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# Integration of 5G with Analytics and Artificial Intelligence

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**ABSTRACT:** We envision a world where virtually all devices are much more intelligent, simplifying and enriching our daily lives. Today, artificial intelligence (AI) is delivering enhanced experiences and new capabilities to our society in more ways than ever. AI not only provides the ability for our devices to perceive, reason, and act intuitively, but also changes how we approach and solve technical challenges. For more than a decade, we have been conducting foundational AI research to make AI ubiquitous — we have taken a system-level approach that optimizes power efficiency across hardware, software, and algorithms. This is exemplified by our leadership in delivering powerful performance at ultra-low power consumption across a wide variety of devices through our Qualcomm AI Engine, now on its 6th generation. At the same time, our foundational research in 5G is making it possible to build a cellular system that can efficiently connect virtually everything around us. Today, the global transition to 5G is now in full swing: there are over 175 mobile operators that have launched commercial 5G services globally and many more are actively investing in new 5G deployments. We are driving the continued technology evolution into the next phase — 5G Advanced, which starts with 3GPP Release 18, and it is a set of future standards that are expected to elevate 5G capabilities to new levels as well as expand 5G into new devices, deployments, and industries.

**KEYWORDS:** 5G, analytics, artificial intelligence, ubiquitous, 6<sup>th</sup> generation, evolution, society

## I. INTRODUCTION

All US cellular carriers have now launched some form of 5G. What is 5G? 5G simply stands for fifth-generation cellular wireless. Its standards were first set in late 2017. There are three basic types of 5G service: low-band, mid-band, and high-band. They're all incompatible right now, and they all perform differently. Even though all the US carriers "have" 5G right now, it will be another couple of years before we see significant changes from it. By comparison, 4G first rolled out in 2010, and it was 2012/2013 before major apps that required 4G to work became popular. However, Ericsson, a leading provider of Information and Communication Technology (ICT) for service providers, estimates that by 2024, 40% of the world will be connected by 5G.<sup>1</sup>

The "G" in 5G simply stands for "generation." 1G was analog cellular service. 2G technologies were the first generation of digital cellular technologies. 3G technologies improved speeds from 200kbps to several megabits per second.<sup>2</sup> 4G technologies are currently offering hundreds of Mbps and even up to gigabit-level speeds. 5G offers several new aspects: bigger channels to offer faster speeds, lower latency for higher responsiveness, and the ability to connect more devices at once. There are many complexities inherent in adopting 5G networks, and one way the industry is addressing those complexities is by integrating artificial intelligence into networks. When Ericsson surveyed decision-makers from 132 worldwide cellular companies, over 50% said they expected to integrate AI into their 5G networks<sup>3</sup> by the end of 2020. The primary focus of AI integration is reducing capital expenditures, optimizing network performance, and building new revenue streams. 55% of decision-makers stated that AI is already being used to improve customer service and enhance customer experience by improving network quality and offering personalized services. 70% believe that using AI in network planning is the best method for recouping the investments made on switching networks to 5G. 64% of survey respondents will focus their AI efforts on network performance management. Other areas where cellular decision-makers intend to focus AI investments include managing SLAs, product life cycles, networks, and revenue.<sup>4</sup>

There are challenges associated with integrating AI into 5G networks, of course. Effective mechanisms for collecting, structuring, and analyzing the enormous volumes of data amassed by AI must be developed. For that reason, early AI adopters who find solutions to these challenges will emerge as the clear frontrunners as 5G networks become

connected. While our smartphones have gotten increasingly smaller,<sup>5</sup> the core algorithms that run them have not evolved since the 1990s. Therefore, 5G systems consume far more power than desired and achieve lower data rates than expected. Replacing traditional wireless algorithms with deep learning AI will dramatically reduce power consumption and improve performance. This approach will be fundamentally more significant than focusing AI primarily on network management and scheduling.<sup>6</sup>

Further, bandwidth used by current cellular networks operates on the radio spectrum. The electromagnetic waves in the frequency range of the radio spectrum are called radio waves. Radio waves are widely used in telecommunication, along with numerous other modern technologies. National laws strictly regulate interference between users of different radio waves, and the International Telecommunication Union (ITU) oversees the coordination of these laws.<sup>7</sup> There is concern that the growing use of wireless technologies will overcrowd the airwaves our devices use to communicate with one another. One proposed method for resolving this issue is to develop communication devices that don't broadcast on the same frequency every time. AI algorithms would then be used to find available frequencies by enabling intelligent awareness of RF activity that was not previously feasible.<sup>8</sup>

Edge computing is the concept of processing and analyzing data in servers closer to the applications they serve. While it is growing in popularity and opening new markets for telecom providers, among other industries, many have argued that introducing "connected" products, such as coffee cups and pill dispensers, did not cause the market to spike as expected. Recent AI technology advancements, however, have begun to revolutionize industries and the amount of value all this connectivity can provide to consumers by combining big data, IoT, and AI.<sup>9</sup>

5G accelerates this revolution because the 5G network architecture easily supports AI processing. The 5G network architecture will change the future of artificial intelligence. 5G will enhance the speed and integration of other technologies, while AI will allow machines and systems to function with intelligence levels similar to that of humans. In a nutshell, 5G speeds up the services on the cloud while AI analyzes and learns from the same data faster.<sup>10</sup>

The management of unstructured data (e.g. Big Data), the leveraging of analytics tools to derive value, and the integration between Cloud, Internet of Things (IoT), and enterprise operational technology are key focus areas for large companies across virtually every industry vertical. Data Analytics provides the means to process vast amounts of machine-generated and often unstructured data. Accordingly, Big Data technologies and predictive analytics enable stream lining of industrial processes.<sup>11</sup> AI technology provides the means to further automate decision making and to engage machine learning for ongoing efficiency and effectiveness improvements. The convergence of Cloud, Data Management, IoT Platforms and Solutions is enabling the next evolution of data analytics in which enterprise will realize significant tangible and intangible benefits from IoT data. The ability to sort data in a raw format, store it in different structural formats, and subsequently release it for further analytics, will be of paramount importance for all industry verticals.<sup>12</sup> IoT Data as a Service (IoTDaaS) offers convenient and cost-effective solutions to enterprises of various sizes and domain. IoTDaaS constitutes retrieving, storing, and analyzing information and provides customers either of the three or integrated service packages depending on the budget and the requirement. Every large corporation collects and maintains a huge amount of human-oriented data associated with its customers including their preferences, purchases, habits, and other personal information. As the Internet of Things (IoT) progresses,<sup>13</sup> there will an increasingly large amount of unstructured machine data. The growing amount of human-oriented and machine generated data will drive substantial opportunities for AI support of unstructured data analytics solutions. Industrial IoT (IIoT) and Enterprise IoT deployments will generate a substantial amount of data, most of which will be of the unstructured variety, requiring next generation data analytics tools and techniques. Streaming data IoT business data is highly valuable when it can be put into context and processes in real-time as it will facilitate completely new product and service offerings.<sup>14</sup>

The Internet of Things (IoT) refers to uniquely identifiable objects (things) and their virtual representations in an Internet-like structure. Stated differently, the concept involves the notion that there are many things (assets, objects, etc.) in the world that may be addressed/labeled/cataloged for various purposes. The world is moving beyond standalone devices into a new era where everything is connected via IoT technologies. This has broad and deep implications for products, services, and solutions across every industry vertical.<sup>15</sup>

IoT technologies and solutions may be broadly classified into three categories: (1) Consumer IoT, (2) Enterprise IoT, and (3) Industrial IoT. In terms of Consumer IoT, there are a few particularly important consumer-oriented markets including Connected Automobiles, Connected Homes, and personal electronics such as Wearable Technology. Connected Automobiles refers to the use of IoT and broadband communications (LTE, WiFi, and soon 5G) technology in the car with the use of smartphones or other technologies typically manifest as handheld or wearable devices. Vehicles are at the forefront of a major convergence happening that includes a few key technologies: 5G, Artificial Intelligence, Data Management (Big Data, Analytics, Visualization, etc.), Cloud Technologies, and IoT.<sup>16</sup>

Connected vehicle technology is rapidly evolving to encompass Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), Vehicle-to-Device (V2D), and Vehicle-to-Pedestrian (V2P) signaling and communications. Integration with non-vehicle industry vertical applications and services are realized through various Vehicle-to-Home (V2H), Vehicle-to-Device (V2D), and Vehicle-to-Grid (V2G) solutions. Collectively speaking, the term Vehicle-to-Everything (V2X) encompasses all of these technologies, use cases, applications, and services.<sup>17</sup>

At its core, V2V is about public and personal safety as the technologies provide signaling and communications for collision avoidance and notice of potential hazards that may affect more than one vehicle. Similarly, V2P technology supports signaling to pedestrians about potential vehicular dangers. V2I technology allows connected cars to interact with surrounding infrastructure such as traffic signals, buildings, kiosks/billboards, parking lots, and even humans. It is important to understand that V2X technologies and solutions also provide a foundation upon which commercial services and applications will be developed and supported.<sup>18</sup>

## II. DISCUSSION

Wearable technology is increasingly becoming an important medium for communication, infotainment services, health solution, textile, military, and industrial solutions. Wearables provide both a new user interface as well as a convenient and always available means of signaling, communications, and control via IoT.<sup>19</sup>

This segment has the potential for massive transformation in many industries. Early adopter industries include clothing, healthcare, sports, and fitness. For example, wearable devices and digital healthcare represent two dominant trends that are poised to redefine virtually everything about how health products and services are delivered and supported. Ranging from telemedicine to self-monitoring and diagnosis, wearable devices and IoT will start as a novelty and achieve necessity status as insurance company cost optimization become the main driver for adoption and usage.<sup>20</sup>

Mind Commerce sees an evolution from single-purpose wearable devices (such as Smart Watches) to wearable technology that acts as a conduit to the larger universe of objects and the Internet. In terms of wearable technology acting as a conduit, we see the following:

- Controls for Communications and Apps: Gesture, Voice, Motion and others
- Interface between Wireless network and other Devices: Body Area Network (BAN) and ad hoc connections to devices and machines
- Man Machine Interface (MMI): Watch becomes part of ecosystem including AR, BAN, and IoT in general<sup>21</sup>

Mind Commerce sees the prospect for “Smart Wristbands” to be the link to the macro world (via WiFi, WiMAX, 4G, 5G, etc.), the near-to-me world (via BLE, NFC, Beacons, WiFi, etc.), and the personal world (e.g. Body Area Network) including other wearables such as Augmented Reality. Mind Commerce sees Smart Wristbands as just one potential link (between the macro world via wireless WAN technologies and micro/local world via short-range wireless) as there will longer-term be various articles of clothing and other aspects of Body Area Network technology to provide the same function. The primary take-away point is that silo, single-purpose devices (such as Smart Watches) are merely a market introduction strategy. Longer term we see apps and services playing a much more significant role as devices themselves become more utilitarian in nature.<sup>22</sup>

Mind Commerce believes that discoverability (of IoT devices, sensors, and gateways) via wearables and wearable controls of an IoT Dashboard will be an important area. IoT will not only engender new products and services, but also make automation easier and more accessible, we see a new class of consumer service that we refer to as “Ambient IoT.” Ambient IoT refers to the view that IoT (devices, gateways, sensors, etc.) will surround the consumer (e.g. ambient environment).<sup>23</sup> There will be a need for control for the consumer to, minimally know what is out there, and optimally control what is there, or at least control privacy and protect security. Enterprise IoT is concerned with a variety of factors dealing with business operations efficiency and effectiveness. For example, one important area to consider is the transition from traditional Enterprise Resource Planning (ERP) to IoT enabled ERP, and the impact of IoT enabled ERP on enterprise as a whole. Leading ERP solution providers are adding IoT capabilities into ERP systems to generate meaningful insights for businesses. ERP systems are coupling sensors and other IoT devices to transmit data into ERP system on a real-time basis without human intervention.<sup>24</sup>

In another example that cuts across the Consumer, Enterprise, and Industrial IoT markets, consumer appliances data is fed directly into manufacturers ERP system without using any middleman system. This expedites fault finding program and proactive maintenance using machine generated data. This type of consumer centric ERP process will be the new reality for enterprise ERP systems integrated with IoT solutions. The industrial sector is rapidly integrating Internet of Things (IoT) with other key technologies such as 3D Printing, Big Data and Streaming Analytics. Typically referred to as the Industrial Internet of Things (IIoT) or simply the Industrial Internet,<sup>25</sup> IoT in industry includes Connected Manufacturing in which the combination of certain key technologies are anticipated to substantially advance the Industry 4.0 revolution towards increasingly smarter manufacturing. In terms of core functionality for Connected Manufacturing, IIoT provides the basis for communications, control, and automated data capture. Data Analytics provides the means to process vast amounts of machine-generated and often unstructured data. Accordingly, Big Data technologies and predictive analytics enable streamlining of industrial processes. AI technology provides the means to further automate decision making and to engage machine learning for ongoing efficiency and effectiveness improvements.<sup>26</sup>

IoT is poised to transform many industry verticals such as Agriculture, Automotive, Healthcare, and more. Initially focusing on improving existing processes and augmented current infrastructure, IIoT will evolve to encompass next generation methods and procedures. For example, IoT in Agriculture (IoTAg) represents a more specific use of technology wherein agricultural planning and operations becomes connected in ways previously impossible if it were not for advances in sensors, communications, data analytics and other IoTAg areas.<sup>27</sup> IoT in Healthcare is another promising example. The evolving area of Real-Time Remote Medical Diagnosis Systems promise to revolutionize the detection and prescriptive abilities of healthcare diagnostics as IoT technologies integrate with Electronic Healthcare Records systems. IoT technologies are anticipated to make a substantial impact upon physical infrastructure, cities, and buildings. Improving the operational effectiveness and efficiency, safeguarding assets, and establishing new value-added services are the fundamental goals of establishing Smart Infrastructure, Smart Cities, and Smart Buildings. Intelligent use of IoT technologies will be the key to continuous improvements in the areas of process automation.<sup>28</sup> The use of Big Data and Analytics tools will be key to transforming data captured into actionable information.

IoT is an integral component of the global Smart City trend. Many countries have initiated efforts to create "Smart Cities." These efforts include global ICT infrastructure suppliers and communication service providers deploying a combination of technologies including AI, Broadband Wireless, Cloud Computing, and IoT Technology to improve the efficiency and operational effectiveness of urban centers and surrounding suburban environments.<sup>29</sup>

Improving the operational effectiveness and efficiency, safeguarding assets, and establishing new value-added services are a few of the fundamental goals of Smart Buildings. Certain leading companies within the Commercial Real Estate (CRE) sector are realizing tangible benefits from developing Smart Buildings. The CRE industry is able to charge higher fees for IoT enabled intelligent buildings as well as leverage various capabilities to provide Smart Workplace solutions.<sup>30</sup>

### III. RESULTS

Convergence makes 5G and AI use cases exciting: 5G could unleash the artificial intelligence revolution, moving it into a different league and creating new AI use cases. When Apple launched the iPhone, few people understood its significance. There was a reason for this. At the time of the product announcement in 2007, wireless internet speeds were quite slow. 3G was launched by NTTDeCoMo in 2001 but network rollout had been gradual at best. It was the convergence of touchscreen phones and 3G and then 4G which created a demand hardly anybody had anticipated. ‘The growing importance of AI will go hand in hand with the emergence of 5G’. There was also a catch — as popular applications emerged, demand for 3G rocketed, and the 3G network became stretched.<sup>31</sup>

According to Allied Market Research, the global 5G market will grow from a valuation of \$5.13bn in 2020 to \$797.8bn by 2030. IDTechEX has drawn similar conclusions. In a recent report, it concluded: “The 5G market is just about to take off.” It forecast that by the end of 2032, consumer mobile services applying 5G technologies will generate around \$800bn in revenues. Dr Yu-Han Chang, Technology Analyst for 5G at IDTechEX, says: “5G enables greater data flows and quicker data collecting, allowing AI to generate more accurate models and predictions. “5G and AI together will speed the evolution of a fully connected and intelligent world.” 5G is slated to offer speeds in excess of 100 times faster than 4G, which seems like an incredible increase but applications will emerge to fill the opportunity created. As ever, with these things, when you drill down, complications emerge. There are, in fact, two distinct 5G networks. At one level,<sup>32</sup> mmWave, also called 5G II, operates at 100 MHz and provides between 24 – 100 GHz (gigahertz) and offers extremely impressive latency but is limited to a range of 300 metres.

By contrast, Sub-6 GHz, or 5G I, operates at 50 MHz, has inferior latency to 5G II, but is superior to 4G, provides between 3.5 – 7 GHz but has a range of 1.5 kilometres. In other words, 5G II can support more powerful applications, but because of the low range, it requires more investment in infrastructure. Consequently, to date, most 5G rollout has been for 5G I. The implications for AI will not be immediate, but they will be highly significant. Although AI is probably more common than is generally supposed, its impact has been limited to date. So, while most of us use AI without necessarily realising it, for example, when we use our smartphone as a navigation tool, AI’s real impact lies ahead. The growing importance of AI will go hand in hand with the emergence of 5G. The convergence of the two technologies will have an enormous impact on us all, will have huge economic significance and will transform business. The Internet of Things (IoT) will underpin the convergence between 5G and AI. Adam Bujak, CEO and Co-founder at KYP.ai, the process intelligence company, said that “5G will power the growth of the IoT. It will allow organisations to use more connected devices and intelligent sensors. “We will be able to conduct our processes more digitally in the physical world and online by using connected devices and services.”<sup>33</sup> Therefore, we’ll see the growth of physical [physical + digital] products and services, including virtual reality modes of operations and customer interactions.” IDTechEX says that “5G [especially mmWave]’s high throughput and ultralow latency enable it to tap into various high-value sectors such as 3D robotic control, virtual reality monitoring, and remote medical control that earlier technologies couldn’t.” We will see connectivity between products like never before. At one level, we might see coffee cups communicate with coffee vending machines — saying, “I’m empty.” But at another level, we will see the connectivity of autonomous vehicles, which will be of massive significance to the future of transport. The data collected by the IoT will also provide the kind of ammunition that machine learning or AI needs to develop and create greater insights. The convergence of 5G and AI will underpin the emergence of the metaverse. The 2020 hype concerning the metaverse has partially turned to cynicism. Part of the issue here relates to the definition of the metaverse. At one level, it conjures up thoughts of a Matrix-type world, but in reality, its meaning is more prosaic. I have heard people say a Zoom call involves the metaverse, and they define it as combining digital and physical worlds.<sup>34</sup>

Virtual and augmented reality or immersive reality will underpin the metaverse, and 5G and AI will transform it. The convergence of 5G and AI will create new use cases in games and streaming services, for example, offering 3D and virtual reality viewing supporting how we communicate. It will also change social media. The convergence of AI and 5G will also create tools we will use in our daily lives — for example, real-time language translation tools. Business-to-business applications will be many, but one of the most important aspects will be the support 5G gives remote working. Take as an example how Grammarly supports communications by text. But as virtual and augmented reality technologies advance, it is not difficult to imagine how 5G and AI can transform not only remote work but mobile work. Still, with B2B, there is also the issue of automation technologies. Adam Bujak says: “5G will extend the reach of digital transformation and bring us more opportunities for innovation and automation. We will have more data and

insights from all these phygital processes and connected devices, allowing us to train AI and to tap it for business and process analytics. In turn, there will be more possibilities for outcome-driven intelligent automation of services.”Office automation is one opportunity, but 5G and AI in combination will also support industry and manufacturing; at one level, it will be able to support the maintenance of equipment, monitoring machinery and identifying potential issues in advance, but it also presents the enticing prospect of remote operation of machinery. The connectivity of transport, including autonomous vehicles, drones, and transport infrastructure such as ensuring traffic lights support optimal traffic flow, will be transformed by AI and 5G working in parallel. The opportunities presented by AI and 5G in healthcare are multiple, but one of the most enticing will relate to remote monitoring of patients when they are out. But many more AI and 5G use cases will emerge; the above is just the beginning. The convergence of these technologies will prove incredibly important and will unleash AI, finally justifying much of the hype seen over the last decade.<sup>35</sup>

#### IV. CONCLUSIONS

Artificial intelligence is used in a wide variety of areas and industries. It helps businesses better understand their customers, it can automate processes, and it can even improve systems that make up a business — such as its supply chain. Today, 5G is immensely more powerful than its predecessor,<sup>33</sup> 4G, and with this in mind, it’s not surprising to learn that 5G is now the army knife of connectivity, as it can link millions of IoT devices and at the same time, serve metaverse users with real-time virtual reality. The power of 5G comes at the price of complexity, a complexity that is best managed by AI:

- AI orchestrates 5G servers in an operator network,
- AI can optimally allocate the spectrum and optimize it for each device's latency, bandwidth, and reliability;
- AI can detect intrusion in a network.<sup>34</sup>

What is even more interesting is how AI reaches new levels in the context of industry 4.0, as 5G enables it to connect every single tool, person, and machine. For instance, with a wireless 5G camera, you’ll be able to control a robot arm, pilot robots in warehouses, or even measure the performance of every single hand-carried tool in a car manufacturer chain. As demonstrated, AI and 5G form a powerful duo. For one thing, it helps businesses gain efficiency and run at a higher level of capacity. Thanks to this duo, the multinational engineering, and technology company, Bosch, has proven how they can save up to €800K per year of energy and raw materials, for every one of their factories. At firecell, we make 5G connectivity easy and affordable so that every industrial company around the world can afford to set up a 5G network on its premises. So that every enterprise, no matter its size, can benefit from the undeniable advantages of using AI with a 5G network.<sup>35</sup>

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