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# THE IMPORTANCE OF SPECTRUM LIBERALIZATION FOR PRIVATE 5G NETWORKS

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## 1. INTRODUCTION

Fifth Generation cellular connectivity (5G) is here and will facilitate a wide range of applications and services, not only in the consumer domain, but more importantly, in the enterprise vertical domain.

Considering the enterprise verticals, 5G is much more than “just another G.” The introduction of Enhanced Mobile Broadband (eMBB) and Enhanced Ultra-Reliable Low-Latency Communication (eURLLC) will enable a completely new set of use cases on factory floors, in shipping ports or warehouses, and in mines or oil fields. Furthermore, by allowing the connection of 1 million devices per Square Kilometer ($km^2$) through Massive Machine-Type Communication (mMTC), 5G will enable setting up massive wireless sensor networks and, therefore, be a key enabler for Internet of Things (IoT) applications.

While recent 5G network deployments in the consumer domain have already shown great success, 5G will have the capabilities to expand the reach of cellular connectivity to the enterprise verticals, therefore unlocking additional markets. By operating private cellular networks in the enterprise domain, 5G will open new revenue opportunities for the entire telco industry. To understand the magnitude of this enhancement, ABI Research recently looked at the Return on Investment (ROI) horizon of 5G, which showcased that the time it will take for 5G investments to break even will be reduced by one-third with enterprise business models in place.

Even though revenue opportunities are much higher than in the consumer market, the enterprise verticals domain is much more fragmented and harder to address with a traditional telco approach. Furthermore, it needs to be understood that bringing 5G to the enterprise sector is a marathon, rather than a sprint, mainly because of the progress of relevant standardization by The 3rd Generation Partnership Project (3GPP). While eMBB capabilities have already been standardized with Release 15 (frozen in 2019), eURLLC capabilities and the support for Time-Sensitive Networking (TSN) will only be standardized with Release 16, which was frozen in early July 2020. Commercial deployments at scale will only start toward the end of 2021/beginning of 2022.

From a spectrum point of view, Release 16 includes important standardization work for the operation of 5G New Radio in unlicensed spectrum bands (referred to as NR-U). In contrast to License Assisted Access (LAA), 5G NR-U also has a standalone option, which means it will not require any anchor in licensed spectrum, so it allows implementers to operate their own private network without having to invest into licensed spectrum (either directly to regulators or through Mobile Network Operators (MNOs)).

A rising number of enterprises are looking at deploying private on-premises cellular networks, with only very limited interaction with public cellular networks so that they can customize the network to the respective specific requirements regarding network performance and data integrity. Enterprises can achieve this either by using licensed spectrum through MNOs or by spectrum sharing arrangements, giving enterprises direct access to licensed spectrum (further described in Section 2). Alternatively, the use of unlicensed spectrum with technologies like MulteFire and NR-U offer enterprises an alternative opportunity to manage and operate their own private network.

To understand the value of unlicensed spectrum and cellular deployments using MulteFire or NR-U technology for enterprise connectivity, it is important to consider recent developments regarding the regulatory environment that will allow enterprises, in some cases, to acquire licensed spectrum. Subsequently, this whitepaper focuses on industrial manufacturing, ports & logistics, and mining & energy to determine the value of private cellular networks and the role of unlicensed spectrum and MulteFire technology to realize the associated enhancements.

## 2. SPECTRUM OPTIONS FOR ENTERPRISE 5G DEPLOYMENTS

While traditionally, licensed mobile networks have been exclusively available to network operators, there is a growing momentum for different initiatives across the globe that allow enterprises to come into possession of licensed spectrum directly. These spectrum sharing arrangements affect the value proposition and could decrease the attractiveness of unlicensed spectrum for enterprise connectivity, so it is important to understand these initiatives in order to assess their impact on unlicensed spectrum. While each of these spectrum sharing arrangements differ in their technical background and the specific mechanisms through which spectrum is shared, their commonality is that they allow enterprises to acquire spectrum assets directly that had previously been available to them only through leasing from MNOs.

## 2.1. SPECTRUM SHARING BETWEEN PUBLIC AUTHORITIES AND ENTERPRISES (UNITED STATES, CBRS)

The Citizen's Broadband Radio Spectrum (CBRS) is a U.S. initiative giving enterprises access to shared spectrum though a coordinated national framework that includes spectrum sensing and spectrum databases. This has allowed enterprises to lease spectrum that was previously available only to public authorities. The most prominent and commercially relevant example is the CBRS spectrum band (3.55 Gigahertz (GHz) to 3.7 GHz), primarily used by the U.S. government for radar systems, which is now being made available for use by licensed users with a Priority Access License (PAL) acquiring spectrum access through an auction that was to start in July 2020, or registered users with General Authorized Access (GAA). Incumbents' rights to use the spectrum band (such as the military, satellite providers, or Wireless Internet Service Providers (WISPs)) will remain unaffected.

In order to prevent different users from interfering with each other, a Spectrum Access System (SAS) is employed to automatically assign frequencies on the CBRS band based on a three-tiered system to set out a clear hierarchy for spectrum access:

- **Tier-1 Users:** Incumbent users of the CBRS band, such as the military or fixed satellite operators
- **Tier-2 Users:** Network operators (and other holders of a PAL)
- **Tier-3 Users:** Private enterprises that have applied for GAA

The success of using shared spectrum for enterprise connectivity depends heavily on the maturity of the supporting device ecosystem. The United States is characterized by a mature and strong device ecosystem, represented by the CBRS alliance as well as a number of Open Radio Access Network (RAN) network infrastructure vendors, which explains the initial success, with deployment projects reported to be in the thousands (as of January 2020). In regions without this strong device ecosystem (e.g., Europe or Asia-Pacific), shared spectrum arrangements have not spurred as much interest within enterprises as regulators had hoped. While there are more than 300 applications for GAA on the CBRS band, in Germany, national regulator Bundesnetzagentur (BNetzA) has counted 50 applications (including Proof-of-Concept (PoC) projects and commercial 4G deployments) for locally licensed enterprise spectrum, which is further described in Section 2.4.

## 2.2. SPECTRUM SHARING BETWEEN OPERATORS AND ENTERPRISES (UNITED KINGDOM)

Another way for enterprises to gain access to mobile network spectrum assets is by gaining access to spectrum resources previously held by MNOs. One of the prominent examples of such an arrangement is British regulator Ofcom making spectrum available for enterprises on the C-Band (3.8 GHz-4.2 GHz), which is licensed to different MNOs. To guarantee efficient spectrum allocation, enterprises can apply for access, if the operator is not currently using the spectrum and does not have any intentions to do so for the three subsequent years. Spectrum reallocation requires a lengthy and complicated on-site evaluation, which is complemented with arrangements as described in Section 2.1, in which Ofcom opens access to spectrum assets on the 1.8 GHz and 2.3 GHz bands. These bands are not auctioned to network operators, so enterprise applications for spectrum assets on these bands are considerably easier and less time consuming than on the 3.8 GHz band.

## 2.3. SPECTRUM SHARING ON THE 1.9 GHZ FREQUENCY BAND (JAPAN)

Traditionally used for Digital Enhanced Cordless Telecommunications (DECT) and Personal Handyphone System (PHS) services, the Japanese Ministry of Internal Affairs & Communications decided to open the 1.9 GHz frequency band (part of the 3GPP band 39) for enterprises to operate private/unlicensed LTE networks on that band. In order to drive enterprise digitalization, the Japanese ministry decided to open a bandwidth of 5 Megahertz (MHz) to enterprises in October 2017, which is also referred to as a Shared Extended Global Platform (sXGP).

Having worked in partnership with the XGP forum, MulteFire Alliance added support for band 39 to the MulteFire 1.1 specifications, which allowed the first commercial rollout of MulteFire technology in Japan.

## 2.4. LICENSING SPECTRUM FOR ENTERPRISES ON A LOCALIZED BASIS (GERMANY)

In addition to spectrum sharing between public bodies or MNOs and enterprises, a third model is emerging that allows enterprises to come into possession of cellular network spectrum without having to rely on network operators' spectrum assets, as a growing number of national regulators (especially in European countries) decide to set aside a certain portion of cellular network spectrum for enterprise usage exclusively. One of the early adopters has been German regulator BNetzA, which set out respective guidelines as early as November 2018 to provide 100 MHz of spectrum on the C-Band (3.7 GHz-3.8 GHz). These frequencies are awarded through direct applications to the regulator, rather than public auction. To ensure that this spectrum will be used as efficiently as possible, enterprises are granted a maximum period of 12 months for network deployment and commissioning. Similar initiatives are arising in European countries like France, the Netherlands, and Sweden following comparable requirements.

Currently, setting aside mobile network spectrum is limited to C-band spectrum, but there are clear plans to adopt a similar framework for millimeter wave (mmWave) spectrum in the years to come. Germany is planning to release 100 MHz of spectrum on the 26 GHz and 28 GHz bands for enterprise verticals by summer 2020, while the European Commission is actively pushing member states to follow suite in 2020 or 2021.

While the use of unlicensed spectrum offers an affordable deployment solution for enterprises looking to deploy a private network for basic factory automation purpose, the access to licensed spectrum (either from regulators directly or through MNOs), allows enterprises to deploy 5G private networks, even for mission-critical use cases, where deterministic networking is required to guarantee non-interference from unauthorized devices.

In addition to network determinism, globally harmonized access to spectrum is another dimension that enterprises will consider in their decision to deploy a cellular network, as they might be looking to connect a multitude of different sites in different countries or contents with each other. Currently, access to licensed mobile network spectrum is highly fragmented, so the use of unlicensed spectrum would offer globally harmonized spectrum access.

The availability of multiple different types of spectrum for enterprises will strengthen the value proposition of 5G private networks to the enterprise verticals, as it increases the degree of customizability, depending on the enterprise use cases.

## 3. 5G APPLICATIONS IN THE ENTERPRISE VERTICAL DOMAIN

Having explored different arrangements that allow enterprises to deploy a private cellular network using either licensed or unlicensed spectrum, it is now time to look at the opportunities for private cellular networks in different enterprise verticals to understand how the use of unlicensed spectrum and the MulteFire technology will enable realizing the immense benefits that are ascribed to enterprise 5G. In line with industry expectations, ABI Research expects the main interest in private cellular networks will come from the manufacturing, shipping ports & logistics, and the oil & gas industries.

## 3.1. INDUSTRIAL MANUFACTURING

One of the most promising use cases for mobile cellular connectivity certainly is the industrial manufacturing domain. Looking at the factory floor of today, fixed-line connections make up 90% of the total number of connections in industrial manufacturing, while the remaining 10% consist of wireless technologies. This highlights the need to modernize communication infrastructure to be able to fully profit on the promises that come with Industry 4.0. In line with that, ABI Research expects the number of wireless connections to grow exponentially, making up 85% of all factory floor connections in 2030, while fixed-line connections will contribute the remaining 15%.

### 3.1.1. Technology Aspects

In order to transform the connectivity landscape on the factory floor, manufacturers need to meet certain technology requirements. While these requirements largely depend on the distinct set of use cases that manufacturers address, reliability and network availability are of key importance, irrespectively of the use case, with a minimum of five-nines reliability (99.999%) demanded by manufacturers to prevent valuable production losses due to network unavailability. Table 1 shows the specific network performance requirements by use case, distinguishing between motion control and mission-critical use cases (e.g., mobile machine control panels), as well as process and workflow automation use cases.

***Table 1:***
*Industrial 5G Use Cases Network Requirements*

*(Source: ZVEI)*

| Use Case | | Availability | Cycle Time (Latency) | Typical Payload Size | Number of Devices |
|---|---|---|---|---|---|
| Motion Control | Printing Machine | >99.9999% | <2 ms | 20 bytes | >100 |
| | Tooling Machine | >99.9999% | <0.5 ms | 50 bytes | ~20 |
| | Packaging Machine | >99.9999% | <1 ms | 40 bytes | ~50 |
| Mobile Control Panels | Assembly Robots/ Milling Machines | >99.9999% | 4-8 ms | 40-250 bytes | 4 |
| | Mobile Cranes | >99.9999% | 12 ms | 40-250 bytes | 2 |
| Process Automation | | >99.99% | >50 ms | Varies | 10,000 devices/km2 |

To enable key advantages of cellular connectivity, a deterministic network, custom security mechanisms, and mobile edge computing (enabling low latencies) on the enterprise's premises to guarantee the required low latencies, at least part of the cellular network needs to be dedicated exclusively to the implementer to control and there are different ways to achieve this.

Most prominently, manufacturers are looking into setting up their own private network, completely detached from any public cellular network. According to a recent ABI Research study, 66% of manufacturers across different manufacturing areas favor this deployment scenario. Connectivity could be provided either by MNOs using their licensed spectrum assets or by the enterprises themselves, if there are regulations in place that allow enterprises to come into possession of licensed spectrum. Using unlicensed spectrum (for example, through deployment of NR-U or MulteFire technology) offers an alternative deployment scenario for enterprises that want to deploy and operate their own cellular network without MNO involvement, regardless of the existence of flexible spectrum sharing models.

Furthermore, the industrial manufacturers looking at deploying private cellular networks on their factory floors typically operate several manufacturing sites in different countries or even continents, which they are looking to connect. In order to guarantee that cellular modules work seamlessly in any of these production facilities without having to worry about interoperability of machine components in different regions, these enterprises require access to globally harmonized spectrum. Current spectrum sharing arrangements for enterprises are very fragmented and country-specific, so using unlicensed spectrum (e.g., on the 5 GHz frequency) offers a viable alternative.

### 3.1.2. Business Case Aspects

Production processes are becoming more complex in response to the further digitalization of production workflows in the wake of Industry 4.0, so the number of machines and components requiring connectivity will increase further. Costs are around US$225 per cable drop, which also increases the overall costs of wiring a factory floor to several US$100,000s. In addition, costs of renewing fixed-line connections, especially when it comes to heavily rotating equipment, must be considered. Furthermore, fixed-line connections result in a somewhat rigid production layout based on defined production lines, while manufacturers demand greater flexibility in designing their production processes. To provide this flexibility, connecting production machines wirelessly is of key importance.

Looking at automotive manufacturing, for example, the current rigidity in production layout requires a new factory for each new car model that is built. In addition to the costs associated with building and wiring a new factory, time-to-market is another important consideration, as wiring a new car factory takes, on average, 9 months (the same time as planning for a new car model). Increasing the flexibility of factory production enables changing the layout of production lines within days (rather than months), resulting in a considerably shortened time-to-market.

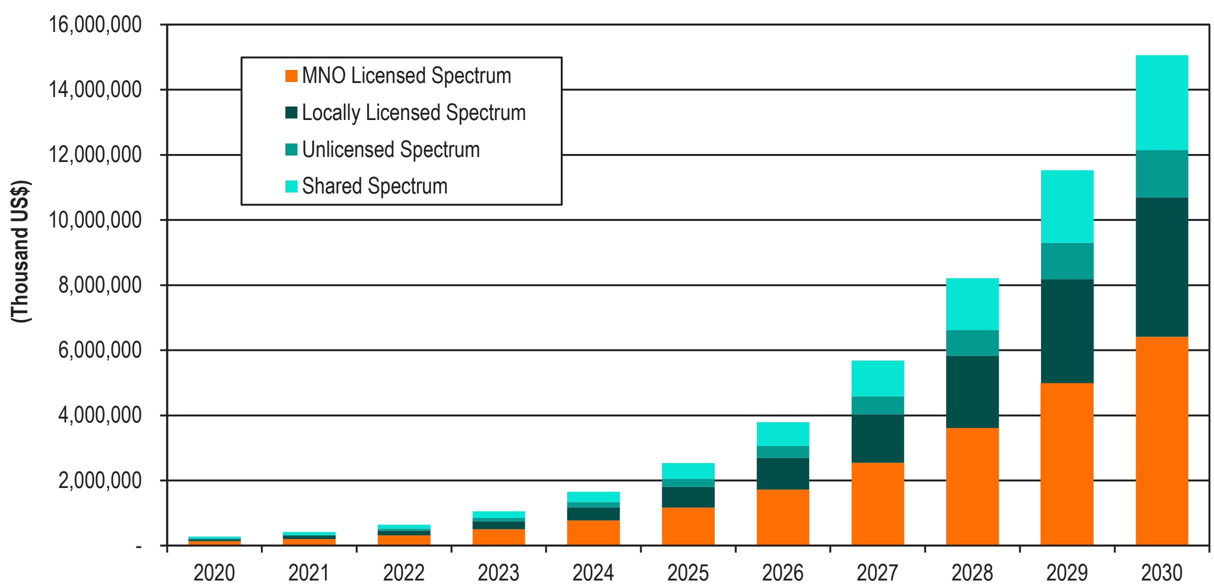
In addition, current fixed-line connectivity on the factory floor is largely dominated by the use of proprietary protocols (e.g., PROFINET or ETHERCAT), which are governed by a very small value chain and often lock the implementer into a specific vendor. By supporting TSN as of Release 16, 5G will guarantee the same level of determinism as proprietary protocols, such as PROFINET or ETHERCAT. Cellular connectivity either in licensed or unlicensed spectrum relies on cross-industry standards, which democratizes the value chain and guarantees interoperability between different equipment. Not only would this make interoperability between machines easier, but it would also enable simpler retrofitting of industrial machinery. The lifetime of industrial machinery usually exceeds 20 years, so enabling retrofitting is one of the main concerns for manufacturers.

In terms of market sizing, ABI Research forecasts that the Total Addressable Market (TAM) for private network equipment in industrial manufacturing will grow from US$275.26 million in 2020 to more than US$15.06 billion by 2030. While ABI Research forecasts that network deployments in licensed spectrum will account for more than 70% of this revenue (translating to US$10.69 billion by 2030), shared spectrum deployments are expected to contribute 19% of revenue, translating to US$2.91 billion by 2030. Consequently, network deployments using unlicensed spectrum are forecast to account for revenue of US$1.45 billion (10% of private network revenue). Looking closer at the addressable market for licensed spectrum deployments, network deployments using spectrum that is licensed to MNOs will generate revenue of US$6.41 billion, while deployments in locally licensed ("dedicated") enterprise spectrum will amount to US$4.28 billion by 2030.

***Chart 1:*** *Industrial Manufacturing Private Network Revenue by Spectrum Type*

*World Markets, Forecast: 2020 to 2030*

*(Source: ABI Research)*



## 3.2. PORTS & LOGISTICS

Shipping ports and logistic environments are very complex, characterized by multiple concurrently running processes. From a connectivity point of view, this carries two important implications: 1) the requirements for automating these processes are particularly stringent; and 2) the operational benefits gained from automating these workflows are particularly large.

### 3.2.1. Technology Aspects

Resulting from the variety of concurrent workflows and processes that need to be automated, the performance requirements for networking solutions to address these use cases are particularly stringent. While the remote operation of ship loading cranes (the so called Rubber Tire Gantries (RTGs)) involves transmitting large amounts of video footage, particularly high uplink throughput of at least 30 Megabits per second (Mbps), the real-time operation of Automated Guided Vehicles (AGVs) and Autonomous Mobile Robots (AMRs) requires latencies of no more than 30 ms. To minimize disruption to the supply chain because of machine downtime or faulty operations, reliability and availability of the network needs to be as close 100% as possible, with five-nines reliability (guaranteed by 5G URLLC capabilities) as the minimum requirement.

In addition to these use case-specific key performance indicators, a 5G standalone network will allow setting up multiple separate virtual network slices within the same physical network infrastructure. This will allow enterprises to address a range of use cases with the same physical network, instead of having to deploy multiple connectivity technologies.

Deploying on-premises edge capabilities and shifting processing capabilities toward this on-premises edge will strengthen network integrity and help enable sub-10 ms latencies that will be standardized with eURLLC capabilities. To safeguard integrity of the network data of ports and warehouses, at least part of the network control would ideally reside on the implementers' premises, so that sensitive data on the condition of equipment do not have to leave the premises). However, in order to integrate smart logistics applications into the wider supply chain, a cellular network deployed on the premises of a shipping port or a large warehouse ideally needs some connection to a public cellular network. This could be achieved by installing local breakouts or sharing certain network functions between the public and the private cellular networks.

### 3.2.2. Business Case Aspects

In line with the variety of use cases, the benefits of wireless over fixed-line connectivity vary depending on the application.

Locking at remote operations in shipping ports, the alternative to remotely operating RTGs would be to return to manual operation, which would need one operator per RTG. Teleoperation enabled by wireless communication, on the other hand, allows each worker to operate up to four cranes concurrently, resulting in a four-fold efficiency enhancement. At the same time, automated quality control of loading mechanisms can identify (or even prevent) faulty loading of cargo ships and reduce the negative business effects resulting from supply chain disruptions.

Early deployments of 5G capabilities on the premises of the port of Hamburg or the Shanghai Yangshan Port in China show that automating workflows could reduce operating costs of a port by as much as 70% and dramatically increase the QoS by minimizing the risk of faulty loadings.

A similar picture emerges when looking at early cellular deployment projects in warehouses. By introducing 5G on the warehousing floor, a logistics giant in Shanghai managed to reduce inventory turnover by a total of 37 days. Furthermore, delivery performance was improved by 25%, while long and short-haul transportation costs could be cut by 10%, and wasted pick-up runs dropped by 23%.

In a recently undertaken ROI study, ABI Research calculates that the average Tier One warehousing operator could decrease its yearly Operating Expenditure (OPEX) by as much a 13% by introducing cellular connectivity on the warehouse floor, across different geographical regions.

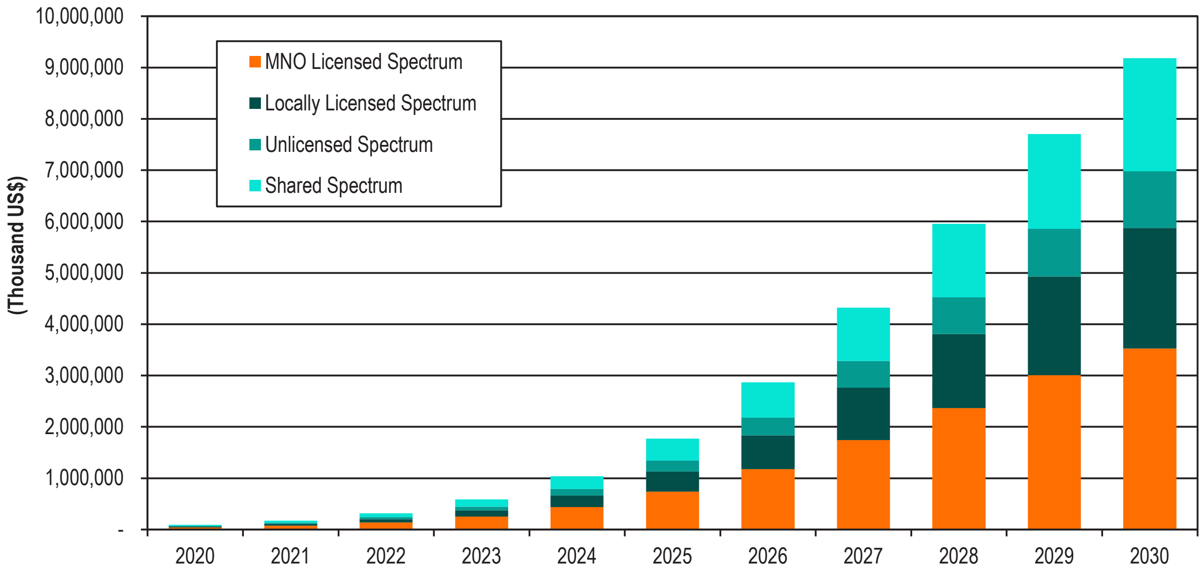
The use of unlicensed spectrum to automate warehouse workflows can provide an even more affordable deployment scenario than using licensed spectrum either through an operator or through spectrum sharing. British online giant Ocado, for example, is deploying cellular technology using the 5 GHz frequency in its warehouse in Andover, Hampshire to power thousands of robots to process more than 65,000 orders per week. Because of robust handover that cellular connectivity offers compared to current Wi-Fi-based solutions, it can achieve a speed of up to 4 Meters per Second (m/s), which represents an increase of 30% as compared to AGVs relying on current Wi-Fi connectivity.

In terms of market sizing, ABI Research forecasts the TAM for private networks will increase from US$91,45 million in 2020 to US$9.18 billion by 2030. Network deployments using any form of licensed spectrum are expected to contribute US$5.88 billion by 2030, accounting for 64% of overall revenue. Private network deployments in MNO-licensed spectrum will generate revenue of US$3.53 billion, while deployments in locally licensed, dedicated enterprise spectrum will account for US$2.35 billion by 2030. Shared spectrum and unlicensed spectrum deployments are forecast to contribute 24% and 12% to 2030 revenue, translating to US$2.2 billion and US$1.1 billion, respectively.

***Chart 2:***
*Ports & Logistics Private Network Revenue by Spectrum Type*

*World Markets, Forecast: 2020 to 2030*

*(Source: ABI Research)*




## 3.3. MINING & ENERGY

The mining & energy sector is characterized by a particularly hazardous environment, where the main benefits from automation are less exposure for a manual workforce to hazards, as well as safer, more efficient workflows. Use cases focus on the remote control of vehicles and machines or smart ventilation, using many sensors to control the airflow inside a mine.

Furthermore, as the current situation around lockdown measures in response to the outbreak of COVID-19 has shown, the mining & energy sector is in need of further digitalization to reduce OPEX in order to increase profitability, even in situations of low-energy demand.

### 3.3.1. Technology Aspects

From a technology point of view, three fundamental considerations are motivating the digitalization within the mining & energy sector: increasing productivity, safety, and sustainability.

The cellular network is used primarily for mission-critical applications, so network reliability and availability are pivotally important. A loss of signal, even for just a few seconds, could cause major disruptions to the operation of the entire site.

When considering the geography of the typical energy production site, two challenges arise for a wireless connectivity solution: 1) in a mine, propagation of Radio Frequency (RF) waves through different kinds of stone is difficult; and 2) oil and coal fields cover particularly large areas (up to several thousands of km2), requiring a particularly wide coverage area.

Networking data are highly sensitive and attacks on the network communication could have devastating effects on the continuity to a large area, making network integrity of key importance. Operating a private onsite cellular network with deterministic frequencies will enable the stringent requirements toward network integrity, which can be done either by using licensed spectrum (through MNOs or a shared spectrum arrangement, where in place) or by using unlicensed spectrum either in the 1.9 GHz or the 5 GHz band.

### 3.3.2. Business Aspects

One of the main advantages of digitalizing operations on energy excavation sites is the lessened dependency on manual labor, so fewer workers would need to be sent into hazardous environment. Studies suggest that by automating workflows in a mine, up to 50% of the manual jobs can be replaced. Furthermore, by connecting operations and automating workflow processes, operators can optimize energy consumption of mines and oil fields. Early trials suggest that up to 54% of energy consumption within a mine can be saved. Considering an average energy consumption of 36 Megawatts (MW) per mine per year, this would translate into energy savings of around 18 MW per year.

In comparison to other wireless technologies, cellular connectivity offers a valuable addition to the portfolio, especially when considering challenges around propagation of RF waves, because it supports a larger coverage area per base station, as well as more robust handovers between base stations. In the Las Bambas copper mine in Peru, for example, mining operator Rio Tinto managed to replace 17 Wi-Fi Access Points (APs) with a total of 3 private Long Term Evolution (LTE) stations. While a single LTE base station is reported to cover up to 6 km of tunnel, it would take 60 Wi-Fi APs for the same area of coverage. In addition, the price advantage of cellular connectivity over Wi-Fi also holds when considering the cost per base station (or Wi-Fi AP). The more robust handover between cellular base stations (as compared to Wi-Fi APs) is important to guarantee constantly high QoS, especially in a mine, which is characterized by non-ideal conditions for propagation.

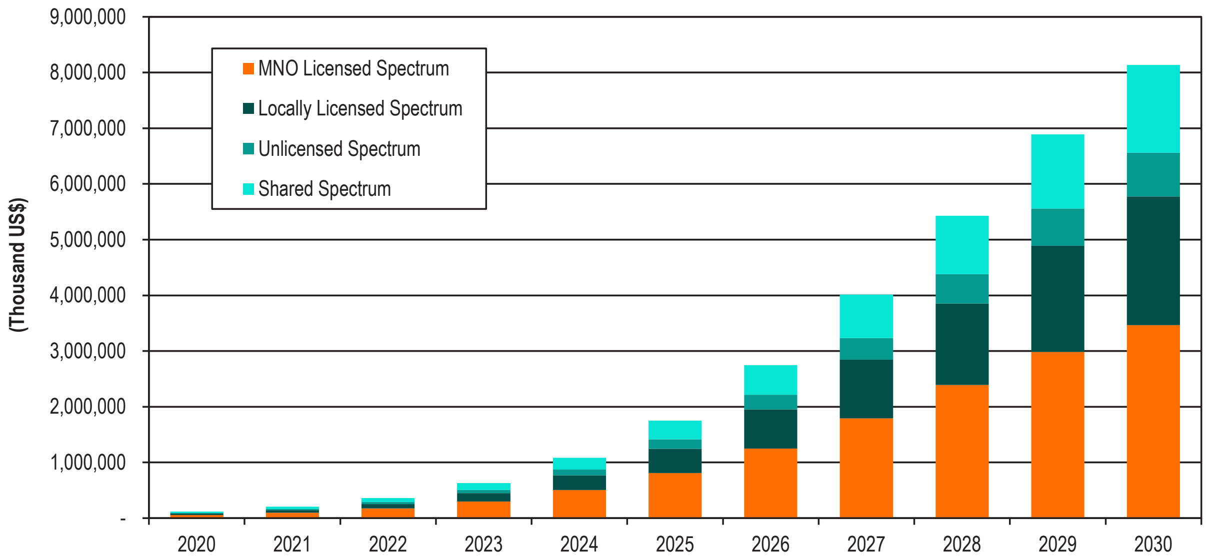
In addition, cellular connectivity can also enhance revenue potential by enabling overall digitalization of energy excavation sites to increase and automate end-to-end supply chain visibility. This is an important move away of manual calibrations of field operations to align with demand, which could take weeks of planning in a process relying on manual components. In contrast, an automated supply chain will enable suppliers to immediately scale up oil & gas production in high-demand situations or scale down production to react to a reduced demand instantly. On one hand, this will guarantee a stable price level that is not subject to demand volatility. On the other hand, it will guarantee that energy suppliers realize the maximum available revenue opportunity by instantly scaling production in a high-energy demand situation.

When it comes to looking at the market size for private network in the mining & energy domain, ABI Research believes that the majority of private network deployments will use licensed spectrum. While the overall addressable market is expected to increase from US$116.86 million in 2020 to US$8.13 billion in 2030, deployments in licensed spectrum will account for revenue of US$5.78 billion, consisting of US$3.47 billion in network deployments in MNO licensed spectrum and US$2.31 billion in network deployments using locally licensed ("dedicated") enterprise spectrum. Deployments in shared spectrum arrangements are forecast to generate revenue of US$1.57 billion, while deployments in unlicensed spectrum will account for US$786.32 million by 2030.

***Chart 3:***
*Mining & Energy Private Network Revenue by Spectrum Type*

*World Markets, Forecast: 2020 to 2030*

*(Source: ABI Research)*



# 4. CONCLUSION

As this whitepaper has shown, 5G offers immense opportunities for a range of different enterprise verticals due to its unique combination of eMBB, eURLLC, and mMTC capabilities. Furthermore, using TSN and network slicing capabilities based on the concept of network virtualization will address a great variety of different use cases (requiring fundamentally different network characteristics within the same single physical infrastructure. However, it is also clear that there is no such thing as the enterprise vertical, as this domain is characterized by a high degree of fragmentation and different requirements. This makes it necessary for traditional telco industry actors to develop a consistent go-to-market strategy that will address all of these requirements concurrently. Furthermore, several bottlenecks need to be addressed to make 5G fit for enterprise applications, both from an ecosystem and a regulatory point of view.

- **The Importance of 3GPP Release 16:** The reliance of all industrial and logistics applications on eURLLC capabilities and the support for TSN means that large-scale deployment must wait for the development of compatible hardware, which ABI Research expects to be available in late 2021/early 2022.
- **Flexible Spectrum Allocation Policies:** Most enterprise verticals demand their own network slicing capabilities or require sensitive network data to always remain on-site, increasing the call for private wireless networks. Regulators need to address enterprises' central demands to acquire cellular spectrum without having to involve a network operator. Arrangements like the CBRS, UK spectrum sharing, or the licensing of local frequencies directly to enterprises (and in the case of Germany, for a very affordable fee), are addressing this. Furthermore, operating a private network in unlicensed spectrum (with NR-U) will allow for an economical alternative to licensed spectrum.

In order to guarantee full network integrity and make sure enterprises retain a maximum degree of independence in managing and operating their own networks, deploying private networks on the implementers' premises will become one of the most appealing deployment scenarios for enterprise connectivity.

There are multiple ways for enterprises to come into possession of spectrum to deploy a private network, and each has its individual advantages.

Enterprises could lease licensed spectrum from operators to deploy their own private network. The key benefit of unlicensed spectrum, spectrum sharing (such as CBRS in the United States or Ofcom's spectrum sharing in the United Kingdom), or locally licensed spectrum (such as in Germany, France, and an increasing number of other countries) is that it gives enterprises access to spectrum without having to go through an MNO.

Operating their own private networks enables enterprises maximum possible degrees of network customization to guarantee data security and integrity of the network traffic by on-premises deployments of the core network, as well as edge capabilities. In addition to data integrity, on-premises edge deployments will also be a critical enabler of sub-10 ms latencies, which are of key importance, especially for automating mission-critical applications. Furthermore, enterprises can boost five-nines network availability and reliability by customizing the network infrastructure.

The use of unlicensed spectrum specifically offers enterprises with an immediate opportunity to deploy a network, without even having to apply to the national regulator for spectrum. Furthermore, while licensed spectrum assets are highly fragmented, the use of unlicensed spectrum allows enterprises with multiple production sites across the globe to deploy private networks in all of these different sites, using exactly the same frequency band.

Licensed spectrum (either through an MNO or locally licensed spectrum) offers deterministic networking and guaranteed QoS, and allows enterprises to deploy private network networks for business- and mission-critical applications, which rely on guaranteed non-interference.

All in all, NR-U, spectrum sharing arrangements (like CBRS in the United States), and decisions to set aside licensed spectrum for enterprise usage exclusively (as is the case in Germany) strengthen the value proposition of mobile private networks for enterprise digitalization, because they offer a multitude of different deployment options that enterprises can choose from, depending on their requirements.

**Published November, 2020**
©2020 ABI Research
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