5G and Industrial Internet Of Things

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Abstract— **The world is adapting mobile technology in fast pace. It is expected that in 2020 the number of mobile hosts will be exceeding 50 billion hosts [20]. As a result all these hosts will be interconnected and there will be a huge demand for the creation of smarter environments such as smart factories, cities and smart homes. This survey outlines the key opportunities and challenges of 5G in the Industrial Internet of Things. It also describes how 5G will transform the Industrial IoT. Additionally it presents a basic 5G-enabled system architecture. Furthermore it describes the current trends and their affect on the industry 4.0. Besides the characteristics, key technologies of the 5G based IIoT are also analyzed..** (*Abstract*)

Keywords— Internet of Things (IoT), AMQP, MQTT, XMPP, CoAP

I. Introduction

In the last decade, the current manufacturing industry is going through a tremendous change.

After many years that the power of steam relieved factory workers from hard manual labor and the invention of mass production also known as Industry 1.0, which later were improved by the introduction of electricity power in the various processes and is described as Industry 2.0 we moved in the 1980s, to the automation of production with the use of PLCs, computers and robotics also known as the third industrial revolution or Industry 3.0.

Today we are experiencing the fourth era of industry or Industry 4.0, which is the era of Cyber Physical Systems (CPS). CPS consists of storage systems, smart machines and production facilities which can exchange information autonomously, trigger various actions between them and control each other independently. The outcome of the Industry 4.0, were 4.0 stands for the fourth industrial revolution were internet technologies are used to create smart products and smart services through a smart way of production [14]. Moreover the fourth industrial revolution encompasses areas which are not normally classified as an industry, such as smart cities.

The above exchange of information is achieved by the Internet of Things (IoT). The technical concept of IoT compromises thousands of sensors and low-power devices which operate real time and they are capable of transferring the data to server (local or cloud) or interacting with each other through the Internet [2] .

Wireless communications and networking will play a significant role in IIoT. The last two decades we experienced a huge improvement and usage of wireless networks and they are essentials parts of our lifestyle. Also, the quality of experience and the quality of service, of cellular networks has also been dramatically improved [2]. The fifth generation of mobile communication networks also known as 5G is the technology which industrial companies are betting on. The strong point of 5G is that not only offers massive machine-type communications (mMTC) but also ultra-reliable low-latency communication (URLLC) for machine connectivity [19],[7]. 5G can change the surface of IIoT as it can bring together exceptional machines, unique software and of course people at work in order to produce valuable results which will help them produce faster, make better decisions and in general operate smarter [19].

II. Communication categories of 5G networks

As said above 5G networks will be the next generation of mobile internet connectivity, providing faster speeds as well as reliable connections not only on smartphones but also on more other devices than ever before. They are expected to give a huge boost to Internet of Things technology by providing the required infrastructure. Due to the flexible nature of 5G wireless networks they can become highly autonomous [12].

5G technologies that come along with it can transform the current industry surface. It is also known that 5G will take care of a lot of use cases and requirements. All of them can be grouped into one of these three services[10][13].

A. Ultra-reliable low latency communications (URLLC)

One of the most important advantages of 5G is the URLLC which provides low latency for mission-critical services. It provides ultra-responsive connections and high speed mobility. URLLC applications require significantly reduced latency compared to what is provided by today's wireless technologies[10]. The requirements of such apps are very strict especially in terms of end-to-end latency and/or reliability. The requirements of latency are counted in milliseconds while the reliability demands are higher than 99.999% [12], while it provides low to medium data rates between 50kbps and 10Mbps. Use cases include autonomous vehicles, smart grids, remote patient monitoring and telehealth, industrial automation. With URLLC 5G should be able to connect controllers, switches and sensors at latency and reliability levels equivalent to those of wired connection.

B. Enhanced mobile broadboand (eMBB)

This service is already in the focus of 4G mobile networks [1]. It provides faster speeds for various use cases which require high data rates such as video streaming and virtual reality. Main features of eMBB are peak data rates up to 20 Gbps, universal data rates around 100Mbps, tens of thousands of simultaneous users. However, the capabilities of 5G extend far beyond eMBB [19]. Use cases in the eMBB include the ultimate user experience with high mobility of about 500 Kmph. Use cases include enhanced indoor and outdoor broadband, enterprise collaboration, augmented and virtual reality. It is worth to mention that it helps in network energy saving by 100 times[10].

C. Massive Machine Type Communication (mMTC)

Communication between devices such as sensors or motors are often referred as M2M or MTC communication which means Machine Type Communication [4]. mMTC provides internet access for sensing, metering, and monitoring devices, so latency and throughput are not a big concern. It aims to provide connectivity to a huge number of devices whose traffic profile is typically a small amount of data (spread) sporadically[10]. mMTC supports extremely high connection densities, enabling industrial-scale IoT. With it, 5G will be able to connect up to a million IoT sensors and devices per square kilometer [7][10]. It provides asynchronous access and it also supports long range along with high density of devices [9]. The main concern is the optimal power utilization of these devices as they are battery powered and the expectation of battery life is around 10 years. Use cases include IoT, asset tracking, smart agriculture, smart cities, energy monitoring, smart home, remote monitoring.

The expansion of service scope for mobile networks enriches the telecom network ecosystem. A number of traditional industries, such as automotive, healthcare, energy, and municipal systems participate in the construction of this ecosystem. 5G is the beginning of the promotion of digitalization from personal entertainment to society interconnection. Digitalization creates tremendous opportunities for the mobile communication industry but poses strict challenges towards mobile communication technologies.[6][3][11]

III. Challenges in 5G networks

5G as the next generation of mobile technology has become a big buzzword in the industry. It is not just about high data rates but is a set of technologies which is going to be applied to a wide range of use cases and requirements. This will impact a lot of industries, businesses and lives of people.

TABLE I. 5G REQUIREMENTS THAT WILL ALSO BE APPLICABLE IN INDUSTRY 4.0[8]

Requirements	Desired Value	Application Example
Latency	< 5ms	Control and safety applications
Battery Life	> 10 years	Connect hard to reach physical elements, low maintenance
Connectivity	300000 devices per AP	Massive M2M connectivity
Reliability	99.99%	Protection and control
Data rate	1-10 GB/s	Virtual representation
Seamless and quick connectivity		Mobile physical devices

In Table 1 we see some of the challenges that 5G networks and their architecture design has to deliver. In order to achieve the extreme data rates , the low latency and the extraordinary reliability many concepts have been proposed such as the network slicing by the NGMN alliance. Network slicing is a specific form of virtualization that allows multiple logical networks to run on top of a shared physical network infrastructure. The key benefit of the network slicing concept is that it provides an end-to-end virtual network encompassing not just networking but compute and storage functions too. The key technologies that make network slicing possible are network function virtualization (NFV) and software defined networking (SDN).

Software-defined networking (SDN) is designed to make networks more flexible and agile. The main idea behind SDN is to move the control plane away from network hardware and enable external control of data through a logical software entity called a controller [15].

On the other hand, NFV is a key enabler of the coming 5G infrastructure, helping to virtualize all the various appliances in the network [12].

IV. IIoT characteristics & challenges

The Industrial Internet of Things (IIoT) refers to interconnected sensors, instruments, and other devices networked together with computers' industrial applications, including manufacturing and energy management. This connectivity allows for data collection, exchange, and analysis, potentially facilitating improvements in productivity and efficiency as well as other economic benefits.[5] The IIoT is an evolution of a distributed control system (DCS) that allows for a higher degree of automation by using cloud computing to refine and optimize the process controls.[14]

The industrial internet of things (IIoT) refers to the extension and use of the internet of things (IoT) in industrial sectors and applications. With a strong focus on machine-to-machine (M2M) communication, big data, and machine learning, the IIoT enables industries and enterprises to have better efficiency and reliability in their operations. The IIoT encompasses industrial applications, including robotics, medical devices, and software-defined production processes.

The IIoT goes beyond the normal consumer devices and internetworking of physical devices usually associated with the IoT. What makes it distinct is the intersection of information technology (IT) and operational technology (OT). OT refers to the networking of operational processes and industrial control systems (ICSs), including human machine interfaces (HMIs), supervisory control and data acquisition (SCADA) systems, distributed control systems (DCSs), and programmable logic controllers (PLCs).

The convergence of IT and OT provides industries with greater system integration in terms of automation and optimization, as well as better visibility of the supply chain and logistics. The monitoring and control of physical infrastructures in industrial operations, such as in agriculture, healthcare, manufacturing, transportation, and utilities, are made easier through the use of smart sensors and actuators as well as remote access and control.

By adopting connected and smart devices, businesses are enabled to gather and analyze greater amounts of data at greater speeds. Not only will this enhance scalability and performance, but it can also bridge the gap between the production floors and general offices. Integration of the IIoT can give industrial entities a more accurate view of how their operations are moving along and help them make informed business decisions.

A. *Characteristics of IIoT*

Since the industrial surface is changing day after day it is too difficult to characterize the large set of requirements of industrial automation. Below we are presenting some the most common use cases for communication in industrial automation :

- Interconnection of automation equipment distributed over large distances.
- Interconnection of dedicated real-time automation systems with operator work-places for control and supervision
- Closed-loop control, ranging from slow to fast control applications with sampling rate between seconds to milliseconds.
- Interlocking and control applications.
- Monitoring and supervision applications.

IIoT systems are described by a layered and modular architecture of various digital technologies.[2] This architecture consists of three layers:

1. The device layer which refers to the physical components.
2. The network layer which includes cloud computing , physical network buses and communication protocols that transport the data to the service layer, which consists of applications that manipulate and combine data into information that can be displayed on the driver dashboard.
3. The content layer or the user interface.

The IIoT is enabled by technologies such as cloud computing, cybersecurity, edge computing, mobile technologies, machine-to-machine, 3D printing, big data advanced robotics, internet of things, cognitive computing and RFID technology.[18][11][14]

Five of the most important technologies are described below:

1. Cyber-physical systems (CPS): the basic technology platform for IoT and IIoT and therefore the main enabler to connect physical machines that were previously disconnected. CPS integrates the dynamics of the physical process with those of software and communication, providing abstractions and modeling, design, and analysis techniques.[1]
2. Cloud computing: With cloud computing IT services and resources can be uploaded to and retrieved from the Internet as opposed to direct connection to a server. Files can be kept on cloud-based storage systems rather than on local storage devices.[4]
3. Edge computing: A distributed computing paradigm which brings computer data storage closer to the location where it is needed.[5] In contrast to cloud computing, edge computing refers to decentralized data processing at the edge of the network.[6] The industrial internet requires more of an edge-plus-cloud architecture rather than one based on purely centralized cloud; in order to transform productivity, products and services in the industrial world.[3]
4. Big data analytics: Big data analytics is the process of examining large and varied data sets, or big data.[7]
5. Artificial intelligence and machine learning: Artificial intelligence (AI) is a field within computer science in which intelligent machines are created that work and react like humans.[8] Machine learning is a core part of AI, allowing software to more accurately predict outcomes without explicitly being programmed.[9]

B. *Challenges of 5G and IIoT*

Challenges of the IIoT consist of the lack of security standards in the IIoT. The huge demand of IoT components has led to the production of sensors , microcontrollers and systems without any security measures. This exposes the IIot and it's a real threat especially for spy industry and integrity of the data.[8].

Furthermore businesses often struggle to implement IIoT technology due to a lack of unified standards, a realization that IIoT sensors won't work with legacy equipment or confusion about how to utilize IIoT tech in ways that make the most sense for business operations and customer needs.[2][7]

Moreover the main challenges for adoption of 5G in industrial automation both from a technical and business perspective are described below.

1. Spectrum availability: 5G spectrum is divided into three categories:
    a. The licensed spectrum with the ability to occupy a part of the spectrum for a particular area such as an industrial plant.
    b. The dedicated spectrum which can be allocated for specific use as 3.7GHz in Germany for industrial applications.
    c. Unlicensed/shared spectrum is described by the protocol 3GPP which adds support for unlicensed spectrum (5G NR U) including standalone operation. Furthermore it can support URLLC services in non public locations controlled by tenant/owner.

2. Latency: M2M communication in Industry 4.0 will often require very low latency networks. 5G is being proposed to provide a latency of less than 5ms. Latency can be improved if the handshake requirement is significantly reduced. According to the ITU-R [6], the target performance indicators of 5G include data rates up to several Gb/s, wide-area coverage and deep indoor penetration for up to a million nodes per square kilometer, E2E latency close to 1 ms and a reliability of 99,999 % of packets. By fulfilling these characteristics, 5G becomes an important candidate to provide mobile connectivity

for a wide range of applications in the manufacturing and process industry[14][8][3].

3. Reliability: The most important requirement for an industrial automation system is availability. In addition to promising very low latency, 5G also promises to deliver ultra high reliability, defined as 99.999% or higher.[6][4]

4. Determinism: Lower latency and ultra-reliability need to be translated into time synchronies, time sensitiveness, and deterministic in nature instead of probabilistic and opportunistic. Both antenna technologies and signal processing algorithms need to make the channels hardened enough, and traffic priorities need to be given to tasks with timely requirements instead of fairness. Frequent and smaller data packets are transmitted may sacrifice the extreme spectrum efficiency and throughput chased by traditional cellular technologies. In order to turn around data fast, new network edge might be embedded right into the access network elements.

V. 5G IMPACT ON INDUSTRY 4.0

We are in the middle of the fourth industrial revolution. IoT is the new game changer for businesses and individuals. However, a revolution is often triggered by the rise and demand of certain driving factors. Similarly, IoT and its development are also backed by certain key components. Thus, if organizations want to prosper with IoT, they need to consider who and what is driving IoT and its innovation. Many businesses are investing to technologies that reduce energy consumption and automation.[6] 5G can be the leading technology of Industry 4.0. 5G won't redesign the production line but it will enable new operating models. With network characteristics that are essential for manufacturing, 5G will offer manufacturers the chance to build smart factories that can take advantage of the emerging tech that's changing the industry.

Moreover smart technologies such as IoT, AI and Blockchain are adapted in higher percentage day by day. The number of IoT devices is growing at an ever-increasing speed. The estimated value of the market will be over 69 billion dollars [15] with more than 20 billion Internet of Things devices connected.

Wireless communication will become increasingly important in order to reduce wire installation costs, ease of maintenance and the possibility to make measurements that were previously impossible because of wired communication and available wireless technologies lacking support of some of the stringent requirements.

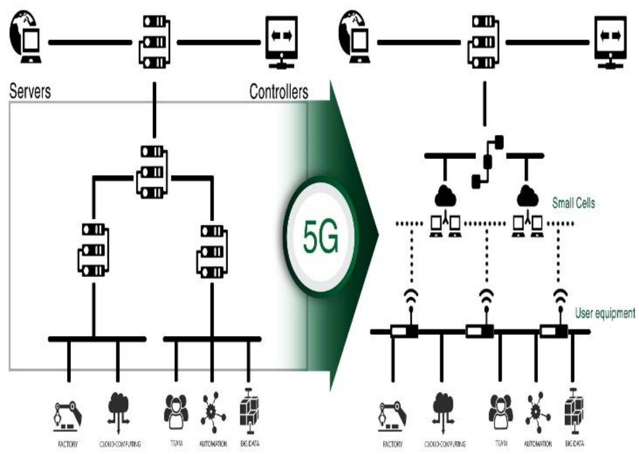
According to the International Data Corporation (IDC) report, the services of the global 5G will support 70% of companies to spend $1.2 billion on the connectivity management solutions.[9][3]

That evolution will continue; whereas 4G has been driven by device proliferation and dynamic information access, 5G will be driven largely by IoT applications, a wide range of IoT use cases.[8][19]

With 5G deployments starting in 2019, the mobile ecosystem is becoming even larger, and more widespread and extensive.[11][20]

VI. 5G IIOT USE CASE SCENARIO

In the use case presented below we visualize how 5G can be applied in an Industrial environment by replacing the ethernet infrastructure. By taking advantage of the unique characteristics of 5G spectrum and also by the low latency we can replace the ethernet cabling and the traditional network backbone with small cells which can work smoothly with the available user equipment by supporting all the desired applications such as cloud computing, big data, automation, robotics, microcontrollers, sensors etc.



In some cases, an organization may opt for 5G simply because it is cheaper than adding additional fixed connections. Many industrial buildings are really old and there is no space for additional cables. Adding wires at these buildings would cost millions of dollars more than connecting it with 5G, which offers equivalent connectivity and greater flexibility. The above picture could also match a scenario like this.

5G can also be used to control facilities remotely. For example, a small factory can be controlled by remote workers who work in another factory[18][2].

By improving the efficiency of existing processes, 5G has the potential to drive huge productivity gains. For operations such as the above 5G is the clear choice as it works in these types of environments while all other technologies including Wi-Fi and 4G do not. Also security, flexibility and price considerations will likely drive these organizations to want to control their own networks.

VII. CONCLUSION

The aim of this paper is to outline the benefits and the advantages of applying 5G networks with Industrial Internet of Things. Industry 4.0 and manufacturing industry stand to benefit greatly from 5G communication technologies. Various promising use cases have been outlined. Key technologies of 5G networks have been described that are potential candidates for the realization of 5G in Industry 4.0. The economical factor of applying 5G and IIoT is huge and it should be considered by the business owners as it will reduce running costs and it will extend the capabilities of industrial plants. Businesses who will not adapt the above technologies will miss the train of evolution and they will eventually collapse. Furthermore it is important to consider the factor of security in 5G IIoT as this technology is coming to be applied at a really expensive industry with really sensitive data. Having a full stack of protection purposely built into the different layers of IIoT implementations would enable industries and enterprises to securely conduct their operations. These security layers include the device, the network, and the cloud. In the next decade, the manufacturing industry is expected to evolve toward a distributed organization of production. Finally, it is really important to understand that IoT and IIoT with the support of 5G can help give companies an edge over the competition. Increasingly, companies need to use these technologies to avoid falling behind their competitors, and their importance for businesses will continue to grow over the coming years[16]. These technologies will also become increasingly common in consumers' daily lives. As the future continues to become connected, smart and digitized, IoT and IIoT play a growing role in our professional and personal lives.

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