDP (US$855 billion) will be attributed to the value generated by AI infrastructure suppliers, while the remaining is attributed to AI cloud service providers using AI-as-a-Service.

Overall, the combination of AI and 5G will create US$5.5 trillion in value directly in 2035, which will be the equivalent of 3.3% of the global GDP that year. The large part of AI and 5G direct contributions to the GDP will come from the 5G ecosystem, provided that telecommunications equipment requires much larger Capital Expenditure (CAPEX) and Operational Expenditure (OPEX) than what is required for the cloud infrastructure.

INDIRECT VALUE FROM THIRD PARTIES

For a given technology, the indirect value to the GDP, as defined in this report, is attributed to the value streamed from two main categories of players:

- **Technology Suppliers:** Companies involved directly with 5G or AI ecosystems procure components from the technology supply chain to build their infrastructure, networks, and service platforms. In the case of AI, technology suppliers include AI chipset manufacturers, third-party AI software developers, and AI applications developers. For 5G, technology suppliers include, but are not limited to 5G device and component manufacturers, computing vendors, network software providers, testing companies, intellectual property providers, and content creators.
- **Third Parties Using the Technology for Value Creation:** These companies use technology to create value-added services or to build new business models that take advantage of this specific technology. For example, several companies are using AI to enhance the value proposition of their services or improve the experience of their customers, but they do not monetize AI services directly. Also, 5G and AI will serve as catalysts for many other technologies, such as AR/VR, the Internet of Things (IoT), edge computing, cloud computing, cognitive computing, autonomous machines, immersive Internet, and Geo-Information Systems (GIS), and could enable them to reach their full potential. The combination of these technologies will unlock several new business opportunities, otherwise not possible with existing technologies. As a result, new businesses and services will surface and flourish as much as LTE has enabled businesses like Uber, Deliveroo, and Didi to emerge, and other services like YouTube, Facebook, Tencent, Instagram, and Alibaba to thrive.

ABI Research anticipates that the value attributed to AI's indirect contributions to the GDP will reach US$754 billion in 2035, while 5G's indirect contributions will reach US$330 billion. It is important to note that these numbers are given for illustration only. In fact, the indirect value of 5G and AI cannot be explicitly dissociated, because 5G will play a key role in boosting the growth of AI when 5G will gain a certain level of maturity, which is expected in 2025.

[1] *Companies that are implementing AI for automating their own infrastructure, for creating value-added services, or for optimizing their operations are not considered as a part of the AI ecosystem in this report.*

So, the combination of AI and 5G indirect contributions will approach US$1.1 trillion, which will be equivalent to 0.6% of the global GDP. Most of this value will be created from 5G and AI technology supply chains, but the value creation from third-party services will be as important. Indeed, starting in 2025, the combination of 5G and AI will lead to the creation of completely new use cases and business models that we cannot even imagine today.

ENHANCED PRODUCTIVITY ACROSS VARIOUS INDUSTRIES

AI and 5G are major innovations that have the potential to improve efficiency and performance across many businesses and industries. This efficiency can be achieved through implementing distributed intelligence and ubiquitous connectivity that allow workers and machines to communicate, share information and intelligence on demand, and collaborate in an autonomous way. This development will help businesses enhance the performance of their infrastructure and enable their workforce to convert hours invested in addressing jobs that could otherwise be done by machines into more productive tasks. This combination could also improve the production output quite significantly.

ABI Research has investigated the impact of 5G and AI on productivity across major industries and markets, including agriculture, industrial manufacturing, automotive, retail and supply chain, media and entertainment, and healthcare. ABI Research's approach is based primarily on two main elements:

1. Identify key pain points the two technologies will solve for each industry or vertical studied.
2. Evaluate the impact on productivity for each pain point addressed. Productivity is defined here as an entity that quantifies an output produced out of a given effort made in the production process. In other words, productivity measures the ratio of output to inputs used for any production process. ABI Research's forecasts for productivity related to deploying 5G and AI consider two main elements:
    a. Minimizing the input in the production process, such as by reducing power consumption, workforce, or operation tools required for a specific production process.
    b. Maximizing the output in the production process for the same input, which is commonly referred to as production process yield.

ABI Research's calculations assume that by the end of the forecast period, which is 2035, both 5G and AI will have almost achieved their full potential.

Overall, the combination of AI and 5G will have a huge impact on the productivity of many industries. ABI Research estimates that the combination of AI and 5G will help increase the global productivity across adjacent industries by 5.8% in 2035, which will be equivalent to US$11.4 trillion in 2035. Industrial manufacturing, automotive and transportation, and retail and the wholesale trades are the three key markets that will be most impacted, but the combination of AI and 5G will also help boost the productivity of other industry sectors, including healthcare, media and entertainment, agriculture, government affairs, financial services, construction, and energy.

OVERALL IMPACT ON GLOBAL GDP

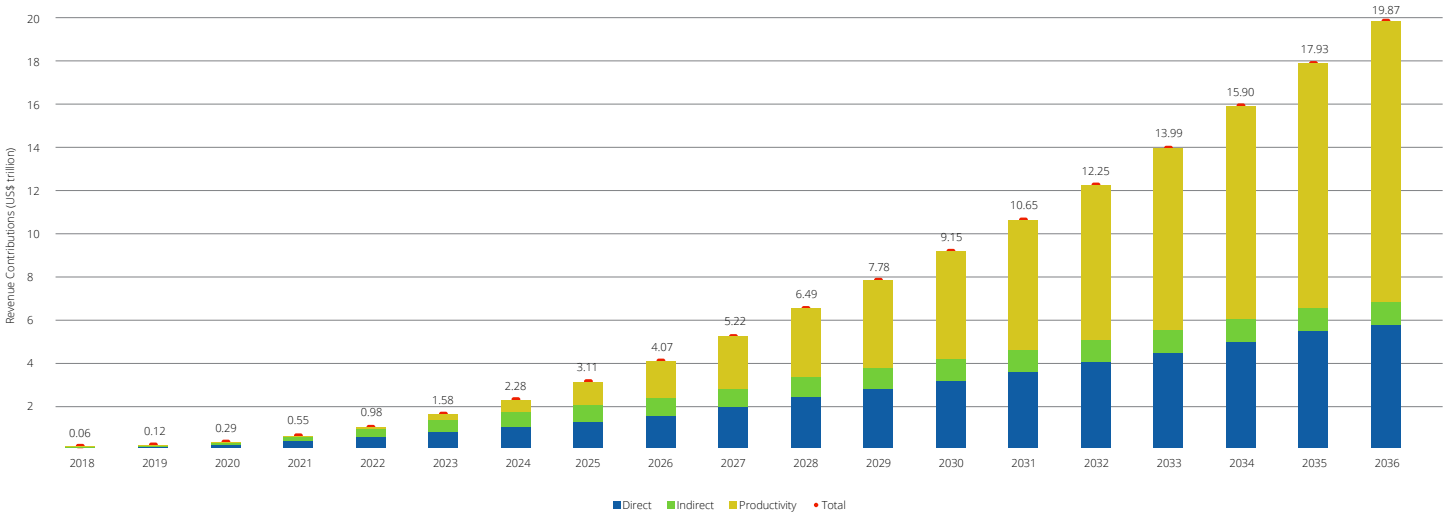
ABI Research's early forecasts indicate that the combination of 5G and AI will likely create tremendous opportunities for the mobile value chain beyond the consumer market to reach out to the industrial market. The combination of 5G and AI will also have a tremendous impact on productivity though better yield per capita, enabling a highly automated environment for many industries.

Chart 1 shows the total contribution of 5G through direct, indirect, and productivity contributions.

Chart 1: Contribution of 5G and AI to the Global GDP

World Markets, Forecast: 2018 to 2036

(Source: ABI Research)



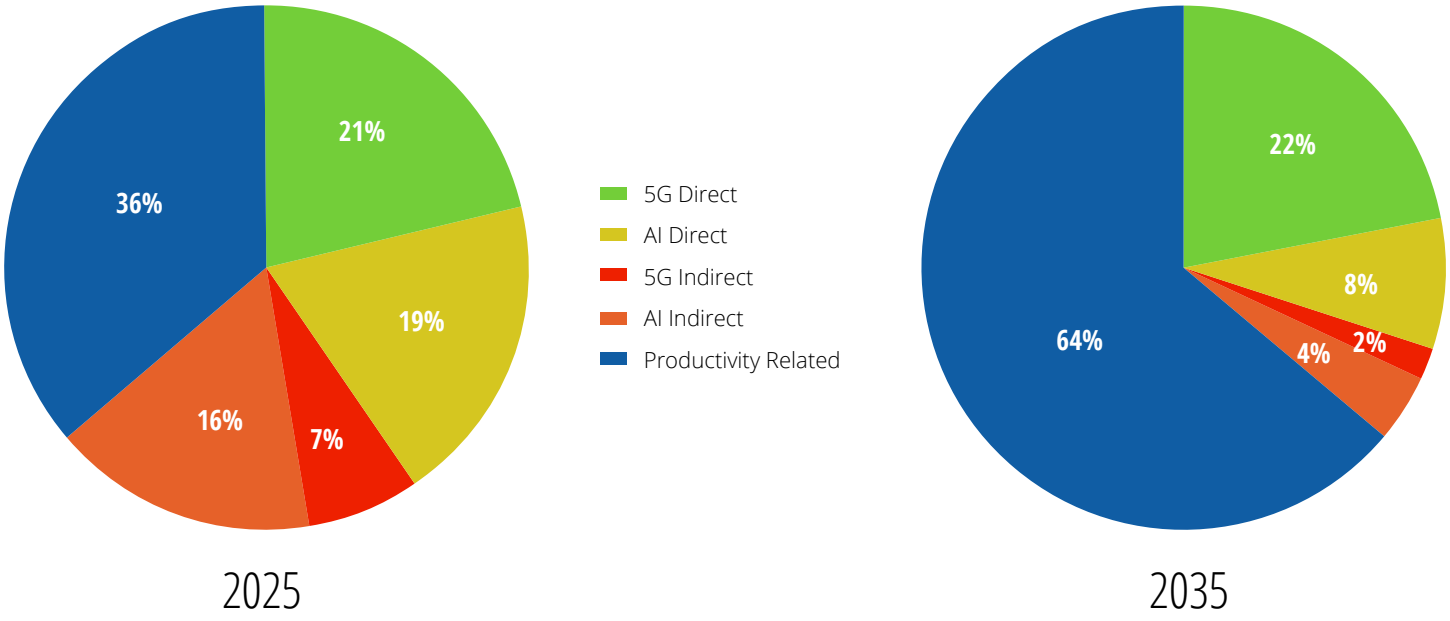
As a result, the total output of the AI and 5G combination to the global economy will reach US$17.9 trillion by 2035 or 9.7% of the global GDP. Chart 2 illustrates the breakdown between direct, indirect, and productivity-related contributions throughout the forecast period.

The most important illustration in Chart 2 is that productivity-related contributions will surpass all other revenue in 2028, by which time 5G will be generating tremendous value in consumer and enterprise markets. This productivity gain will continue toward 2036, when 5G will be a key technical facet in many aspects of everyday life.

Chart 2: Breakdown of Direct, Indirect, and Productivity-Related Contributions of 5G and AI

World Markets, Forecast: 2025 and 2035

(Source: ABI Research)



5G AND AI USE CASES

5G and AI hold the potential to become the technological platform for many new applications. 5G and network transformation will democratize distributed processing resources, while AI applications on these platforms will allow new waves of innovation. Below are a few of the use cases ABI Research has identified, based on industry pain points and how the combination of 5G and AI can potentially solve them.

INDUSTRIAL APPLICATIONS

In the manufacturing segment, 5G and AI will be instrumental for implementing Industry 4.0 initiatives, including highly automated factory floors, recyclable infrastructure, mobile robots, remote control machines, and optimized logistics. Connected cameras running AI models will be able to predict defects long before they happen, while factory safety can be improved to the point that no humans will be needed to run a production line. ABI Research expects productivity in the industrial manufacturing sector to increase by 6% in 2035 using the combination of AI and 5G.

There are several use cases being discussed, but mobile robots and reconfigurable production lines are the most disruptive and promising areas. According to the International Federation of Robotics, the global average was 85 robots per 10,000 employees globally, with South Korea and Singapore leading with 710 and 658 robots per 10,000 employees in 2017, respectively. These numbers will increase exponentially according to ABI Research's forecasts, which indicate 340,000 connected robot shipments in 2026. Collaborative robotics, mobile robots, and reconfigurable production lines will push the limits of human control, and 5G and AI will be a necessary component of connected factories. The following use cases illustrate two major trends in the manufacturing segment.

SHORT-TERM USE CASE: COLLABORATIVE ROBOTICS

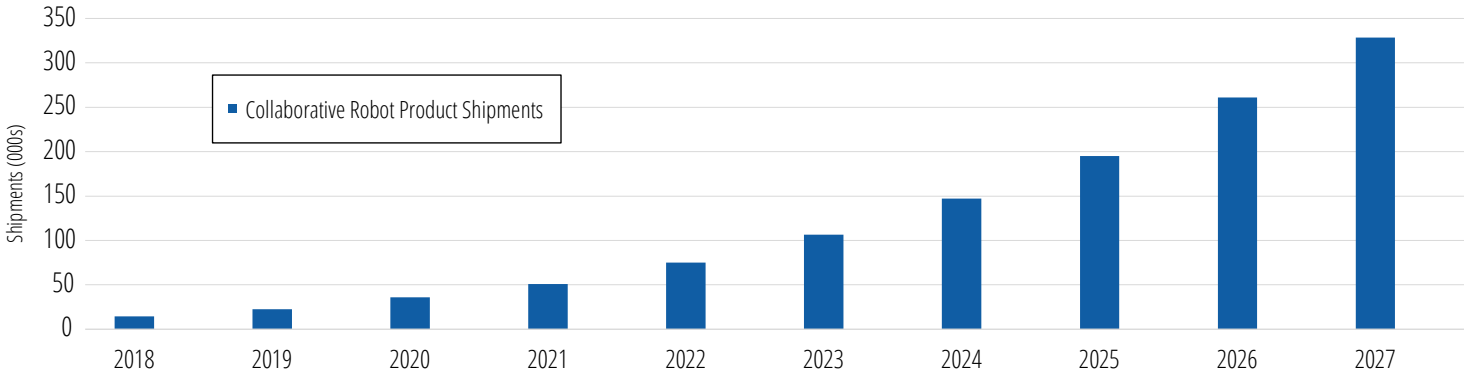
As manufacturing continues to proliferate and labor markets tighten, countries and companies strive to to increase productivity through automation. Manufacturers have already started to provide tools to make humans more productive and have increased the importance of capital-intensive robots in the global competition. Robots used to be strictly separated from human workers during operation, mainly because they could present physical danger to humans. However, merging the best qualities of humans and robots enables an unforeseen amount of productivity growth. The relative strengths of humans and robots, such as complex decision-making and intelligence (humans) and repeatability and precision (robots), complement each other, and when humans and robots work collaboratively, the accrued advantages increase dramatically. In such cases, robots and humans will become codependent on each other.

AI is enabling robots to perform tasks that used to require human eyes, hands, and minds. To comply with uncertainties caused by humans, while solving the work efficiently, robots need to be equipped with a wider variety of sensors. The mixture of affordable and advanced sensors allows the robot to perceive the environment and gain enough data to train an AI platform. Widely available inertial measurement units, force and torque sensors, and Non-Destructing Testing (NDT) approaches will all help with collecting a huge amount of data. Advanced features of 5G, such as URLLC, are fundamental prerequisites for the reliable flow of real-time data. Once this significant set of data has been collected through 5G connectivity, AI applications are able to generate actionable insights for the machines, and in parallel, human workers can enjoy the ultimate safety experience.

Chart 3: Collaborative Robot Product Shipments

World Markets, Forecast: 2018 to 2027

(Source: ABI Research)



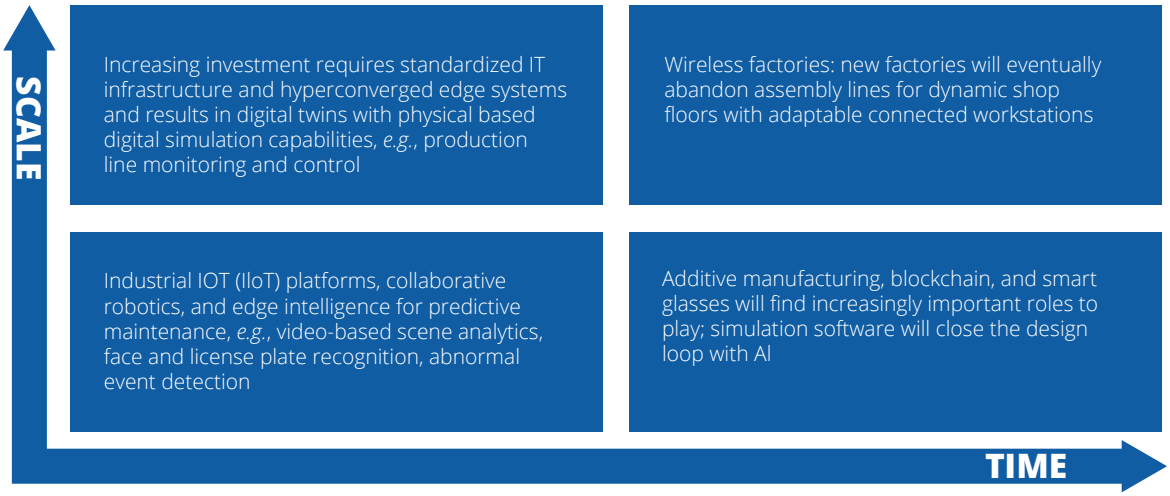
LONG-TERM USE CASE: INDUSTRIAL HUMAN-MACHINE COLLABORATION

Robots can learn in multiple ways. Given a task, a robot can explore the action space by itself, however, this can take a significant amount of time if the task is too difficult to perform. To accelerate the learning process, an industry expert can teach the robot to do a task using imitation learning. During imitation learning, the robot observes the expert using its sensors, such as machine vision systems, joint angle sensors, and force and torque sensors, and it tries to learn the mapping between observations and actions. Humans used to have to teach machines step-by-step what to do, but now machine learning enables the robot itself to figure out what to do exactly and how to solve a unique problem. Soon, robots can take over repetitive or physically demanding tasks, and the combination of AI and 5G opens up new industrial opportunities in the future. For example, edge compute servers and 5G connectivity, coupled with machine vision on the factory floor, can aid robots with transferring learning between use cases and applying inference across different industrial use cases.

Based on the concept of a wireless factory, it is possible to significantly increase the flexibility of the production lines and shorten production lead times. This concept is based on wireless URLLC between robots and wireless energy supply via electric induction. Wireless factories can reconfigure their production lines in a much quicker and simpler way, adapting to changing needs. Moving equipment around and reconfiguring it is more efficient, when it does not need a wired connection; currently, reconfiguring a production line to manufacture a different product normally requires hours or days of downtime, as well as manual efforts. The disruption caused by the combination of 5G and AI will reinvent the role of the factory worker.

Figure 1: Transformative Technologies in the Manufacturing Sector

(Source: ABI Research)



MEDIA AND ENTERTAINMENT

The media and entertainment industry is undergoing a rapid transformation, with immersive media, tactile Internet, AR/VR, 360°, and 6 Degrees of Freedom (6DoF) video changing how end users will be entertained in the near future. All these applications have high computational and storage requirements, while codecs, including H.264, High Efficiency Video Coding (HEVC) and Audio Video Interleave (AVI), are minimizing the impact on networks. Open Visual Cloud, which provides open source encoding, decoding, inference, and rendering building blocks to easily build and deploy media use cases. This highlights the importance of the

media sector and how Information and Communications Technology (ICT) vendors are creating products and services to target the media industry specifically.

Content producers are currently assessing interactive content and video, with Netflix being the first to launch a series where the user is presented with choices, directly affecting the flow of the show. This will inherently create the need for higher bandwidth in the network and can be one of the "killer applications" that uses 5G for its higher capacity. But the clear opportunity is when 5G and AI are combined for direct behavioral consumer feedback, which can help content producers tailor shows to produce more captivating content.

SHORT-TERM USE CASE: CONTENT LOCALIZATION AND PERSONALIZATION

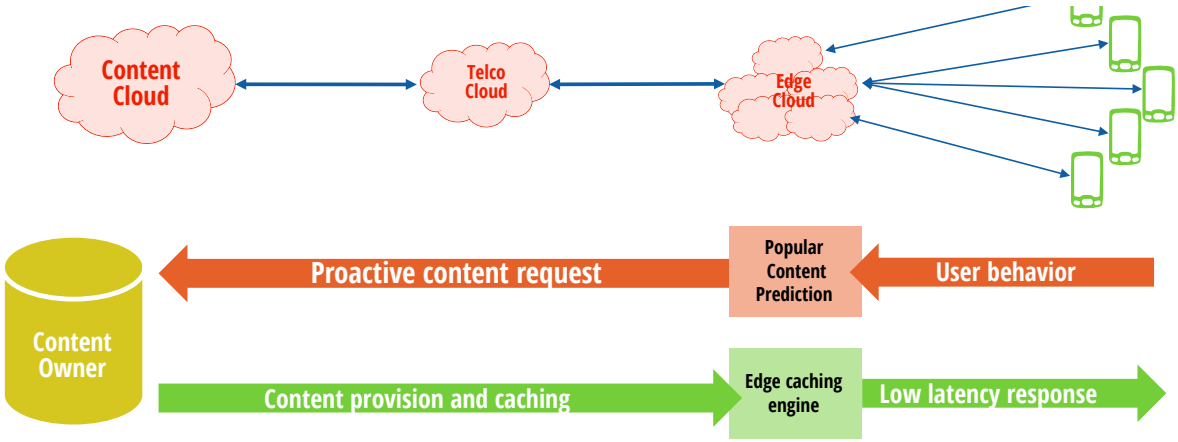
To personalize content, an edge compute server running an AI application can gather data from end-user devices, such as popular content and user behavior patterns. These data can then be used in two ways:

- In an isolated environment, running on the very same edge compute server to proactively identify future popular content and then request it from the content server.
- In a federated system, where data from devices across the network are collected by edge compute servers, which are then aggregated in a central location to train a content prediction model.

Figure 2 illustrates the first scenario presented above, which can act as the entry point for this use case, on which the second scenario can be built.

Figure 2: Combining 5G and AI for Content Localization and Personalization

(Source: ABI Research)



The combination of edge caching with 5G and AI for media localization introduces many advantages. Telco operators will be able to predict traffic spikes across their networks, especially when video accounts for more than 70% of mobile traffic in 2018. Another application relates to encrypted traffic, with all web companies (including Netflix and YouTube) using encryption to prevent content tampering. Content localization and personalization can be enabled through two main approaches:

- The device will need to provide content details to the edge compute server. This means that either the device or the app data will need to be shared with the edge compute server.
- The content owner or the public cloud company will sign agreements with telco operators to provide these data from its device apps to the edge computing servers. By doing so, content owners can obtain deeper data to improve the user experience, while telco operators will gain access to content metadata, so they can implement the use case described above.

- As of 2020, several mobile network operators are partnering with content providers and Webscale companies, allowing the latter to deploy their software in network edge servers, thus bringing their content and applications much closer to end users.

An edge compute deployment coupled with 5G connectivity may open possibilities for much richer content—and potential revenue for content owners. These new opportunities may be something content owners find lucrative, especially when traditional video revenue is stagnating.

LONG-TERM USE CASE: VIDEO STREAM DELIVERY WITH REAL-TIME INPUT

This year and the next one will be the embryonic years of 5G, and the fixed wireless use case in the United States has been the first one to receive commercial interest. Many infrastructure vendors are now offering 5G Customer Premises Equipment (CPE), which are expensive devices compared to traditional broadband modems. These devices can easily become the edge of the network that will connect to the telco—or public—cloud with a dedicated network slice. These devices can then become hubs for VR applications that use AI to offer real-time feedback to end users. The VR application may reside in the telco or public cloud, while the edge computing server in the 5G CPE can process video streams and user input in near-real time to minimize transport traffic and exchange metadata with the VR application.

In the short term, AI can be leveraged for Quality of Experience (QoE) metrics and real-time adjustment of content to suit the current application and connection quality, with variables such as resolution and amount of buffer (if applicable); longer term, these data are actionable for pre-emptive load balancing of servers based on content/location/time/etc. to ensure QoE, with more direct content adjustment and enrichment possible. This could include dynamic point of interest and gaze direction based on viewing patterns, tailoring events to specific users based on genre/character/theme preferences, and input creation and improvement through AI-powered haptic mapping.

The edge computing server, in this case, may not necessarily be part of the 5G CPE, but it can be placed in the edge cloud. New types of mobile devices may become the VR displays that exchange low-latency data with the edge computing server.

RETAIL

In retail today, customers are increasingly demanding tailored products and experiences. Consumer tastes are changing daily as reliable connectivity technologies are entrenched in consumers' consumption and buying habits, particularly for tech-savvy millennials and Generation Z. Moreover, ethically-minded shoppers are further shaping retail through their buying decisions. This shift in consumer behavior is pushing retailers to institute overarching feedback loops that span in-store intelligence (e.g., customer analytics, merchandise planning, and localized trends), distribution channels, and manufacturing processes capable of responding to real-time consumer demand.

Major retailers are exploring AI in a bid to effectively blend consumer experiences that result from physical and digital retail channels. With the former, the absence of a "digital footprint" left by customers is a challenge that AI is helping to solve, thereby addressing one of the major advantages that brick and mortar retail faces relative to e-commerce. According to ABI Research estimates, the diffusion of AI in the brick and mortar retail market will create US$23 billion in revenue by 2026.

The most trivial retail product is destined to be personalized, and in the near future, the entire (retail) cloud will be filtered, elevating the degree of personalization delivered to consumers via a proximate connection, such as 5G. The sheer amount of retail digital bits allows new potential products to morph easily, thereby paving the way for a host of retail use cases to be transformed, as described in Table 1:

Table 1: Key Retail Use Cases
(Source: ABI Research)

Use Case	Description
Customer Service Robot	Robotic assistants consist of voice and touch-enabled mechanized robots equipped with digital screens. With conversational commerce already a growing trend thanks to Amazon Alexa and Google Home, robots can offer a similar experience in the physical store. Reliable cellular connections, such as 5G, with some add-on intelligence can improve the functionality and reliability of robotic assistants.
Robotic Shopping Cart	Likely to remain a niche technology over the next 5 to 10 years, robotic shopping carts do solve a major problem for physically impaired customers for whom this use case adds enormous value.
Line Management	Using capabilities like predictive analytics, traffic counting, and machine learning, retail stores can proactively prevent long lines at the checkout, a major cause of reduced traffic and lost sales in physical stores. AI algorithms can predict wait times by combining various data points, including historical traffic patterns, weather conditions, holidays, and special events.
Targeted Advertising at the Shelf	AI and increased penetration of 5G networks can be deployed to engage customers in more targeted ways, increasing the effectiveness of promotions. Targeted advertising at the shelf is less intrusive relative to an in-person approach and it occurs at the moment when the customer is making a purchase decision. Although a narrow use case, targeted advertising at the shelf could prove to be a highly effective form of advertising.
POS/Autonomous Store	Using facial recognition technology to pay is a use case that has been emerging recently. In addition cameras equipped with AI software can be trained to recognize unpackaged products that do not carry barcodes or Radio Frequency Identification (RFID) tags (*e.g.*, fresh groceries). Image recognition at the POS decreases checkout times, improves the customer experience, and reduces the size of lines, a major cause of customer churn.

SMART CITIES

Smart cities are a growing market attributable to a rapid urbanization, along with an aging infrastructure that is ready to be upgraded. Traffic congestion, high levels of pollution, security needs, and limited public resources all create the need for the efficient use of technologies and services. Legacy smart city approaches have mainly focused on monitoring using limited sensors to achieve modest, incremental cost savings and improved public services to citizens. Typical examples include smart waste management, smart street lights, and parking sensors. To take smart cities to the next level, both in terms of service quality and the cost at which they can be provided, will require AI and reliable and low latency local communications.

Data about inhabitants of a smart city constitute a golden commercial opportunity, so one thing is certain: a vastly larger volume of previously unmeasurable data will be quantified, digitized, and trackable. Enterprises that will add value are those that provide a smart city ecosystem propelled by three dimensions: value chain data streams for tracking purposes, application segments that can use those data streams, and business paradigms that commercialize the impending ubiquitous tracking.

Table 2: Smart City Platform Data Streams, Application Segments, and Paradigms

(Source: ABI Research)

Value Chain Data Streams	Application Segments	Smart City Paradigms
Car movements Ride-share taxis Utilities Cell phone locations and cell logs Civic cameras Interactive devices Grocery loyalty cards E-retailers Photo face recognition E-wallets and e-banks Fitness trackers	Mobility Transportation Energy & Utilities Smart Buildings Safety Security Education Healthcare Retail	Smart Funding Shared/Distributed Economy Public-Private Partnerships Data Crowdsourcing City as a service Cross-vertical applications Demand-response

Future AI systems need to be secure and unhackable before they take charge of smart city (critical) infrastructure, so the growing role of AI in society keeps raising the stakes for computer security. With AI gradually entering the real world, there are three main areas that will dominate the AI security discussion among solution providers: verification, validation, and control. The first and second ask "Did we build the system right?" and "Did we build the right system?", respectively. Good control, or the ability for a human to monitor the AI system and change its behavior if necessary, is equally important. For a human in the loop system to work well, it is crucial that the human-machine communication is robust, an area that 5G reliability is expected to enhance considerably.

TRANSPORT

In automotive, AI has already made a deep impact on the transportation space, both in terms of vehicle automation and transportation management. Deep learning has transformed image recognition and decision-making systems, which are now being deployed in the early autonomous vehicle system. A combination of 5G and AI will unlock some complex use cases that will take transportation automation to the next level. In transportation, all environments are unique and can change dynamically; consequently, transportation systems will need to respond in real time to locations as they change—it is at this intersection where the interaction of AI and 5G can create value. In the short term, the key use cases that will use 5G and AI are intelligent and connected vehicles, and in the long term, autonomous driving, and self-coordinated Unmanned Aerial Vehicles (UAVs).

By 2035, autonomous vehicles will be widely deployed and car sharing will be the norm in many metropolitan areas, as well as AR-based navigation, autonomous driving, cooperative mobility, truck platooning, automated traffic management, and mobility management services. All of these elements will help the automotive and transportation sectors enhance productivity by almost 14%.

SHORT-TERM USE CASE: INTELLIGENT AND CONNECTED VEHICLES

The connected vehicle will be able to send data to the local road infrastructure. This will allow the outcomes of the software policies that govern the roads to be more accurately measured, and even adapted in real time. Due to improvements in edge computing, a device at the edge of the network will be able to tweak their policies in response to the outcomes, updating the model on the device level. This will be especially important as

each locality will have its niches and be changing relative to levels of traffic and types of vehicles that are on the roads. ABI Research has forecast that current transportation management systems are predicted to reduce transportation costs by up to 10% and reduce monitoring time by up to 50% by 2023; systems that use 5G and AI will yield further improved performance. Changes in the decision-making policy in one of the areas of a transportation system could require real-time responses in another part of that system to remain safe.

LONG-TERM USE CASE: AUTONOMOUS DRIVING

High-Definition (HD) maps are essential for autonomous driving. An HD map is an extremely precise Three-Dimensional (3D) software representation of an area. These maps are generated using data from a combination of Light Detection and Ranging (LiDAR), radar, cameras, Global Positioning System (GPS), and infrared sensors, and can be accurate to the centimeter level. These maps can provide a key reference point for an autonomous vehicle system to navigate through its environment and allow a decision-making system to focus on responding to the unfolding events and route planning.

Full HD maps are also advantageous because they will reduce the amount of work that the autonomous driving software has to do to recognize the world around it. By comparing the actual world to what is predicted in the map, they can focus the vehicle system's attention on things that are different or dynamically changing, like identifying pedestrians or bicycles. HD mapping systems will become prevalent in the Society of Automotive Engineers (SAE) level 4 and 5 autonomous driving systems. ABI Research forecasts that the total global installed base of such systems will be 3.5 million by 2025. The value proposition of autonomous driving vehicles is that they will be able to simultaneously reduce the cost of driving by getting rid of the need to pay a driver, while increasing utilization of the vehicle. ABI Research has forecast in a report covering smart mobility maintenance modular hardware Over-the-Air (OTA) updates and prognostics that the cost of current ride hailing services at 70% utilization in a 24-hour cycle is US$1.49 per mile; in comparison, autonomous robotaxi services cost $0.70 per mile at the same utilization rate, which is a decline in price of 46%.

As each autonomous vehicle will output an average of a petabyte of data every day, sending all the data to the cloud for processing and updating the global HD map will come at an enormous cost. This is where a combination 5G and AI in a federated approach will be relevant for HD mapping.

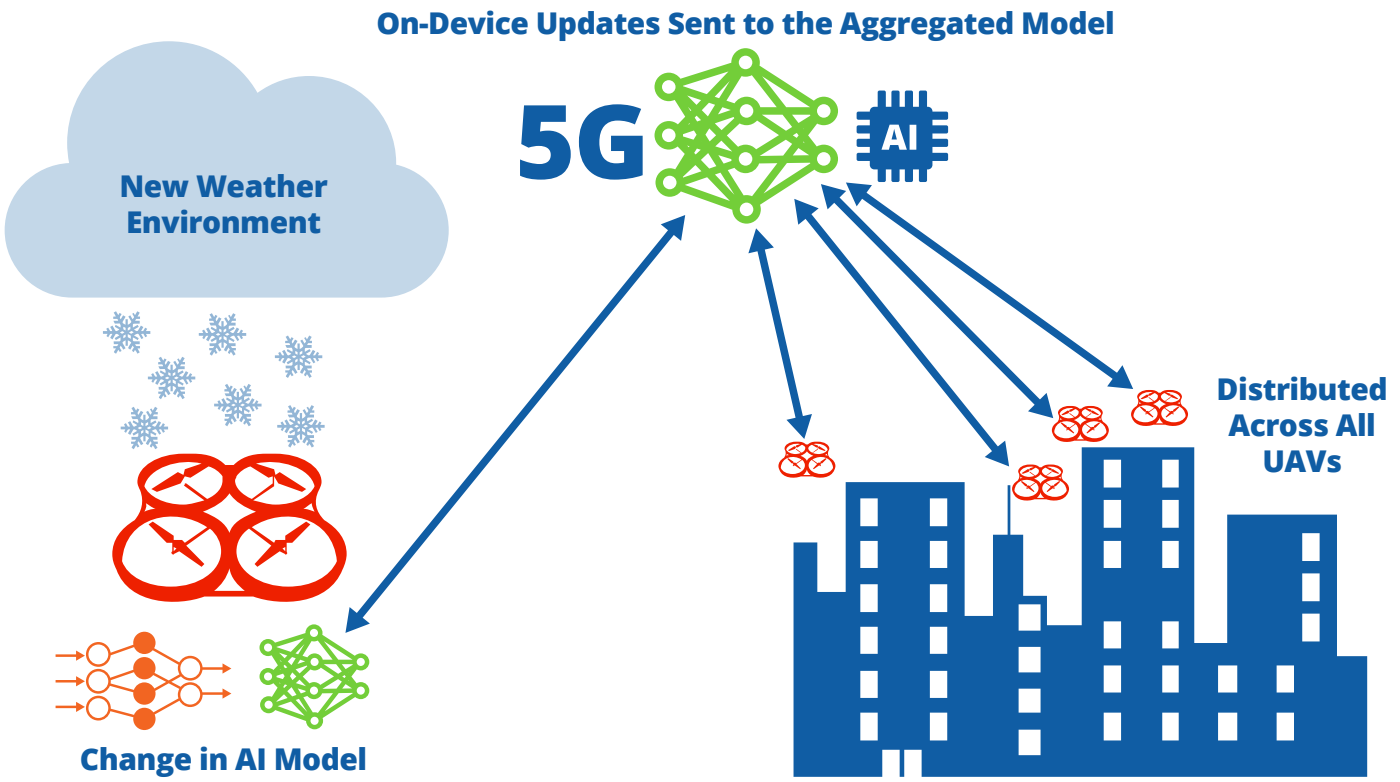
Instead of simply sending all data generated by a vehicle's sensor to the cloud, it would be more effective to update the HD map on-device and only when multiple sensors or vehicles have verified a significant change in the environment, and then that updated HD map would be redistributed to other vehicles operating in the area. For instance, if a collision on the road were to occur and the vehicles in the immediate vicinity were to detect and validate this, that would be a reason to update the HD map. The state of the federated HD map in the cloud would then change and be redistributed in an update to the global HD map and passed to all vehicles near the collision or those planning to use the road where the collision had occurred. These vehicles could then change the routes they were planning to take.

Latency will be critical in this system; if the map cannot be redistributed in real time, it could lead to a vehicle routing itself into a dangerous situation, particularly if any failure has occurred with the vehicle's sensors or Vehicle-to-Everything (V2X) communication system. A combination of 5G and AI with specialized hardware at the edge in the cloud will enable the required real-time low latency.

LONG-TERM USE CASE: SELF-COORDINATED UAVS

Self-coordinated UAV swarms use a mixture of communication between the UAVs and an AI model pre-trained in a simulated environment, so that each UAV can move independently in coordination without colliding. Using 5G and AI will make a fully self-coordinated fleet of UAVs possible. The 5G element of such a system would enable the UAVs to communicate with local mobile networks in real time, which will allow the aggregated model governing UAV coordination to be updated and redistributed in real time. If extreme weather conditions occur that a UAV coordination AI model had not previously encountered, it may create a need to dynamically update that model to find a new solution for navigating that environment safely. This could be achieved by changing the speed, driving style, or permitted distance between UAVs. Self-coordination will be essential to the safety of UAV fleets, especially given that they will be used to transport people and goods.

Figure 3: Self-Coordinated UAV System
(Source: ABI Research)



HEALTH

Currently, AI applications in healthcare are deployed in the diagnosis and treatment phase and in the Research and Development (R&D), or drug synthesis, phase. Current statistics show that, in major countries, there are 5 hospital beds or fewer available for every 1,000 people, while in emerging markets, the number of general practitioners does not exceed 1 for every 1,000 people. 5G and AI will enable better personnel and asset tracking, predictive optimization of resource deployment, remote care, workforce training and surgical

simulations, machine-assisted surgery, and collaborative R&D and diagnostics. Studies have also shown that 58% of hospital assets are idle on average and that US$4,000 worth of equipment is lost or stolen per hospital bed per year on average.

AI will help introduce better training for physicians, increasing their hands-on experience before they even meet patients, especially in the operating room. ABI Research expects the combination of AI and 5G will help the health sector increase productivity by 4.5% by 2035, which translates to US$223.4 billion. The low-latency and high-throughput characteristics of 5G will help enhance data acquisition, model updates, and device prediction accuracy and reliability. Use cases that have high technical complexity are discussed here, namely patient data contextualization and wearable data collection in the short term, and collaborative edge device training and remote early prognosis in the long term.

SHORT-TERM USE CASE: PATIENT DATA CONTEXTUALIZATION

Currently, if a patient needs a prognosis, the patient visits a doctor to be diagnosed. This is critical, as doctors need to perform various tests and observations on the patients to provide professional advice and to administer the right medications. However, there are instances when a patient is either too far away from the medical facilities or too critical to be carried or moved to medical institutions. Doctors, on the other hand, also want to maximize their time by handling the more critical cases. ABI Research currently sees quite low adoption for patient monitoring devices with AI models, but with already proven use cases, ABI Research expects fast adoption and growth over the next few years. Hospitals in Israel and the United States have already started to adopt AI-based predictive analytics. These AI models already reduce patient deterioration costs by 38%, length of hospital stays by 9%, patient falls by 43%, pressure ulcers by 64%, and code blue events by 86%, and the models will only improve. As a result, the number of patient monitoring devices using the data to train AI models for predictive analytics will increase from 53,000 at the end of 2017 to 3.1 million in 2021 with a Compound Annual Growth Rate (CAGR) of 176%. The consistent, low-latency connection that 5G will introduce will further augment this use case and ensure that patients have access to near-real-time monitoring and diagnosis.

SHORT-TERM USE CASE: WEARABLE DATA COLLECTION AND REMOTE EARLY PROGNOSIS

After the doctor leaves the room, clinicians only check on patients an average of every 4 to 5 hours. Physicians use many medical devices to keep track of at-risk patients. Edge devices, such as Electrocardiogram (ECG) monitors, glucose monitoring devices, smart bandages, and wristbands, are already collecting various patient data, including vital signs and cardiac and respiratory data. Inside each device, various Machine Learning (ML) algorithms are used to recognize when a heart condition, sleep apnea, or asthma might worsen, sending alerts to clinicians. These advantages have driven the demands for AI-enabled wearable devices, with global shipments expected to increase from 2.3 million units in 2017 to more than 40.8 million in 2023, with a CAGR of over 50%.

Due to data protection regulations, wearable manufacturers are restricted from accessing personal health data. By using federated learning, manufacturers can update the AI model at the edge, before updating the shared AI model in the cloud using anonymized and averaged data from its large user base. 5G provides reliable communication channels between the patients and the doctors for cases that have been determined to be very critical and require proper medical attention. Doctors will have real-time access to make observations,

capture HD videos and photos, and provide medical advice, all without needing the patient to be present at the medical facilities. The images and videos captured can be kept and used as future training and testing datasets for the AI model.

LONG-TERM USE CASE: COLLABORATIVE TRAINING ACROSS DEVICES USING EDGE SERVICES

Collaborative training techniques can be deployed to edge devices to learn and master the behaviors and conditions of a patient. Highly personalized monitoring and reporting parameters can be created based on the synchronization of data and AI models across different wearables and medical equipment. These parameters can be adjustable depending on the patient's status and response to the treatment. Any outlier or alert will then be sent to doctors or specific medical institutions to take appropriate response.

In addition, collaborative training will be a great way to share critical information that is only available in certain formats, such as images, videos, and verbal instructions. For instance, any abnormality of vital signs or biochemical or hematological readings of a patient captured by biometrics sensors and trackers can be checked against real-time images or videos of a patient's physical appearance before sending an alert to doctors or clinicians. Once the diagnosis has been confirmed, the characteristic and features specific to the diagnosis can be shared across different medical devices. As more devices connect to AI-based predictive analytics models, ABI Research believes that hospitals will save US$52 billion in 2021, led by North America with US$21 billion in savings by 2021.

MOBILE SERVICE PROVIDERS

MSPs are in the very early stage of forging their strategy for 5G and AI. They are now focusing on positioning 5G as a network capable of extending the performance of existing LTE networks. In parallel, MSPs are busy trialing 5G for various use cases across several verticals, with the goal being to test and validate proofs of concept.

Leading MSPs are beginning to experiment and deploy AI driven use-cases: 5G network automation, virtual digital assistant, personalized service, and media analytics. Market drivers are revenue growth, cost saving, and best customer experiences. For instance, they are using the technology for automating certain network functions. However, visionary MSPs are now considering an AI-as-a-Service approach whereby they could use the technology in line with 5G to differentiate their value proposition to end customers, such as augmenting and accelerating the deployment of new services-based innovative technologies, such as the IoT, VR/Extended Reality (XR), robotics, autonomous machines, or location-based services. MSPs are conscious of the tremendous pressure coming from Over-the-Top (OTT) providers, webscale companies, and AI service providers. They see the combination of AI and 5G as a lifetime opportunity that could enable them to reposition their offering. Now that they are advanced in developing the building blocks of 5G and AI technologies, the next step for MSPs is to bring all the pieces together to address the bigger picture, one based on a consolidated AI and 5G strategy to offer meaningful services capable of dealing with end-market requirements. When asked about their long-term strategy for 5G and AI, the main objective of most MSPs is to move away from providing connectivity services only to building an adaptive and flexible network capable of accommodating multiple services with various service quality requirements. They all agree the network of the future should be highly densified and intelligent enough to bring cloud and AI services close to the end user and offer innovative, customizable, efficient, reliable, and secure service experiences to customers.

MSPs are convinced the combination of 5G and AI will simplify the technology complexity for many businesses and will help several industries enhance productivity and operation efficiency, while improving workforce safety and reducing waste.

CONCLUSIONS AND TAKEAWAYS

Cellular network generations have largely followed market demands: from voice, to mobile data, and, ultimately, true mobile broadband with gigabit LTE. 5G will introduce structural disruptions in technology, business, and operational models, and it will not simply be a faster network, but will serve as the catalyst for many other technologies capable of sustaining new use case applications and business models.

5G will enable more distributed intelligence across different nodes of the infrastructure, from the cloud to edge computing servers, end devices, and sensors. Telco network transformation is critical for this future to happen, but when it does, it will transform the generally centralized way AI is provided to more personalized, collaborative, and federated learning, powered by edge computing. This transformation will encourage many businesses to adopt AI without the fear of compromising data privacy or security. The combination of AI and 5G will also help many industries improve overall productivity and enhance the value of products and services offered.

5G and AI will provide distributed intelligence and operational efficiency for new use cases. These will be critical in creating new business opportunities and in improving global economic growth. These two technologies are the most innovative technologies in the market today and will enable substantial economic growth across various industries. Their combination will allow networks and infrastructure to be more efficient, and this efficiency will have a significant impact on business productivity, while optimizing overall network resources. This combination will also augment consumers' lifestyles by enabling automated interaction with things around them in the same way humans interact with other humans. 5G will initially accelerate development of AI applications and it will then be pivotal to distribute intelligence throughout the network. Finally, 5G and AI will create completely new service paradigms.

However, this technology transformation will not happen overnight. It will be a gradual process, as it is when rolling out any new technology. There will be early adopters that will test out new technology and business and operational models, and they will later pave the way for the rest of the market. It should be noted that this transformation will be initially anchored to existing infrastructure, so it will take time for industry organizations to completely transform their businesses. ABI Research believes it will take these technologies up to 10 years to reach their full potential, but some industries are likely to be faster movers than others. Industrial organizations should start planning for this transition now if they want to tap into the potential of these technologies and position themselves as leaders in the new digital revolution the world is about to witness.

APPENDIX

INSIGHT FROM INDUSTRY DISCUSSIONS

ABI Research has engaged with several companies across the entire value chain to understand their vision, approach, and strategic alignment of 5G and AI technologies in order to address the key pain points that different enterprises and verticals need to solve to increase business productivity and improve operation efficiencies. ABI Research has classified the feedback received in three main pockets, namely technology implementers, mobile operators, and technology suppliers. Feedback from mobile operators has been presented in the previous section, while feedback from technology implementers and technology suppliers is presented below.

TECHNOLOGY IMPLEMENTERS

In this study, ABI Research refers to technology implementers as enterprise vertical end users, as described in the use cases above. They are very enthusiastic about the value that both of 5G and AI can bring. This value can be captured through addressing many pain points the enterprise is facing from a business operation perspective. They are also conscious of the limitless business opportunities that these two technologies combined can unlock for them. Many of these companies have endorsed the viability of the use cases mentioned above. However, these players have only a little visibility on how these technologies will develop, mature, and align to solve the key pain points discussed in earlier sections. Most companies interviewed insist they will not engage with large-scale deployments, unless most of the points listed below are addressed by the technology suppliers:

- **Simplifying Technology Complexity**: Technology implementers are looking for their service providers to simplify the technology complexity; for instance, by providing granular and agile solutions tailored to their needs regardless of the use case supported. They want their service providers to abstract the technology complexity and alleviate the cost burdens associated with it. They want 5G and AI technology innovation to be productized into a single and user-friendly platform, so they can focus on what they are best at: creating new business opportunities otherwise not possible without the convergence between 5G and AI.
- **Scalability**: The enterprise market submits to relatively long technology life cycles, so any technology deployment should be backed by a long-term strategic vision. Technology implementers want to use integrated solutions using a single telco's equipment with feature-rich network functions (e.g., Software-Defined Networking (SDN)/Network Function Virtualization (NFV) and service orchestration) to be able to accommodate all of the use cases with which they deal. They want to use equipment that is future proof to enable them to switch to completely new types of use cases or service functions in a matter of days, not months. Deploying such solutions will help them reduce the overall infrastructure cost and ease interoperability with the back-end Information Technology (IT) and Operations Technology (OT) infrastructure.
- **Ease of Integration with Existing IT and OT Infrastructure**: This is an extremely important element, as it could lower the barrier of entry and minimize the implementation and interoperability burdens. Customers prefer solutions that could be easily integrated with their current infrastructure. They want to avoid deploying new technologies that come with completely new IT and security paradigms, which means they will have to replace their entire legacy infrastructure from scratch.
- **Implementation of AI at the Edge**: Technology implementers are still concerned about data security and data privacy that could be compromised. This is particularly the case for certain verticals, such as industrial manufacturing, health, and the retail sectors. These players are also concerned that their reliance on the cloud AI services could increase the total cost of owner-

ship and compromise the service quality for mission-critical use cases. Therefore, they opt for AI implementation at the edge of the network to improve the end-to-end service latency, bringing computing capabilities close to end-nodes and minimizing the risks related to data privacy and cybersecurity attacks.

TECHNOLOGY SUPPLIERS

Technology suppliers in the telco domain are very specialized and highly focused on specific technologies. Only a few can offer end-to-end solutions based on combining connectivity capabilities with computing capabilities. Major technology suppliers that offer both AI products and telco infrastructure see AI and 5G as major catalysts for many other technologies, as this combination could unlock many new business opportunities otherwise not possible with existing technologies.

Technology suppliers see MSPs as key players in leading this transformation, given their massive spending on both CAPEX and OPEX compared with their IT service providers or cloud service providers. Technology suppliers consider MSPs as having the advantage of owning last-mile connectivity, which positions them as natural edge cloud service providers capable of bringing computing capabilities, notably AI, close to their customers. However, technology suppliers recognize that MSPs are acting slowly when it comes to adopting innovation and modernizing their networks. MSPs prefer to keep balanced investments between their legacy markets and greenfield markets that constitute most of the growth opportunity looking forward.

Major areas where MSPs are lagging behind include NFV, service orchestration, and AI implementations. They need to learn from advances that IT and cloud service providers have achieved in these areas. They will also have to choose the right technology partners to accelerate the development of 5G networks and distributed intelligence to deal with a multitude of use cases across various verticals. Technology suppliers with an end-to-end approach combining 5G, AI, and computing capabilities will play a unique role in building a holistic solution that could simplify the technology complexity and lower barriers of ecosystem entry.

Successful technology suppliers will have to comply with industry standards, embrace open source for interoperability between equipment, and create developer tools to unlock the infrastructure capabilities and unleash the potential of innovation coming from every corner of the ecosystem. Technology suppliers have no clear visibility what specific use cases will be serviced first by the combination of AI and 5G, but they believe the retail and smart city applications could be the first to benefit from this combination, followed by the automotive and transportation sectors, while health and industrial manufacturing will not be among the first wave of implementers adopting the technology.

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249 South Street

Oyster Bay, New York 11771 USA

Tel: +1 516-624-2500

www.abiresearch.com

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