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A Review of the Effects of Fifth-Generation Mobile Networks (5G) on the Fourth Industrial Revolution (Industry 4.0) and the Digital Transformation of Businesses

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Abstract: More than just a generational shift, the arrival of 5G creates a whole new range of opportunities for every sector of the economy. It signifies a significant change in the function that mobile technology serves in society. As 5G becomes a reality, it will have a huge impact on us, particularly at work. This paper's goal is to conduct a thorough literature review, investigate how intelligent automation might be enabled or streamlined by 5G, and discuss why 5G development and deployment are critical in the future years. This article emphasizes the significance of 5G revolutionary networks, evaluates its essential enabling technologies, looks at its trends and issues with adaptation, looks at its applications in various industries, including Industry 4.0 and digital marketing, and emphasizes its function.

Keywords: 5G, 5G Networks, Cellular Wireless Networks, Digital Marketing, Digital Transformation, Enhanced Mobile Broadband (eMBB), Internet of Things (IoT), Mobile Communications, Workplace Transformation

1. INTRODUCTION

According to Attaran & Attaran. (2020), Diverse industries have a chance to become more competitive and make a bigger contribution to local economies thanks to the Fourth Industrial Revolution, which also advances the Sustainable Development Goals of the UN. The internet of things, artificial intelligence, sophisticated data analytics, robotic process automation, robots, cloud computing, virtual and augmented reality, 3D printing, and drones are some of the existing and new technologies driving this industrial revolution. Connectivity is one of the main facilitators that makes it possible for these technologies to reach their full potential.

Networks of physical infrastructure have undergone changes during industrial revolutions. The Second and Third Industrial Revolutions were propelled by electricity as networks realized economies of scale by connecting massive facilities via high-voltage transmission grids to smaller distribution networks that served a huge number of users. PWC (2020), the widespread use of 5G communication networks will enable the Fourth Industrial Revolution's full potential to be fulfilled.

Unprecedented levels of connectivity will be made possible by 5G, which will upgrade 4G networks with five core functional drivers: high reliability/availability, large machine-type communications, ultra-reliable low latency communication, and efficient energy utilization. These distinguishing characteristics will revolutionize a variety of industries, including manufacturing, transportation, public services, and health.

Key parties must respond to critical questions to guarantee the widespread deployment of 5G networks. Mobile and telecommunications operators must assess appropriate business models, city managers and government regulators must decide whether and when to invest in 5G infrastructure, and residents must find ways to take advantage of all the advantages this technology has to offer while preserving the rights of the community (O'Halloran, 2019).

Only when all parties involved citizens, business, and government work together to find effective answers to these issues will the switch to 5G networks be successful.

2. OVERVIEW OF 5G NETWORKS

5G is the Fifth-generation of radio mobile networks after 1G, 2G, 3G and 4G. The mobile network is anticipated to drastically improve with 5G, enabling more connections and interactions. The possibility for numerous industries to increase their bottom line will be greatly increased by this network connectivity improvement.

By widely deploying 5G communication networks together with other connection options, the benefits of the Fourth Industrial Revolution and its associated new technologies will be fully realized. A wide range of options will become available as a result of 5G's major functional drivers, including improvements in service delivery, decision-making, and end-user experience (PWC, 2020).

A. 5G Ecosystem

According To PWC (2020), to make the most of the new, end-to-end network architecture of 5G and its associated functional drivers, the 5G Ecosystem Cycle was determined. It makes possible the long-term evolution of society and several industry sectors. The cycle is based on how all of the ecosystem's major components are interdependent with one another and how specific events must take place in each of them in order to start and keep the cycle moving. The 5G Ecosystem Cycle seeks to illustrate the necessity of stakeholder engagement and alignment across the ecosystem, including coordinated decision-making that will have an impact on the ecosystem's succeeding components.

The 5G network is a complicated system in which numerous players play numerous roles. The 5G ecosystem makes it possible for devices, connectivity, and IT infrastructure to all come together. Businesses have access to a variety of options thanks to the 5G ecosystem, including quicker time to market and the ability to develop better products and services.

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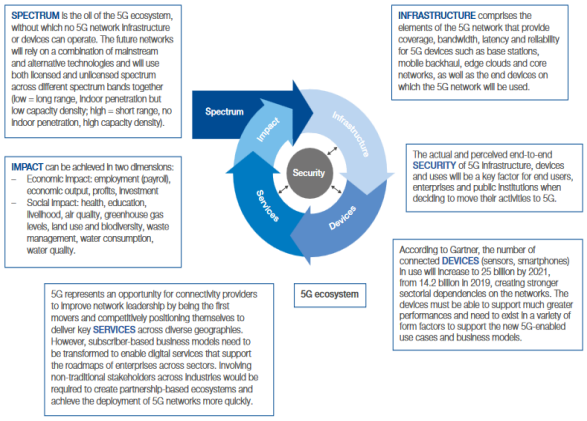

Figure 1. The 5G Ecosystem Cycle

B. 5G Functional Drivers

There are five key functional drivers of 5G that support certain technological applications. They are:

i. Enhanced mobile broadband;
ii. Ultra-reliable low latency communications
iii. Security;
iv. Massive machine-type communications;
v. Power efficiency.

Functional driver	Description	Added value	Use cases
Enhanced mobile broadband (eMBB)	Faster connections, higher throughput and greater capacity (up to 10 Gbps)	Allows for an extension in cellular coverage into diverse structures (large venues) and the ability to handle a larger number of devices using high amounts of data	Fixed wireless access service, enhanced in-building broadband service, real-time augmented reality service, real-time virtual and mixed reality service, crowded or dense area service, enhanced digital signage, high-definition cloud gaming, public protection and disaster response services, massive content streaming services, remote surgery and examination
Ultra-reliable low latency communication (uRLLC)	Reduced time for data from device to be uploaded and reach its target (1 ms compared to 50 ms for 4G)	Enables time-sensitive connections wirelessly	Autonomous vehicles, drones and robotic applications, health monitoring systems/telehealth, smart grid and metering, intelligent transportation, factory automation, remote operation, self-driving cars, mission-critical services (security and safety), high-definition real-time gaming
Security	Robust security properties, leading to high reliability and availability	Creates an ultra-reliable connection to support applications where failure is not an option	
Massive machine-type communications (mMTC)	Increased spectral efficiency plus small cell deployment	Allows for a large number of connections to support data-intensive applications	Asset tracking and predictive maintenance, smart cities/buildings/agriculture, Internet of energy/utility management, industrial automation, smart logistics (advanced telematics), smart grid and metering, smart consumer wearables, environmental management, intelligent surveillance and video analytics, smart retail
Power efficiency	Efficient power requirements for massive multiple-input, multiple-output (MIMO), small cell implementation	Leads to lower costs and enables massive Internet of things	

Figure 2. 5G functional drivers

C. Role of Private 5G Networks In Industry 4.0 & Beyond

As regulators provide businesses greater spectrum to build their own private 5G networks, private 5G networks have gaining popularity across the globe. Companies who want 5G capabilities to deliver their disruptive apps now have a progressive opportunity to do so. Smart manufacturing and the internet of things are now being driven by innovative digital change (Tanna, 2022).

High bandwidth and data rates can be provided by 5G private networks for extremely rapid connectivity. These networks also offer great dependability, scalability, and ultra-low latency of 1 ms. Bulk volumes of IoT-connected sensors and devices can be accommodated by them successfully. As a result, these networks are suitable for enterprises that need extremely low latency to handle vast networks of linked devices.

In addition to flawless communication, private 5G networks support a variety of applications. They assist with mission-critical wireless communication with essential infrastructure, business operations, and public safety. The foundation for smart factories and smart production is laid by 5G-enabled technologies, which also provide producers with enticing advantages. These networks support use cases for cutting-edge technology including autonomous vehicles, collaborative mobile robotics, automated guided vehicle systems, augmented reality (AR), virtual reality (VR) headsets, and predictive maintenance, among others.

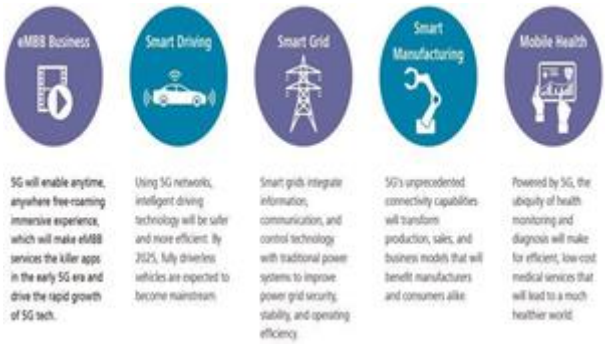

Figure 3. 5G Sectorial Digital Transformation

3. OVERVIEW OF INDUSTRY 4.0

The fourth industrial revolution, sometimes known as "Industry 4.0," envisions the digital transformation of the production, manufacturing, and allied industries. It denotes a new stage in the organization, control, and value generating procedures of the industrial value chain. The Industrial Revolution was sparked by industrial and machine production. There have been three stages thus far.

The introduction of steam power and production mechanization in the 18th century sparked the first industrial revolution. With the invention of electricity and the introduction of assembly lines, the Second Industrial Revolution got underway in the 19th century. In the latter half of the 20th century, partial automation employing computers and robots with memory-programmable controllers made way for the Third Industrial Revolution.

A. The Impact of Industry 4.0 Technology on Production

Real-time data about the entire production process is made available by Industry 4.0. The value chain of the organization is visible to the user. Production-related factors include the raw materials utilized, how they were supplied at various stages, where they came from, and the many tasks involved. It becomes simpler for the manufacturing organization to build plans for controlling the supply chain and increasing the organization's production rate by keeping track of the complete value chain and the production activities (Ghobakhloo and Fathi, 2019). To manage the production activities effectively, the distribution of resources and goods can be successfully regulated.

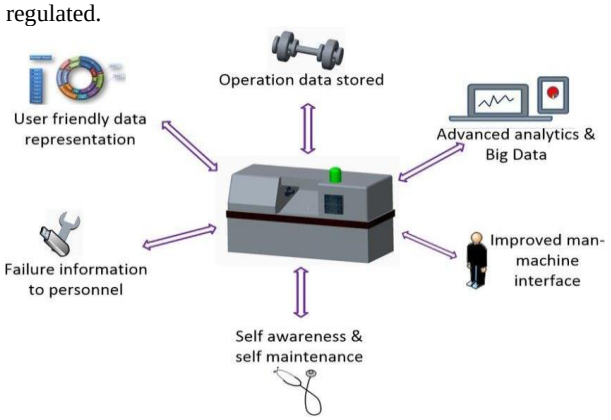

Figure 4. Industry 4.0 Production Transformation

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B. Industry 4.0 Technologies

- **Internet of Things (IoT)** - IoT is the foundation of smart factories, which allow machines with sensors to communicate with other web-enabled equipment. This guarantees the gathering and analysis of enormous amounts of data to assist in making wise decisions.
- **Cloud-based computing** - Bulk data may be stored and analyzed more effectively thanks to the cloud. The supply chain, engineering, production, sales & distribution, and service are all connected and integrated.
- **Edge processing** - data processing takes place "at the edge," or where the data is created. By ensuring that data stays close to its source and minimizing latency, security threats are decreased
- **Digital twins** - virtual representations of manufacturing facilities, assembly lines, workflows, and supply networks. In order to enhance workflows and boost efficiency, they collect data from IoT devices, sensors, and other linked things.
- **AI and Machine Learning (ML)** - help make the most of the vast amounts of data gathered from diverse sources. It increases operational efficiency by facilitating the seamless automation of operations and business processes.

Figure 5. Industry 4.0 Technological Pillars

C. Benefits of Industry 4.0

The advantages that the technology provides make the role of 5G and its ROI prospects with Industry 4.0 important. Automation, decision-making, and manufacturing control are all improved by Industry 4.0 technologies. We are able to produce more and faster thanks to them, and they also open up chances for innovation and resource allocation that is both efficient and economical.

By reducing machine downtime and accelerating batch changes, they help increase productivity. Additionally, it encourages automated reporting and track-and-trace procedures. It also gets more effective to introduce new products.

Industry 4.0 technologies improve collaborative working and encourage knowledge exchange, whereas traditional manufacturing plants operate in silos with little interaction.

Generally, Industry 4.0 has cumulative benefits cutting across several spheres. There include but are not limited to:

- Manufacturing benefits e.g. Improved Productivity, Flexibility and Agility
- Quality and compliance benefits e.g. Improved Product Quality, Easier Compliance
- Customer and patient benefits e.g. Better Customer Experience, Personalized Products
- Operational Benefits of Industry e.g. Reduces Costs, Improved Decision-Making, Increased Profitability

Figure 6. Industry 4.0 Opportunities

D. Challenges with Industry 4.0

Common roadblocks to digital transformation include:

- A lack of people or expertise in managing complex Industry 4.0 and 5G structures
- Concerns about cyber security
- Capital outlay
- Inadequate digital infrastructure
- Lack of understanding of digitalization and its uses

Figure 7. Industry 4.0 Challenges

4. RESULTS & FINDINGS

A. Industrial Advances

Three key ways that 5G will contribute to industrial advancements are as follows:

i. Using predictive intelligence, it will be possible to conduct inspections more quickly and effectively;
ii. Improving workplace and worker safety; and
iii. Improving operational effectiveness.

By reducing carbon emissions and closing the digital gap, 5G has the potential to have an influence on the industrial sector.

5G for Industry Digitization

Due to industrial developments, 5G will likely be a key technology for addressing a number of issues caused by the rapid digitization of various industries. A wide range of societal use cases are supported by 5G, which offers an unrestricted, blazing-fast, dependable, and secure broadband experience. It will offer the networks and platforms needed to power Industry 4.0's digitalization and automation of industrial operations. It will facilitate the extensive adoption of vital communications services and enable the broad deployment of intelligent IoT. (GSMA, 2017).

In conclusion, 5G networks allow service providers to design virtual networks that are specific to the needs of applications like (Condon, 2017):

i. Mobile broadband – communication, media and entertainment, and the Internet
ii. Machine-to-Machine (Massive IoT) – Retail, shopping, manufacturing
iii. Reliable low latency – Automobile, medical, smart cities

iv. Critical Communications
v. Others industry-specific services and energy

B. Social Impact

Of the 17 Sustainable Development Goals set forth by the UN, 5G can contribute to social progress in 11 crucial areas (SDGs). This value is primarily derived from improving infrastructure, advancing sustainable industrialization, and encouraging innovation. It also derives from improving health and well-being. In addition to fostering responsible consumption, sustainable cities and communities, and the advancement of fair employment and economic growth, 5G also has a significant social impact in these other key areas.

i. 5G has the ability to contribute significantly to societal well-being through reduced potential injuries and fatalities
ii. 5G is a key enabler to enhance infrastructure, promote sustainable industrialization and foster innovation.
iii. Ultra-reliable low latency communication is the key defining driver of 5G that will realize socio-economic value.
iv. The second-most defining driver of 5G is enhanced mobile broadband, mainly related to artificial intelligence, mixed reality and drone-based applications.

C. 5G maturity

i. Drone-based apps, mixed reality, and artificial intelligence all heavily rely on improved mobile broadband.
ii. A fundamental benefit of 5G that can be immediately realized is quicker image/video processing, which is supported by improved mobile broadband combined with reduced latency.
iii. Low latency is essential for opportunities reliant on real-time machine learning, a feature that will eventually reach full maturity.

5. CONCLUSION

The industrial sector will continue to profit from the 5G revolution as its role expands. With its higher capacity, quicker speeds, and lower latency, 5G is anticipated to be the driver of innovation in the future industrial landscape. It has the capacity to provide new value for numerous sectors and social groups.

Due to its ability to enable previously unheard-of levels of connectivity, 5G will significantly contribute. With ultra-reliable low latency communication, extremely fast broadband, massive machine-type communications, and efficient energy use, it can upgrade 4G networks. These characteristics will transform a number of industries, including manufacturing, transportation, healthcare, and public services.

5G will significantly advance industry by improving workplace and worker safety; utilizing predictive intelligence for quicker and more efficient inspections; and increasing operational effectiveness. Overall, 5G may have an influence on the industry by closing the digital gap and reducing carbon emissions.

Strong coordination amongst stakeholders is required to make sure that the deployment of 5G will be accelerated and that its components and interdependencies are understood. The functional drivers of 5G provide technical support for many of the present instances, which are then activated through multi-stakeholder engagement. To address the issues preventing widespread 5G adoption globally and to take full advantage of the opportunities it will bring across sectors, regulators, industry associations, network operators, service/technology providers, and public-private partnership organizations must engage in constant communication. In the future, it will become more crucial than ever to define frameworks and models for collaboration in order to start and maintain cooperation more successfully.

6. RECOMMENDATIONS

- More research and interventions are needed to improve cyber security in 5G and Industry 4.0.
- More human capacity must be developed to handle complex Industry 4.0 and 5G structures.
- Globally, adequate digital infrastructure must be set up to accommodate 5G and Industry 4.0.
- Greater awareness of digitalization and its applications is needed.

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