Business opportunities and evaluation of non-public 5G cellular networks – a survey

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***Abstract*— The family of cellular mobile telecommunications standards – including 5G – is mostly defined by the 3GPP standardizing organization. While these are well known in detail by researchers and engineers, but in the business world, people are unfamiliar with the concepts and the content of these documents. It is essential to define and designate how 5G is different from existing wired and wireless technologies, what are the main business benefits, and what are the key potential areas according to the new technology achievements. In our work, we present some fundamental aspects of the 5G business potential, where the key motives lay regarding the Industry 4.0 revolution and the innovation of 5G industrial architectures, including vendors, industrial players, and network operators.**

***Index Terms*—5G, Industry 4.0, Private cellular network, Business development, Industrial use-cases**

I. Introduction

The arrival and development of Industry 4.0 represent a revival similar to previous industrial revolutions in history. The revolution in Industry 1.0 was using complex machines to make work easier and faster instead of manual efforts [1]. The primary inventions of the first industrial revolution of 1784 were steam and chain-driven equipment, such as the weaving machine. The second industrial revolution took place in the 1870s when mass production first appeared — developing techniques for mass production and enabler functions such as assembly on a conveyor belt. The third industrial revolution dates back to 1969 when microelectronics brought a new phase of technology. Based on the program code, a robot/machine could perform several operations and work steps, replacing repeated/complex manual work. The fourth industrial revolution is underway, with production lines and robots becoming more intelligent. We are able to create robots that download and use the program, which means that the same production line can adapt to an industrial need very quickly. As a high-level example, at one minute, the workstation produces a Type A car, and in the other one, it can create a Type B car. To accomplish this, all equipment needs to be involved during the reconfiguration of the manufacturing process and must be connected as cyber-physical systems.

It is relatively easy to determine how much overall revenue can be gained from residential users on current mobile networks. This will not increase significantly in the future, as network operators have almost reached the limit of potential human users, and the population is declining in many countries. In most of the developed countries, more than 90% of the citizens have a mobile phone [2], but using only one or two Subscriber Identity Module (SIM) cards, as the customer does not need more subscriptions. While there are devices in a general household that can use up to 10 or 100 SIM cards, this number can be much higher in industrial use-cases. Mobile Network Operators (MNO) cannot expect significantly more revenue from traditional customers. On the other hand, industrial use-cases could mean a much larger market than before, which is almost completely untapped yet. Thus, the main target user base of 5G is not people but industrial devices, making industrial Campus Networks or as 3GPP defines Non-Public Networks (NPN) [3] one of the flagships of 5G. MNOs and vendors invest in this promise. Besides, they can still stay in the traditional mobile business, but a new market can be created with industrial Campus Networks, similarly to what happened 20 years ago with General Packet Radio Service (GPRS).

Industrial Campus networks [4] have a lot of potential and many directions for development, but the widespread adoption of these solutions is still in its infancy.

The main contribution of the current work is that we present various factors that should be considered to define the business model and pricing of future industrial mobile networks. Moreover, we present some technical parameters to help design, scale, and implement these networks from a service point of view. The paper is organized as follows: Section II summarizes the related work, discussing the potential revenue effects of 5G and the new 5G Non-Public Networks. Section III describes the industrial players' motivations. Section IV presents the key factors of industrial Campus Networks' pricing aspects and customer needs, including network scaling factors, pricing parameters, frequency trading and different types of Campus networks. Section V identifies the business opportunities of customers, discusses the technological risks and backup solutions. Section VI concludes the paper.

II. Related work

5G's new use-cases [5] are generating tension currently for service providers, device manufacturers, and the industry in general. It is clear that 2G-3G [6] and 4G networks are designed primarily for people in terms of use-cases. Of course, a significant number of machines are connected to

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DOI: 10.36244/ICJ.2020.3.5

these networks as end-devices, as well. The almost untapped resources to be provided by 5G are likely to be utilized by machines [7]. Therefore, it is worth separating services based on customer types, as users can be humans or machines [8]. In interpersonal communication, biorhythm has to be one of the important aspects of the network design. Human users' data consumption is related to their biorhythm, which defines the concept of busy-hour on traditional mobile networks. In contrast, machine communication is based on predefined scheduled programs, and the behavior is more determinable [9]. Human data consumption is more stochastic by nature. The current interpretation of busy-hour will probably disappear in the near future or at least significantly alter due to the nature of machine type communication [10]. This should have an impact on both network and service design. 5G network slicing is designed to handle efficiently these kind of network traffic profiles [11]. Networks should be designed [12], scaled, and tuned differently for humans and differently for machine-communication types of services. Machine type of use-cases can include not only the simplest household appliances or vehicles but also complex industrial robots [13]. Hard real-time connectivity – when a sensor-to-machine latency is less than 1 ms – will be utilized by several use-cases, however mostly by non-human applications [14]. With 5G, we will be able to achieve a real-time production monitoring [15], knowing the current state of equipment we are ordering, or the time when it is expected to be manufactured, with proper access rights from anywhere around the globe. It also facilitates the development of real-time business and the advancement of services where precision has immense business importance. All in all, this means that the economy as a whole will benefit from the spread of 5G [16].

To understand the exact economic effects, we have to examine which parts of the industry are affected and to what extent [17] [18] [19], [20]. According to a study published by Ericsson, it is estimated that the 5G-enabled industry digitization revenue for Information Communications Technology (ICT) players will reach $ 1.3 trillion in 2026 [21]. When examining the most prominent domains, energy and utilities account for 19%, industrial production is there for 18%, and it is worth highlighting the automotive industry, which accounts for 8% [21]. In terms of industrial networks, naturally, the factories are the main stakeholders. The short term industrial impact of 5G and Internet of Things (IoT) [22] is expected to be around 619 billion USD. Of course, this includes other high-impact domains utilizing 5G, such as connected cities and vehicles.

The 5G standards [23] and architectures provide an opportunity to build highly flexible private industrial networks [24]. Some services can run on a small portion of network elements. Therefore, we can utilize merely a small percentage of network resources to provide elementary service needs. This allows for designing services and implementations based on individual customer needs. With the interoperability of standards and interfaces [25], systems will be able to co-operate and provide a high-quality experience. 3GPP [3] will develop various solutions for the Non-Public Network [5], providing more options in terms of industrial network architecture. The most facile option is to install all the Core and Radio Access Network (RAN) elements required for service in the industrial area completely separated from any public mobile network (standalone isolated NPN – see Figure 1) [5]. The independence between this NPN and a public mobile network manifests in the use of a unique network identifier, the assignment of private spectrum to the NPN, and the full deployment of a 5G system (including RAN and Control Network) within the logical perimeter of the factory. There are several hybrid solutions where some Core elements are on-site adjacent to the dedicated RAN or shared RAN while others are located at the service provider (Public Network Integrated NPN – see Figure 2). The deployment of a public and private network in a Hybrid NPN solution can vary depending on the considered use-case and customer requirements.

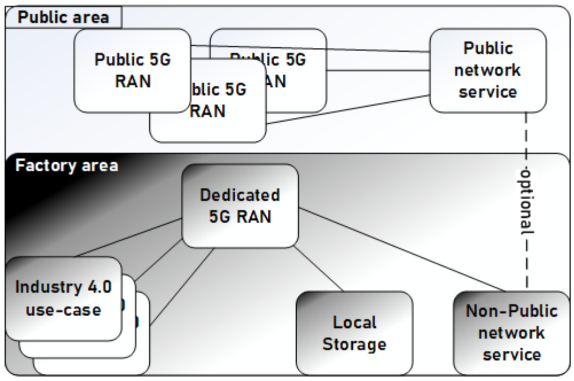

Fig. 1. Deployment as dedicated network

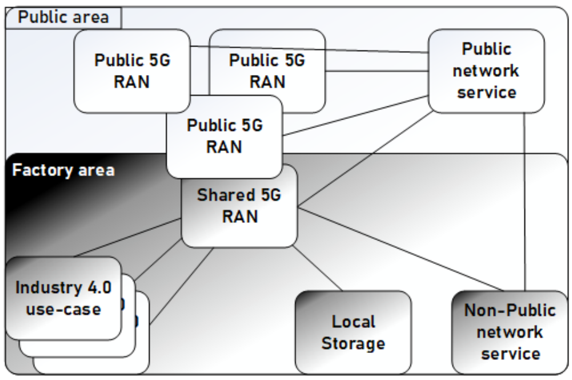

Fig. 2. Deployment with shared RAN and control plane

III. Understanding industrial players' network needs

It is crucial to identify the target groups involved in telecommunications. New technology can be successful if all the target groups are motivated for the new service, product, or technology. New investments are function-oriented: as long as there is no advanced function that the user needs – even if a new technology emerges –, they will not buy new assets, nor will vendors and operators invest in it. The idea of industrial Campus Networks and 5G itself appeared years ago, but now we have reached the point where each group has the motivation and the technical background to implement these types of networks cost-effectively. Taking advantage of these changes, there will be much more communication and feedback between participants in Industry 4.0.

In the case of industrial Campus Networks, we can identify the groups of contributors.

The first stakeholders are the Vendors – suppliers who manufacture the devices directly to the factory or for the MNOs. Examples include Ericsson, Cisco, Nokia, Huawei and so on. They need continuous technological innovations because otherwise, they would not have enough revenue from operation only. Their goal is constant innovation and constant generational change. For them, 5G becomes a ”matter of existence”. In the case of vendors, the issue of greenfield or replacement investment also arises. In the case of a greenfield investment, a new industrial competitor jumps into the development of the latest technology much more efficiently because this is the only way for them. Start-ups would not be able to compete with the prominent vendors in the existing markets anyway. It is easier for a new competitor to start investing in new technology as they do not have any existing infrastructure or network from which they would expect any Return of Investment (ROI). On the other hand, existing prominent vendors find it harder to invest in new technologies too early because they do not want to cannibalize their existing solutions. However, over time, they will have to, as potential competitors' pressure continues to grow. If they do not start investing in new technologies and succeed, they will definitely lose their market position in the future.

The second significant group is the Telecommunication Service Providers (TSP) or MNOs. With the rise of 2G, telco companies had not yet reached the customer limit; there was still a great potential user market that had not been exploited. With 3G, they were still able to grow in terms of revenue, due to the spread of the internet, and the spread of multimedia content. However, the market for 4G has not evolved and grown. Despite that, operators were forced to invest in it to avoid the reduction of their market share. However, they could not significantly increase their user base. It was just a matter of protecting existing markets and retaining revenue at 4G. For MNOs, sales may be stagnant at the moment, but the margin is melting, which results in downsizing and austerity – thus, they definitely need to find a new market. The greenfield and replacement investment phenomena mentioned at the vendors are also notable here.

Finally, in the case of industrial customers, there is a competitive situation. Industrial players can only produce cost-effectively and efficiently if they find a long term network solution that satisfies their needs.

IV. Factors influencing the pricing and designing industrial campus networks

A. *Network scaling*

Telco equipment suppliers are interested in creating a kind of oligopoly market for the MNOs. They often use a flexible interpretation of standards and apply proprietary solutions and protocols. Operators can design and build a network infrastructure more efficiently with a single-supplier solution, where spare parts management, troubleshooting and backup logistics are also much simpler. However, at the same time, vendors can abuse their monopoly position, which can result in price inflexibility and dependence. A multi-vendor environment makes operators less dependent, forces suppliers to compete on price, but in most cases raises interoperability issues and requires a more well-trained team of professionals. As a consequence, a continually increasing product portfolio will be available to the enterprise sector, where they can use separate, private mobile network solutions. Separation may also cover the exclusive use of the radio transmission medium or – similarly to edge-computing – the Core network can be located at the industrial site [26]. The benefits can come from the availability of dedicated resources such as pre-determined bandwidth, reduced latency, higher availability, and complete isolation of sensitive information even from the Telco operator.

Of course, such complex solutions cannot be designed, deployed, and operated without MNO's nearly 30 years of experience. The introduction of new features, implementation of software upgrades, possible troubleshooting, or capacity expansion cannot be solved without the know-how of MNOs. NPN or Campus Network solution is offered to business customers with higher service level requirements than what is possible on the public access cellular network service. As the operator cannot provide personalized service quality on public mobile data networks, there is no guaranteed bandwidth and availability. With NPN solutions, dedicated radio resources, customizable availability, and bandwidth can be provided to business customers for specific user groups at a given geographical location, according to the required services. The operator offers a solution that is separated from the regular Public network service according to the particular business needs using dedicated and redundant network elements to ensure the highest possible availability. It is only possible to access the customer's own internal Local Area Network (LAN) or even access the customer's private cloud-based data centers either via an Internet Virtual Private Network (VPN) or via leased line.

In response to different customer needs, several different NPN solutions can be defined, primarily in terms of the order of magnitude of the required customer terminal equipment and bandwidth. Besides, different architectures determine availability, the degree of on-site redundancy, the number of connection points between the operator and the customer, the number of hardware components that must be installed at the customer's site, and influence the technical solution and so on.

B. Pricing parameters for 5G NPNs

The pricing strategy of a given solution can be influenced by the parameters of the included devices, services, and different operator tasks. Such factors are as follows:

- Traffic-based pricing – based on the amount of data included;
- Creation of a closed and secure system (VPN) and only the subscriptions fixed in the contract can access the service;
- Different IP address assignment methods;
- Various authentication solutions;
- Central green number for handling error reports;
- Service charges at endpoints (SIM cards).

The service shall include the continuous operation, provision, installation, maintenance, and, if necessary, repair of the equipment and related components. After a certain period of time, it is possible to pay the monthly fee by the customer. Pricing is based on the total investment cost (Asset Cost and Construction Cost) plus annual upgrade fee, maintenance fee, data center costs, business and overhead costs, and margin.

Table I summarizes – from the perspective of MNOs – what the main Capital expenditure (CAPEX) items are during the investment. The Table presents the RAN, Cellular Core, and IP transport parts following Figure 1 and 2. In the case of RAN, the most important aspect is the size of the physical area. The fact that the covered area is a hall or an entire part of the city or an outdoor multi-km motorway test track section can influence several technical parameters. The first and maybe the most critical parameter is the used frequency, which can be considered the MNO capability and must be paid for on behalf of the national regulatory organization. The density and the number of transmitter towers and antennas will be greatly influenced by the required user number, data rate per user, and overall data consumption.

The Cellular Core part is influenced by the number of connected eNBs and gNBs, but an equally important factor is the number of connected users at the same time. In the case of machines, it can be assumed that most of them will be connected continuously, while humans will have peak and unused periods due to their biorhythm. Thus, in the case of machines, the focus should be on traffic service to be served in a continuous and uniform quality instead of occasional peak loads. In addition, as we showed in Section II, the architecture can specify which Core elements should be placed redundantly to the macro network.

The IP transport part seems easy at first, as “only” data transmission is required here; however, physical size and architectural solutions can have serious Capex consequences. It is challenging from the transmission technology’s point of view when the architecture consists of long-distance installed radio transcievers (eNBs/gNBs), and different core network functions in different locations.

TABLE I
Key parameters for dimensioning CAPEX of industrial cellular technologies

Radio Access Network	Cellular Core	IP - Transport
Physical size of network, Freq. band, max. data throughput/(user or area), max. subscriber number/(square meter or area)	# of eNB or gNB, # of customer, total data throughput, architecture	# of customer, architecture, total data throughput

C. The key players in the frequency trading of NPNs

In the case of mobile network services, it is essential to decide who provides the service medium, at what price, and what commitments are needed from the user. In terms of frequency management, 3GPP [27] defines three stakeholders that have played a crucial role in the market since the advent of mobile networks: the state, service providers, and customers. The state is the owner, and also the regulator of the reusable frequency bands. MNOs purchase (trade) frequencies from the state over the long term and create suitable services for the customers based on standards. While the customers/users use the service for typically as a form of voice calls or data services developed by the MNOs.

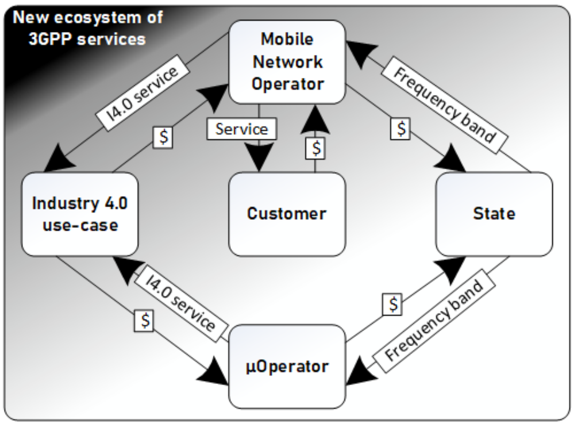

Fig. 3. New ecosystem on MNO market

We suppose there will be five players in the new Industry 4.0-MNO ecosystem. The relationships between them are shown in Figure 3. Traditionally the MNO pays money to the state in exchange for the frequency. On the other hand, they are contractually obliged to launch certain territorial coverage, population coverage or integrate several new base stations using the dedicated frequency bands. In the service providers’ prices, the cost of the frequency will play a role as a distributed expenditure cost. In return, the MNO receives dedicated frequency bands from the state for a fixed period, where the usable frequency band is guaranteed, and the transmitter’s power is typically regulated. Still, there is only a recommendation for the 3GPP standard to be used, MNO decides which technology to use on the frequencies. However, in recent years, companies requiring private/industrial mobile networks have emerged as third party frequency owners, also called micro Operators (μO).

μO receive a long-term dedicated frequency band from the state, but for a limited area. This way, new types of customers who take advantage of their use-cases will be able to connect directly to the μOs, eliminating the MNOs from the process. As this is an unknown area for all key players, the regulatory state has not defined any other frequency usage criteria. μOs are experienced typically in generating new ideas and Industry 4.0 use-cases for MNOs. This new type of operation/connection is also unique for the μOs and for the Industry 4.0 use-case customers. They have neither 3GPP-based network development nor operational experience. The operation of a 3GPP based cellular network can be a challenging task. Therefore MNOs cannot be eliminated entirely from the Industry 4.0 ecosystem. Even if the μO can provide dedicated frequency and some off-the-shelf NPN solution to the customer, MNOs still have the advantage that they can offer much more flexible NPN solutions customized to the customer unique needs. μOs opportunities will be limited by the manufacturer of their off-the-shelf NPN solution. Furthermore, in some countries, μOs cannot buy frequency directly nor from the MNO as national authorities can limit frequency purchase and usage conditions. For instance, in Hungary, these kinds of μO activities are not possible with the current regulation environment; only the big MNOs can buy frequencies. To increase complexity, the network-slicing feature that emerges with the development and integration of 5G standards will allow the MNOs to sell a time or frequency slice to a μO in the network, or vice versa, to offer a slice used by a μO to the MNOs. This will allow further transactions between each other and can threaten the existing relations among the MNO market.

V. BUSINESS DEVELOPEMENT FOR 5G

A. *Defining the potential customers and network types*

In Table II, different types of networks are presented, differentiated by architectural and Service Level Agreement (SLA) features. The four different types of network solutions are not created arbitrarily; they are determined based on the customer needs, our system integrator observations, and TSP experience. However, to understand each type of network and service feature, we still need to specify a few concepts, as the significant part of our target audience has more of the business approach. In explaining these concepts, we try to provide simple comprehensibility and an interpretation that is relevant in the present situation, rather than an entirely correct and standardized technological explanation.

Firstly SLA agreement is required, which is a commitment between a service provider and a client. Particular aspects of the service – Quality of Service (QoS), availability, responsibilities – are agreed between the TSP and the service user. The QoS is the description or measurement of the overall performance of a service or network. Perhaps one of the most crucial QoS features is that certain types of network traffic can be prioritized over other network traffic types. On public networks, voice traffic is treated that way. This feature will be vital in industrial cases, where industrial partners want to prioritize the network traffic of certain types of machines over the others. Still, there are several additional QoS parameters, such as delay, coverage, bandwidth, etc. Another critical concept is network availability, which defines the amount of time period – in percentage – when the network is fully operational. It is a crucial parameter for industrial scenarios. By network control, we mean resource management and customization, network separation from the public network, network security management, and dependency on the public network, and the TSP.

The four network types can be interpreted quickly based on the previously overviewed concepts. In the Type I network, the network still completely depends on the TSP and the public network. There are very limited customization options, but a private Access Point Name (APN) can be provided to the customer. A private APN can be used to create a logically independent network for the client's devices and users. In this case, unique authentication mechanisms and arbitrary firewall rules can be applied. A typical scenario is the private network of banks, where only authenticated users can connect to the network, such as bank employees, ATMs, store terminals.

Network Type II provides a dedicated radio resource in the form of radio repeaters in addition to the logical network separation. This can be useful in cases where the particular customer does not need a special QoS or high data rate, but the radio conditions are not satisfying in the given geographical area.

Network Type III provides some dedicated RAN and Core services, which means the network still depends on the public network, but it offers a high level of control and QoS customization. It can be suitable for private office networks. The main advantage here is the RAN and Core separation from the public network, thus the network parameters can be fully customizable, and a different SLA can be designed.

Finally, network Type IV is entirely independent of the public network. It is able to operate without any problems in case of failure or degradation of certain public network services. It offers full QoS customization and complete control of the network services. For industrial applications and factory sites, such networks will be deployed where very low latency, high bandwidth, dedicated resources will be crucial. A minor disadvantage is that there is no standard agreed-upon 5G stand-alone NPN according to 3GPP yet, and even the solutions of large mobile network vendors are not uniform.

The presented four options are similar to the NPN deployment scenarios of [5], primarily Type II and IV, but it is not equivalent to these cases. [5] examines the topic from the MNO point of view where the NPN RAN can be shared with the public network RAN or the whole network completely isolated. However, there are use-cases where complete network isolation is not possible or would be too expensive, but in contrast, simple RAN sharing would not provide the QoS requirements of the customer. Therefore, as we suggest, there are several use-cases where extended RAN solution would be the optimal choice, which means additional radio equipment e.g., Radio Dot, or Distributed Antenna System besides the public network's RAN. Our

TABLE II
CAMPUS NETWORK MAIN TYPES OF SOLUTIONS

Network architecture	Potential customer use cases	Main features	Limitations
Type I	Requiring advanced user management and logically separated network with possible closed network connection	Private APN No QoS customization Very limited control	Completely dependent on public network SLA can be similar to the public network's SLA
Type II	Sites with poor radio coverage, or special use-cases requiring more bandwidth, redundancy or less latency	Extended RAN Partial QoS customization Limited control	Some resources as on public network except the advanced radio coverage but it can not be considered as dedicated resources
Type III	Advanced user management and advanced radio coverage	Dedicated RAN + Shared Core services High QoS customization High level of control	Still depends on public network Extra resources and features can be used on the dedicated radio interface
Type IV	Industrial use-cases with strict SLA requirements low-latency, high availability	Stand-alone network, Dedicated RAN + Core services Full QoS customization Full control	Standardization is still in progress

network differentiation does not specify all options. Individual cases may vary according to individual customer needs, as they can be expanded with certain services or even simplified. An additional aspect of network design can be the degree of redundancy, which is typically determined by the particular SLA. Similar features are network monitoring and support by the TSP, which also affects the network design and implementation. Currently, there are no real guarantees for the network services in contractual form for public networks. In the case of corporate networks, there are more strict guarantees and penalties, but mostly it only covers data consumption. In the future, this will change drastically for Campus Networks, where additional parameters, such as latency, throughput, jitter, and other key features will be included in SLAs.

B. Infrastructural investment

The range of potential customers can be divided into three groups from an infrastructure point of view, which significantly determines the possible development guidelines.

In the case of a greenfield investment, the industrial customer has not yet implemented the production processes. They have the opportunity to adapt them to meet the expectations of the desired industrial network. Unfortunately, in some cases, the industrial customer is unwilling to adapt its production workflows to the needs of the industrial network or is more expensive to redesign the workflows rather than the telecommunication network. In most cases, the TSP has to design the network according to their concepts and workflow. If there is no other way, and the TSP can not implement the appropriate telecommunication network for the workflow, then the industrial customer is willing to adapt. Still, the role of adaptation is usually the task of the TSP.

Another essential feature of greenfield investments is that all assets are bought at the same time. At that time – at the beginning of the investment – the industrial players react differently to the expenses of the telecommunication network. It is much easier for companies to spend more Capex than later when services are already in operation, and the infrastructure is ready. The telecommunication network is a relatively small expenditure, in contrast to other elements of industrial investment. When the installation is already done and the network is not fulfilling the requirements, the rebuild of the network or the replacement of certain elements could lead to a substantial expenditure compared to the initial situation. It can significantly affect the ROI, one of the most fundamental performance measures (also Key Performance Indicator) of an investment.

When there is some existing network solutions already built, most of the time, the industrial player does not want to replace their network infrastructure, as the costs of construction are high and have not yet returned. Therefore, the customer is more inclined to complementary solutions than to replace the entire network. This is a significant difference between TSPs and green-field investments. Thus, it is necessary to adapt to the needs of the existing network architecture and equipment. In general, these additional installments represent a significantly more substantial investment than if the same telecommunications network were to be implemented as a green-field investment. The TSP can not offer and install the optimal, cheapest, and most efficient implementation due to the existing network dependencies. Furthermore, it is not possible to finish these network installations quickly, as in many cases, production processes can not be interrupted at any time. There will be predefined time windows for these kinds of tasks.

Finally, there are cases where the industrial player has an existing network solution, but it is obsolete and needs to be replaced. So it can now be considered as an almost green-field investment in terms of the telecommunications network. But it differs from a green-field investment as it can be considered what might be worth keeping and using from the previous network infrastructure.

C. Business and technological risks

When planning a new investment, in addition to revenue, it is worth paying attention to the risks that threaten income.

These can be natural disasters or unforeseen events such as war, rebellion, or the fall of governments or pandemics. These events are usually associated with a risk when a network or service failure is not caused by the TSP nor by the equipment. In such cases, the TSP can not influence the events, and they are also a passive endurer. It is necessary to consider the dependencies of a new service and network, and those activities that can make the industrial network vulnerable.

1) Service failure or degradation: As none of the networks operate without errors and service degradation, it is worth considering the various external and internal risks when determining the price of the service during business negotiation and planning. The given service must be examined from the following aspects:

- What is the size of the system and what type of services it provides. Further, the expected damage in case of failure must be examined;
- What type of alternative solutions can be provided in case of failures? Is it enough to offer some modest-quality solution, a fully redundant option, or nothing at all?

From these two concepts above, it is possible to calculate the amount of damage in the event of a certain period of network failure.

2) The importance of redundancy and backup solutions: The cost of built-in backup systems is always extremely high, and hopefully, it will never be in use. Also, the clear return of its investment is quite unlikely. On the other hand, installing a backup system is still recommended in the case of critical services. If human life depends directly on the system, it is absolutely obligatory to design a backup system, to minimize the possible damage. However, this raises several additional questions, which are sometimes philosophical:

- What happens if the machine loses communication with the server? Does it have a default program/state to return to? Or does it execute the last instruction?
- How does the machine/executable program notice the incorrect instruction? Simple counter, logic, or security algorithms can be used, but how do we detect an instruction that the controller issues incorrectly? There may be an instruction that the controller knows about and will be harmful to either a human or to another unit.
- If a robot does not receive instructions for a given time, how to react? Does the executing robot need a self-defense function, i.e., do you notice that it executes the same command indefinitely and has gone into an infinite loop? Does the robot need a self-stop or self-defense function then?
- Should a machine have an emergency mode where self-defense limits can be overridden? Will the executing device know whether the execution of the operation will significantly reduce its own life cycle, or even in reaching its operating limit, should the machine execute this instruction?

These questions are quite crucial as in the first phase of Industry 4.0 mixed environment will be typical. It means that machines and the human workforce will be operating in the same industrial area, where machines can not threaten human life in any circumstances. Another simple example is automated driving, which includes road accident liability as one of the most fundamental aspects of technological integration.

ACKNOWLEDGEMENTS

This work has been performed in the framework of the H2020 project 5G-SMART co-funded by the EU. The authors would like to acknowledge the contributions of their colleagues. The consortium is not liable for any use that may be made of any of the information contained therein.

VI. CONCLUSION

In this paper, after a brief historical overview, we summarized existing studies on the business effects of 5G. In addition to the short technology analysis, our focus has shifted mainly to changes in Industry 4.0 business opportunities. We identified the major players involved in Industry 4.0 and presented their function and possible future role in Section III. An important finding is that, with the arrival of 5G, μOperator and industrial manufacturers will also have a crucial role in the mobile network ecosystem. On the other hand, MNO will enter the industry as an operator expanding their market. We highlighted the advantages and drawbacks of a green-field investment in terms of business development and presented what factors and parameters need to be considered during the pricing of Campus Networks, including the key players of trading frequencies for NPN. Four different types of network solutions are distinguished, focusing on the key features, potential customer use-cases, and limitations of these networks. The main contribution of Section IV is not an architectural definition of the different NPN deployments, rather, we are highlighting these network options, limitations and motivations; moreover, the paper presents some typical use-cases for every scenario. Finally, we analyzed the business and technological risks of industrial 5G networks, presented research questions and concepts, and mentioned some ethical issues.

This paper analyzed the state of 5G NPN, primarily the business opportunities and key players was presented, while from the technical side only high-level evaluation was performed. In the future, we prefer to make further examinations in both domains. From a business point of view, MNOs and μOs benefits would be examined, including the business motivations of cloud solutions, frequency allocation issues, network slicing potentials and energy-efficient networks. Furthermore, it would be interesting to describe how these new features change the network architecture of MNOs, highlighting the main effects on the Core and Radio elements from the business- and also the technical-side.

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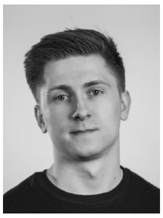

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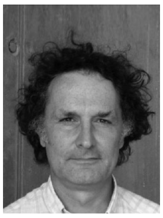

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