D1.3

OPERATOR BUSINESS MODELS FOR SMART MANUFACTURING

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D1.3 – Operator business models for smart manufacturing

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Short abstract:	5G non-public networks (NPN) are seen by the vertical industries as a real competitive advantage regarding wireless-based communication. Mobile Network Operators (MNO) are getting involved in the provisioning of 5G services for industrial customers, whose requirements may differ from the general public. This deliverable investigates how the relationships can be built between Industrial parties, MNOs and other third-parties and which value MNOs can bring in this ecosystem. More particularly, such analysis is based on a list of criteria identifying the main challenges to be addressed by the different stakeholders, in order to fulfill the industrial end-user's needs and to facilitate business relationships. They cover technical, business, security and economic challenges.
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Executive summary

This deliverable focuses on business models and value proposition for various Mobile Network Operator (MNO) engagement options towards the provisioning of 5G non-public networks (NPN) services. More precisely, it explores the three main NPN deployment options:

- **Standalone NPN**, which is fully isolated and independent of any public network,
- **Fully hosted PNI-NPN (**Public Network Integrated NPN), for which all network functions are hosted in the public network,
- **PNI-NPN with shared Radio Access Network (RAN) or core network**, which corresponds to a deployment scenario amidst Standalone and Fully hosted NPN, i.e. for which part of network functions are hosted in the public network and part are isolated.

More than any other cellular technology, 5G has initiated a shift towards a new ecosystem. New stakeholders have emerged, or have diversified their activities, to offer NPN design, integration and operation services, and to share liabilities and costs, but also value and profit.

To analyze these new business relationships, this deliverable presents the different business roles involved in the provisioning of end-to-end NPN solution for industrial users, then focuses on three generic stakeholders, which may take described roles:

- the **Industrial party,** which is firstly the NPN User, but may also be involved in the design, deployment and operation services,
- the **Third-Party**, which is involved in the provisioning of network and industrial services,
- the **MNO**, which is traditionally seen as the public network operator, but is now also offering services for the deployment of non-public networks.

The stakeholders may organize differently depending on their strengths and weaknesses, the type of industrial use cases to be supported by the NPN, as well as the type of NPN User. There are numerous potential combinations regarding the sharing of roles between stakeholders. Therefore, in this deliverable, we select only the most relevant ones for each of the three main NPN deployment options, and for each combination, we describe how business relationships can be organized, which value can be proposed, but also which industrial use cases and NPN user should be targeted. More particularly, we focus on the value proposition from MNOs and identify their key resources.

To further analyze the selected role-stakeholder combinations, a list of criteria is provided. They take as a basis the main challenges to be addressed by the different stakeholders, in order to fulfill the industrial end-user's needs and to facilitate business relationships. They cover technical, business, security and economic challenges, and are used to highlight some of the advantages and disadvantages of the different scenarios for both the industrial user and the MNO. For each criterion, a rating (High / Medium / Low) is provided. However, it should not be understood as a technical or undisputable evaluation, but rather as a subjective perception, discussed with the partners involved in the 5G-SMART project.

Contents

1 Introduction

5G non-public networks (NPN) are seen by the vertical industries as a real competitive advantage regarding 5G wireless-based communication. NPN enable innovative products and services, such as augmented reality or process automation, and can enhance the daily business and unlock high return-on-investment. Several network deployment scenarios have been presented by the 5G Alliance for Connected Industries and Automation (5G-ACIA) in [5GA19-NPN], together with a set of key service attributes which should be considered when assessing the suitability of these scenarios for a given industrial use case. Beyond the technical analysis of their high performance in terms of low latency, reliability, or high data transfer, the 5G-SMART project also explores the value created thanks to NPN and the related business models for Mobile Network Operators (MNO).

1.1 Objectives of this document

This report analyses value proposition and business relationships for various MNO engagement options towards NPN services, offered to a clearly defined user or group of users, as opposed to general public services. Depending on the architecture and on business choices of the industrial end-user, the deployment and operation of a NPN will likely involve several stakeholders.

The main objective of this deliverable is to explore how business relationships and role sharing between stakeholders affect the responsibilities and the costs that industrial users bear. Such an analysis allows to derive the value proposal from the MNOs and to identify their key assets and resources for different NPN deployment architecture options. A complete end-to-end network design principles analysis is dependent on the individual deployment and requires deep insights into confidential process data as well as business data. We, therefore, propose a different approach, which analyzes potentially feasible business models and value proposals for a given set of architectures and network design principles, for Standalone NPN (SNPN), Fully hosted Public Network Integrated NPN (PNI-NPN), and PNI- NPN with shared RAN / Core network (further defined in Section1.4). To do so, we first review the ecosystem of 5G-enabled industry and the present regulatory framework related to spectrum for 5G-enabled use cases. We identify related business roles and stakeholders and, for each NPN deployment option, we illustrate how identified stakeholders may share roles and responsibilities to provide end-to-end services for industrial users. As there exists many possible combinations, we select only the most relevant ones, focusing on the value proposition an MNO can bring in such an ecosystem.

Next, we propose a list of criteria which provides a framework for a value analysis for different actors. More particularly, the proposed criteria assess the main challenges to be addressed by the different stakeholders, in order to fulfill the industrial end-user's needs and to facilitate business relationships. They cover technical, business, security and economic challenges, and are "neutral", in the sense that they do not depend on the underlying NPN technical architecture, nor on the business role shared among stakeholders. The security criterion specifically targets the question of privacy, data protection and trust-intensive services towards enriched connectivity. We then use these criteria to highlight some of the advantages and disadvantages of the different scenarios for both the industrial user and the MNO, and to exemplify the types of use cases and an NPN user that best suits this relationship model. This document does not claim to provide a comprehensive guide or handbook to the "best"

option, which would depend on the country, the industrial end user choices, as well as the individual use case portfolio of the industrial end user. This deliverable does not provide neither a quantitative technical-economic analysis, firstly due to the confidentiality and sensitivity of some of the data necessary for such analysis, secondly due to the unavailability of some of the data. 5G-SMART trialed use cases can for instance not be used as examples as they are largely research-oriented (Technology readiness level (TRL) level 5) and not for operational phase.

1.2 Relation to other documents in 5G-SMART

The relation of this deliverable to other published deliverables of 5G-SMART is illustrated in Figure 1:. This deliverable takes input from the discussion on network architecture options outlined in deliverable D5.2 [5GS20-D52]. D5.2 provides a thorough description of the different viable 5G architecture models and deployment options that are most suitable for manufacturing industries and the reader is therefore referred to D5.2 for a more detailed description of the 5G deployment options. This document centers around business models for MNOs in the Industry 4.0 ecosystem. However, note that this document takes a general view on 5G use cases and deployments and is not trying to be specific for any of the 5G-SMART use cases or trial installations. A reason for this being that the 5G-SMART trials are of research character and do not reflect all properties of a commercial deployment. A quantitative technical-economic analysis of the deployment at the trial sites is therefore not meaningful. With respect to considered use cases, requirements and KPIs, the reader is referred to deliverable D1.1 [5GS20-D11]. Furthermore, this deliverable has a close connection to D1.4 [5GS20-D14], which provides many of the technical details to be considered when deploying a 5G network. The reader is referred to D1.4 for questions related to deployment options and features (type of base stations, locations of the cell sites, antenna characteristics, etc.), certain spectrum aspects and co-existence discussions.

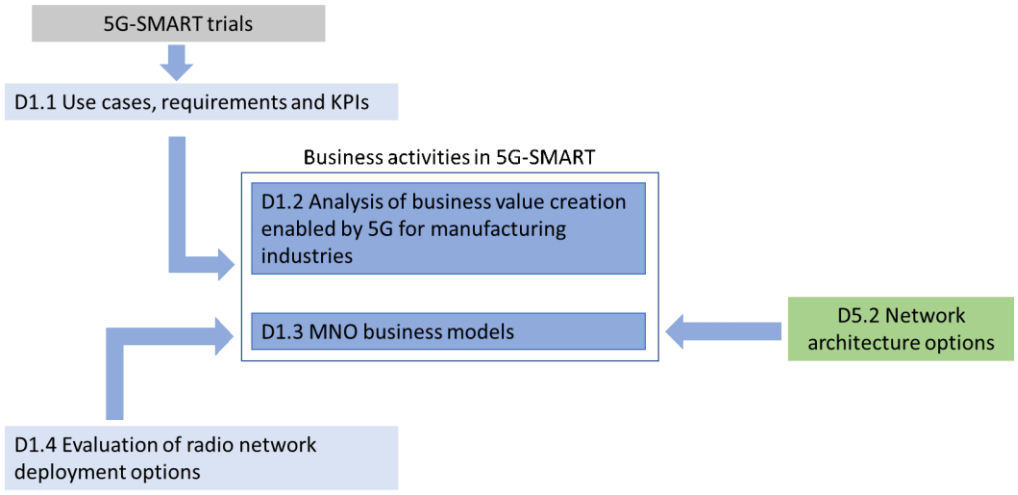

Figure 1: Relation of D1.3 to other documents of 5G-SMART

5G-SMART's deliverable D1.2 [5GS21-D12] has a close relation to this deliverable. Deliverable D1.2 is proposing a framework to analyze and quantify the business value of 5G implementation for industrial

actors. Questions on business models with respect to potential deployment options have, however, been left out of D1.2 and are instead addressed in this deliverable.

1.3 Structure of the document

This deliverable is structured as follows.

Section 2 presents the general context of the proposed analysis. It reviews historical business models, generally considered for 2G/3G/4G, and discusses the major technical and non-technical changes around 5G which have initiated a transformation of both the cellular and industrial landscapes, towards a combined ecosystem.

Section 3 details the proposed methodology for the analysis of NPN. It is defined as a "relationship model", which is inspired from the operation model presented in 5G-SMART's deliverable D5.2 [5GS20-D52]. This model illustrates responsibilities sharing and map business roles to stakeholders. It extends the concept of operation model to better cover business aspects, in particular value proposition. Next, the most relevant criteria are identified and described to analyze pros and cons of a relationship model and may help an industrial end-user target the right model for the desired use cases. The proposed analysis does not focus on the technical performance of an NPN deployment.

Sections 4, 5 and 6 respectively investigate Standalone NPN, Fully hosted PNI-NPN and PNI-NPN with shared RAN or core network deployment options. For each one, only the most representative relationship models have been analyzed, since the number of theoretically possible ones is very high.

Finally, Section 7 provides an overview of such analysis, while Section 8 concludes this document and summarizes the roles that MNOs can play and the value they can offer to industrial end-users.

1.4 General terminology used in D1.3

Contrary to a network offering services to the general public, a 5G NPN provides services to a clearly defined customer or to a group of authorized customers, e.g. users on an industrial campus. High performance may be expected from NPNs, in particular regarding latency or throughput, but also isolation from other networks, which is a key towards security, privacy and accountability. Both 3GPP [3GPP20-28807] and 5G-ACIA [5GA19-NPN] have described various NPN scenarios, depending on the considered use case and network configuration. In this deliverable, we consider the following definitions:

NPN deployment option: This refers to all **technical** characteristics of a given NPN, i.e., its physical components and topology, as well as its logical architecture components and configuration of related network functions, for RAN, core and cloud services. 3GPP Release 16 has defined two types of NPN deployment options: Standalone NPN, which does not rely on network functions provided by a PLMN (Public Land Mobile Network), and PNI-NPN, which is deployed with the support of a PLMN. In addition, in this report we consider the approach proposed by 5G-ACIA and, in line with deliverable D5.2 [5GS20-D52], we also distinguish the case where part of network functions are shared. We therefore consider the following three NPN deployment options:

- **Standalone NPN**, which is fully isolated and is completely independent of any PLMN (denoted as "NPN 1" in deliverable D5.2),

- **Fully hosted PNI-NPN**, for which all network functions are hosted by a PLMN (namely "NPN 4" in D5.2),
- **PNI-NPN with shared RAN and/or core network**, which corresponds to a deployment scenario amidst Standalone and Fully hosted NPN, i.e. for which part of network functions are hosted by a PLMN and part are isolated (namely "NPN 2" and "NPN 3" in D5.2). Note that in this deliverable we will not further distinguish the cases with shared RAN and with shared RAN and core.

There are several stakeholders sharing responsibilities for deployment and operation of the NPN. A list of deployment options hence does not directly reflect the main business view of 5G NPN.

In this report, we consider the following definitions:

Stakeholder: It is a party (a person, organization, social group or society) that holds a business interest in 5G non-public networks and that can either affect or be affected by related business. In a business relationship, a stakeholder can be a customer, a supplier, a complementor (selling a product or a service that complements the product or service of another company, resulting in mutual added value) or a competitor [BN11].

Business role: It refers to a set of functions, activities, skills, level of authority (or permission) and related responsibilities, which allow to complete a process or provide a service, in our case, in relation to the design, deployment and running of a 5G non-public network.

Note that a stakeholder may undertake several business roles and that a business role can be shared between several stakeholders.

Business relationships: association between two business roles, performed by different stakeholders, which a contract actualizes by specifying mutual expectations and constraints [5GPPP21].

Value proposition / creation: It is the value, i.e., a product or a service in its broad sense, which a supplier promises to deliver to a customer, to solve a problem or to satisfy a need. In short, it is the reason why a business relationship is established. For example, a value proposition may be an innovative service, which represents a disruptive offer compared to the ones currently available on the market. A value proposition may also be similar to existing market offers, but with complementary or customized services, or with novel features allowing a price reduction.

Business model: There exist many definitions for business model depending on the scope of the discussion, but the rationale behind it includes how an organization creates, delivers and captures value. Developing a full business model analysis is not within the scope of this document, partly because at the current stage of development of 5G, not all relevant variables can be accounted for. We will focus, instead, on analyzing some of the key parts of a business model for MNOs towards smart manufacturing companies. In particular, we describe the business relationship by means of the assigned role to the stakeholders, the value proposition, and the key capabilities required for creating the identified value propositions.

2 Industry ecosystem transformations with 5G

In this section, we present historical business models, related to 2G, 3G and 4G, and review some of the evolutions related to 5G that initiated a shift towards a new ecosystem and new business relationships. In particular, we focus on technical drivers, the growth of industrial expectations, and the evolution of spectrum regulation in some countries. Yet, these evolutions have taken a different shape depending on the country regulation and on the existing ecosystem, such that no generalization on the ecosystem transformation and business relationships can be made.

2.1 Historical business models and early stages of private networks

2.1.1 Connectivity as main value proposition

In the previous generations of cellular, the MNO has remained the principal intermediate between customers and the various cellular stakeholders, including hardware providers (for both the network infrastructure and end-user devices), software providers and urban facility managers, for sites hosting antennas. MNOs usually target two types of customers:

- **End-users**, either in the mass market (i.e., individuals) or other business customers (i.e., private companies or public administrations). For the mass market, MNOs act as connectivity service providers and traditionally offer standardized “mobile broadband”. Subscriptions may differ in speeds, data volumes and pricing levels to match each customer’s needs and budget. For business customers, dedicated end-to-end connectivity services have been designed.
- **MVNO** (Mobile Virtual Network Operator). In this case, the MNO acts as a network operator, i.e., an MVNO enters into a business agreement with an MNO to obtain bulk access to network services at wholesale rates, then sets retail prices independently to its own customers. MVNOs generally offer lower-cost subscriptions or target niche customers, with specific needs, e.g. professionals, elderly, music-lovers, etc. MVNOs do not own spectrum nor a full network infrastructure. They capture value from customer relationships (billing, sales, marketing, etc.) and connectivity services tailored to the targeted customers’ needs.

In the following, we focus on value proposition and business models for end-users.

Given the substantial cost of specialized vendor-specific network equipment and infrastructure for previous generations and the legal obligation to operate at a national scale, the essential value proposed by MNOs is **connectivity**, which was sufficient to achieve high growth and create a sustainable market demand. In this case, we can clearly talk about a value chain, and the MNO is in the middle of it, intermediating between infrastructure manufacturers and content or service providers for end-users [MBQ+18]. The value of mobile networks is specialized into segments that include:

- the **Radio Access Network (RAN)**, which generally represents the largest investment, affordable only to the biggest players, i.e. hardware and software network equipment, but also physical infrastructure hosting antennas, power supply, maintenance, operational units driving to customer’s home/premises, etc.,
- the **Core Network (CN)**, which is at the heart of connectivity services management, and
- **Customer relationships**, for customer services, billing, sales and marketing.

2.1.2 Historical business models of MNOs

Focusing on business models developed by MNOs for previous generations, no general pattern can be proposed for business customers (case-by-case offers). On the contrary, main historical business models for the general public services generally offer a rather straightforward pattern for value creation: very simply put, a customer had just to contract an MNO to access cellular networks, with limited choice on the subscribed connectivity services. Three main patterns can be identified for the mass market, as illustrated in Figure 2 [PwC19].

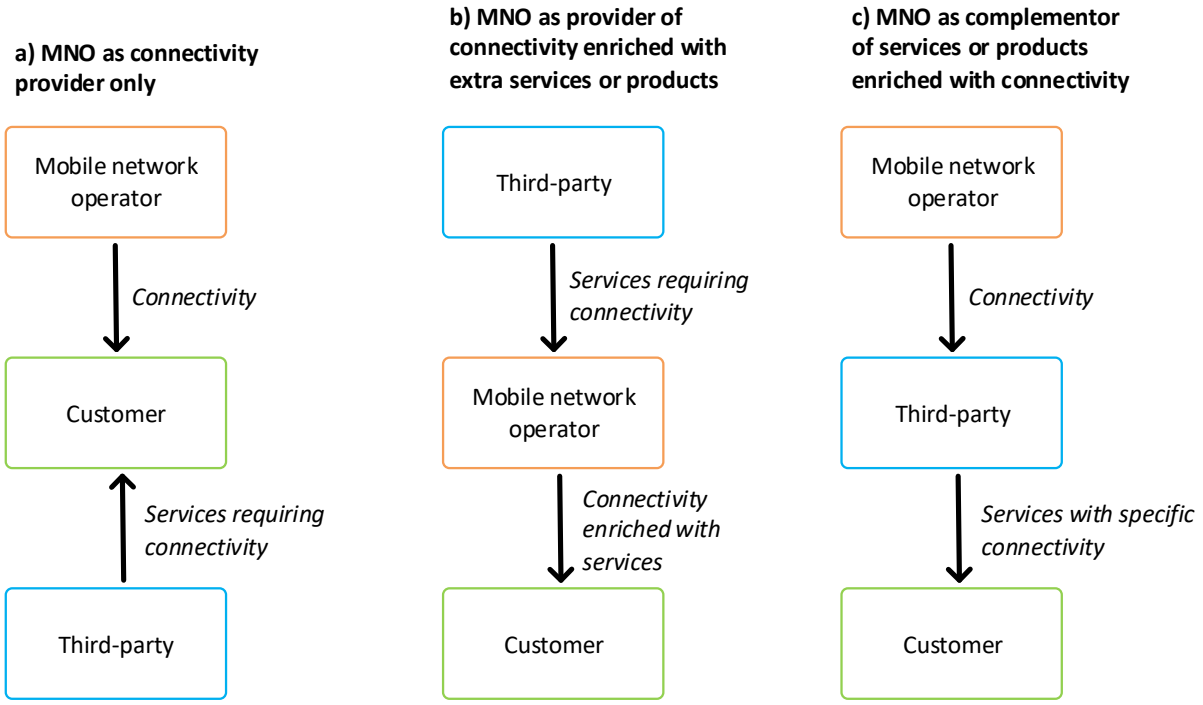

Figure 2: Main business models of previous generations

MNO as connectivity provider only (Figure 2a): This model is traditionally considered for the general public. Here, the MNO sells connectivity services directly to end-users, who simultaneously (but separately) contract with their chosen third parties to access services over that connectivity. For example, a customer contracts an MNO for a data plane with 10 GB data per month and contracts a content provider for music and movies. This business model can somehow be extended to industrial customers, e.g. for some IoT use cases. Here, the MNO provides all the tools to prototype, test, connect and manage connectivity for IoT devices. Subscription may include the choice of a radio technology (NB-IoT, LTE-M, etc.), as well as the purchase of a certain number of SIM cards and a data plan (e.g. per device per month).

This model is principally related to the possibility of "standardizing" connectivity offers for end-users. The MNO offers connectivity as value proposition and is able to deliver an end-to-end connectivity service to its customers. The MNO essentially acts as a "connectivity provider" in this case.

MNO as reseller of connectivity, enriched with extra services or products (Figure 2b): Thanks to collaborations with third-parties, typically device manufacturers or over-the-top service providers, the

value proposition of an MNO can encompass connectivity services bundled with additional products (e.g. a smartphone at no extra cost) or services (e.g. included subscription for music or movies). In the case of industrial end-users an MNO could offer, for example, a bundle for augmented reality or training through virtual reality. Such a subscription could include devices, like a headset and a set of dedicated application for data processing, in addition to the suitable connectivity services to ensure higher performance.

This model essentially allows to accommodate special requirements and to customize the provided connectivity offers to the needs of the devices and applications using this connectivity. In this case, the MNO acts as a "solution creator" [PwC19].

MNO as complementor of services or products, enriched with connectivity (Figure 2c): While the previous business model was led by the MNO, it can also be led by the third-party, i.e., this third-party buys connectivity services, sourced from a MNO, and includes them as part of its own bundle. For example, an IoT device manufacturer can sell to end-users *connected* devices, provided with SIM cards and a subscription tailored to their use and capabilities.

This model is generally preferred for highly specialized markets, when the third-party has higher market penetration or brand strength compared to the MNO. In this case, the MNO can be considered as a "solution enabler" [PwC19]. This type of business model may help the MNO identify new relevant services and understand their specificities.

2.1.3 Private mobile networks in previous cellular generations

A first evolution of the cellular ecosystem appeared with private network offers. Business customers may enjoy their own private cellular network, tailored to their needs. Private networks are far from new and were already available in 2G. Railways were the first ones to take advantage of them, however, private cellular networks did not reach a broad adoption since both the technology and use cases were not mature enough.

The technological innovations and regulations that came along with 5G have disrupted the traditional framework and led to novel business relationships. The value creation is increasingly shifting from connectivity services to data-driven services, and this pushes MNOs to adapt or reinvent their own value creation model. In the following, we review three characteristics that shaped 5G private networks. They relate to technical breakthroughs (section2.2), end-user growing expectations (section 2.3) and to some extent, spectrum regulation (section 2.4).

2.2 A transformation initiated by technical breakthroughs

Previous-generation systems have been firstly designed to support mobile broadband services running on public networks. First differentiation capabilities across use cases allowed to propose new services, for example regarding IoT, but the technological breakthroughs of 5G address precisely this differentiation challenge, as it was designed from the start for vertical markets such as automotive, energy, food and agriculture, city management, government, healthcare, manufacturing, public transportation, and many more.

In this deliverable, we focus on the vertical industry, i.e. industrial and ICT (Information and Communication Technologies) players, which offer services and products specific to industrial needs,

as opposed to a horizontal market in which products or services meet the need of a wider range of customers, across different sectors of an economy. While principal focus of this deliverable is on factory automation and manufacturing, other use cases are also used as examples, such as logistics or the energy industry.

Much more than 4G with private mobile radio (PMR), 5G addresses the challenges of non-public networks for industrial scenarios. Potential improvements are three-fold [NGMN15]:

Enhanced network capabilities and Industrial requirements: Thanks to novel technical features, such as advanced radio techniques, new frame structure and synchronization mechanisms, 5G gives the possibility to deploy high-bandwidth low-latency networks, even in a harsh propagation environment, such as indoor industrial shop-floors, with metallic surfaces. These new capabilities have raised interest of new customers from verticals, in particular industry, leading to new business opportunities and potential growth of the 5G market.

→ As a result, non-public networks, either standalone or hosted in the public network, can be tailored to the industrial services running on top to them.

Operational sustainability and 5G architecture options: Previous generations' network hardware is mostly specialized and vendor-specific, which highly limits the flexibility in functional use and makes it more complex to scale with growing number of devices and growing traffic volume. 5G technological innovations, in particular network "softwarization" and virtualization, give the possibility to run network software on almost any hardware and, to some extent, to operate a simple core network on commercial "off-the-shelf" servers. They have enabled the shifting from closed proprietary hardware, with dedicated software, to widespread software development practices (DevOps) on more open platforms. In addition, built-in monitoring tools simplify network operations. This has provided the agility to create new services without the need for changing the underlying physical infrastructure, as well as to support multiple services, with distinct requirements (bandwidth, reliability, terminal density or low power usage), albeit on a common infrastructure.

→ As a result, non-public networks, either standalone or hosted in the public network, become more accessible to deploy, operate, and reconfigure, following the industrial user's needs.

Beyond technical aspects, the business perspective: 5G technologies improve operational sustainability and, at the same time, modify business relationships. They offer capabilities to launch new services, otherwise requiring extensive proprietary solutions, and open opportunities for new partners to develop business in the ecosystem. In particular, network virtualization and softwarization allow the seamless integration of services and resources, potentially provided and operated by a wide range of third parties, thanks to resource orchestration capabilities at different layers. This can be considered as the first step towards the splitting of the connectivity value chain into a wider ecosystem, where many stakeholders are engaged in the provisioning of 5G services. For example, 5G slicing, that can be enabled by virtualization and softwarization. It allows creating logically separated, self-contained, independent and secured sub-networks, which are built on the same physical network infrastructure but target different services and technical requirements (e.g. rate or latency). A network slice can be dedicated to one enterprise customer, or shared by multiple tenants. Network resources (such as dedicated radio, transport and core resources, user plane functions at the edge, etc.) are managed

automatically thanks to programmable and flexible 5G networks and Service Level Agreement (SLA) driven orchestration, such that required network functions are flexibly created, quickly deployed and automatically managed.

2.3 Growing expectations in a competitive environment

Compared to previous generations of mobile networks, the changes in the ecosystem are more radical and they transform the granularity, duration and trustworthiness of business relationships.

First, industrial parties can now fully participate in the value creation process around 5G and share their needs and expectations on 5G standardization and regulation. In particular, they are actively participating in 3GPP standardization and industry fora like 5G-ACIA. Recent technological innovations give the possibility to meet very high-performance requirements (in terms of data rate, latency or device densification). Services customization may be the most relevant driver of 5G for verticals, in particular industry. By customization, we mean the ability to deploy a network:

- meeting the high quality-of-service requirements of industrial services,
- allowing reconfiguration to meet new requirements or to adapt to new use cases,
- letting, to some extent, the NPN user choose which network management operations have to be conducted or, on the contrary, delegated.

Second, the provisioning of these customized services with 5G triggered the transformation of business relationships, while historical business patterns for the mass market are principally based on generic connectivity offers, i.e., a few “standardized” offers are available on the market and have to match the greatest number of customer’s needs and budget. The customization of 5G services to industry-specific needs is made possible through technological breakthroughs, but will also be made possible thanks to new 5G provisioning bundles, which will aggregate and integrate a wide range of use case tailored services and simplify their management, as it is already the case, to some extent, with IoT for LTE-M networks. End-to-end solutions, including devices, SIM card, data subscription and specific data processing tools, can be bought for various use cases, such as asset tracking, factory monitoring and maintenance, or intelligent video surveillance.

Finally, 5G business relationships have also evolved thanks to new partnerships, established by the various ICT and OT stakeholders. Compared to legacy business patterns, industrial parties can be involved in the design and operations of their private networks and support the associated liabilities. This new flexibility of business relationships creates new synergies within the 5G ecosystem but, at the same time, it puts competitive pressure on traditional cellular stakeholders to rollout 5G networks and have spurred MNOs to propose new value for new customers.

2.4 Spectrum for 5G-enabled industrial use cases in Europe

The 700 MHz (694-790 MHz) band, the 3.5 GHz (3.4-3.8 GHz) band and the 26 GHz (24.25-27.5 GHz) band are identified by the European Commission as the 5G pioneer bands. While the 700 MHz and the 3.6 GHz auctions are done or under way in many countries, 26 GHz auctions are to date fewer and can be exemplified by, for instance, Finland and Germany. For an overview of the timing of the 5G pioneer bands in different countries and overview of industry spectrum, see for example [5GOBS21] or [ERI21].

From a 3GPP perspective [3GPP20-21916], "the overall trend in Rel-16 is to make the 3GPP 5G System (5GS) a communication-enabling platform suitable for a wide range of industries ("verticals"), such as transportation (autonomous driving V2X, Railways, Maritime), automated factories, healthcare, public safety and many more ". The work continued in Release 17, supporting both enhanced Mobile Broadband (eMBB) and vertical use cases.

Regarding spectrum management for accessing spectrum for local use, ETSI has developed the evolved Licensed Shared Access Shared (eLSA) [ETSI19-1036521, ETSI20-1036522, ETSI21-1036523]. It is an evolution of the previous LSA system. The eLSA platform can be used for handling licenses in an automated manner, such as the requesting and granting of licenses. It intends to support different regulatory national frameworks and it can be used for both licensing and leasing use cases.

2.4.1 Spectrum regulation for local spectrum

We define local spectrum as spectrum dedicated to local use only, as opposed to spectrum used at a national or regional scale. Spectrum regulation for local spectrum differs between countries in Europe and the National Regulator Authorities (NRA) interest in allocating spectrum for verticals, such as Industry 4.0, differ. In 2019 a handful of NRAs started providing different regulative methods for providing local spectrum for verticals, as compared to national spectrum allocations.

The regulatory methods for providing spectrum for 5G-enabled industrial use cases presently holds approximately the following alternatives:

- Allocation of local spectrum
  - License, individual right of use with no incumbent in the band
  - License, individual right of use with incumbent in the band
- Leasing of MNO spectrum
  - Leasing of bands, subject to NRA consent
  - Band-specific leasing of MNO spectrum, possibly mandatory in the conditions of the band.
- Deployment of services provided by an MNO and using the MNO spectrum:
  - If neither local licenses nor leasing is available in a country.
  - In France, for example, the 3.6 GHz obligations are the following ones:
    - Licensees of 3.6 GHz are required to make available the provision of services on a 'fair and reasonable basis' for a particular location, particular service characteristic etc.
    - Could be by offering wholesale of network slicing opportunities (or by leasing out parts of the spectrum)

2.4.2 Example: Allocation of local spectrum in Germany

Germany was the first country in Europe to implement application and allocation procedures for local 5G spectrum, targeting Industry 4.0. The NRA of Germany, the *Bundesnetzagentur*, officially opened the application procedure for local spectrum of up to 100 MHz in the 3.7-3.8 GHz range in November 2019 [BNetza21]. Since then, more than 100 licenses were granted, to industrial manufacturers and consulting companies, but also to a wide range of universities, colleges and research institutes, and to

MNO-affiliated companies such as Telefonica Germany or Verizon Deutschland. Additionally, since January 2021 it is possible to apply for licenses in the 24.25-27.5 GHz range.

The application consists of

- information on the required bandwidth and on the area, in which the local spectrum will be used, given in GPS coordinates of the boundaries of that area
- locations of antennas, given in GPS coordinates, as well as orientation angles and signal strengths
- application concept describing the purpose, why the local spectrum is needed
- declaration of consent of the owner of the land
- a statement that the applicant or a contractor is competent to operate a mobile network.

The spectrum is reserved for local, non-public, use. Any entity, except MNOs who are excluded in the 3.7-3.8 GHz band, can apply for the local spectrum, e.g. companies and research organizations.

The license fee F in Euro can be calculated by the equation

$$F = 1000 + B \cdot t \cdot 5 \cdot (6a_1 + a_2),$$

where 1.000 € is the base fee, B the bandwidth in MHz, t the duration in years, a the area in square kilometers (differentiated by a_1 for urban and transport areas and a_2 for other areas).

For the 24.25-27.5 GHz spectrum, the license calculates as

$$F = 1000 + B \cdot t \cdot 0{,}63 \cdot (6a_1 + a_2).$$

The licensee is obliged to use the spectrum within one year of allocation. In event of non-use for at least one year, the allocation may be revoked (Use-it-or-lose-it principle). The licensee is expected to solve coexistence issues with his neighbors, but in case of disagreements, there are fallback conditions in the license.

Several other countries in Europe, Croatia, Netherlands, Poland and Sweden, are presently considering allocating spectrum for industry in parts of the 3.6 GHz band. Regarding 26 GHz, also Croatia, Finland and Sweden are considering allocating spectrum for industry in the band. UK has already allocated the lower 26 GHz band for “Shared Access License”. The regulation differs between the countries.

2.4.3 Example: Mandatory leasing of MNO spectrum in Czech Republic

The EU regulation [Dec243/2012/EU] declared that member states shall allow the transfer or leasing of rights of use of spectrum. Voluntary leasing solutions are possible, and there are examples for 4G using the 2.6 GHz (Band 38) in Sweden and Finland [Lease3Swe] [LeaseElisaFin]. In the Czech Republic, the regulator CTU has set up a regulative framework in 3.4-3.6 GHz for leasing of 2*20 MHz for interested parties [CzTelOff20]. The operators are obliged by the regulative framework to lease out spectrum in the specified 2*20 MHz at 3400-3440 MHz.

The Lessee is defined as

- Having access to the land estate in question (Owner, Lessee, etc.), and not being a public space

- Intending to operate a local non-public network, not to provision interpersonal communication services or Internet access services.

The Lessor is required to

- Lease out upon the request of the Lessee. The Lessee needs an Individual Authorization granted by the Czech regulator CTU
- Publish the possibility to lease spectrum within 6 months from being granted the spectrum
- Put legal and technical requirements on the Lessee through the lease contract
    - especially conditions of mutual coordination of networks and synchronization of networks
    - interference limits can be negotiated, but with the option to enforce existing limit values if demanded
- Not lease out spectrum longer than the duration of the block allocation
- Lease out a minimum bandwidth of 10 MHz, in multiples of 10 MHz
- Charge a fixed and an annual cost according to a pre-defined formula
    - the one-time cost of 50.000 CZK (~1900 Euro)
        - prolongation with 6 months' notice inhibits new fixed cost
    - annual cost of m/12*1000*V*a
        - m means number of months of lease per calendar year
        - V means leased width of a spectrum range in MHz
        - a means actual surface area of the land estate in square kilometers
        - the annual cost of 20 MHz for a factory plant of size 500*500 m2 would be 5000 CZK (~190 Euro)
    - Update the conditions of an existing lease to accommodate a new lease if required. Costs are put on the new Lessee.

Several other countries in Europe have implemented or are considering leasing for industry in parts of the 3.4-3.8 GHz range, Finland, Denmark, France and Norway, but the regulation differs between the countries. For some, the regulator created an obligation on the mobile operator licensee to lease spectrum to verticals only if they were not able to provide suitable services.

2.4.4 Regional alternatives

In France, private local licenses have been proposed in the 2600 MHz TDD band (band #38, 2575-2615 MHz), a non-pioneer 5G band, by the regulator ARCEP [ARCEP21]. This band is techno-agnostic and can be used either for 4G or 5G. Spectrum is granted through a portal opened in May 2019 and so far, there have been a dozen applications, generally for a 10-year 20 MHz grant, among them, the airport operator, ADP Group and its subsidiary Hub One, the major French electricity company EDF, and the national railway company SNCF.

The application form consists of:

- information on the area, in which the local spectrum will be used, given in GPS coordinates of the boundaries of that area,
- a description of the project, why the local spectrum is needed,
- the desired amount of spectrum and envisaged period of use,

- a description of the envisaged synchronization model (type of frame and subframe, ratio Uplink / Downlink).

By default, the license owner should ensure that the field received at the boundaries of the area stated in the application does not exceed 30dBµV/m/5MHz but a waiver can be obtained provided that an agreement has been reached with neighboring license owners. The regulator ARCEP reserves the right to deliver, at a later date, authorization of use to other actors for secondary usage within the same frequency band and for the same area as the ones stated in the local license. This secondary user will have to ensure that no prejudicial interference is generated to the primary license owner. Finally, the license owner is subject to an annual license tax.

Other countries in Europe with local licenses in non-pioneer bands are Finland (2300-2320 MHz) and, to some extent, UK (bands in the Shared Access License).

2.4.5 Summary on Spectrum

To date approximately 10 countries in Europe have allocated, or envisage, local spectrum for verticals in the 3.6 GHz pioneer band, either through local licenses or leasing of MNO spectrum under certain conditions. Naturally, regardless if these alternatives are available or not, it is possible for MNOs to provide services for verticals in 3.6 GHz, for example by offering wholesale of network slicing opportunities. Local licenses also appear in the early allocations of the 26 GHz pioneer band in Finland and Germany. Parties interested in local spectrum need to consult the NRA for accessing the status in a particular country.

3 Analysis of value creation in Non-Public Networks

5G is a disruptive technology that has the potential to upset the traditional cellular market. Beyond technical solutions to fulfill requirements and KPIs, the success of 5G non-public networks will also largely depend on the business relationships that will be developed between the various stakeholders in the new ecosystem. Indeed, 5G players and industrial players are interdependent and need to mobilize each other to provide NPN solutions based on technologies, expertise and resources, which are not controlled as a whole by any single actor within the 5G industrial ecosystem.

Given the potential high cost and high responsibilities induced in the design, deployment, integration and operation of industrial non-public networks, each player will carefully evaluate a *make or buy* decision. This question is likely to become even more complex, as 5G allows multi-tenant NPN solutions, through the seamless integration of complementary services provided by a wide range of stakeholders and possibly orchestrated at different layers.

In this section, we propose a methodology that helps analyze the different NPN technical deployment options from a business perspective. In Sections 3.1 and 3.2, we identify the main business roles and the stakeholders involved in 5G industrial non-public networks. Then, for each option, we map these stakeholders to business roles; Section 3.3 describes how an oriented graph illustrates such role assignment, allowing for an easy visualization of the value proposition and the related revenue flows. Finally, Section 3.4 characterizes the criteria we selected to discuss role assignment, business relationships and value creation for a given NPN deployment option. These criteria allow to identify pros and cons of business relationships and to derive key assets and challenges of MNOs.

Remark: The proposed methodology does not pretend to be exclusive, nor does the list of criteria claim to be exhaustive.

3.1 Main business roles for NPN

3GPP proposed a first set of roles for non-public networks [3GPP20-28807]. However, it mainly focuses on 5G provisioning ecosystem and on the sole perspective of the network operator. These roles have been extended by 5G PPP research projects (Phases I and II) to better reflect the various potential customer-provider relationships between verticals and network stakeholders, and they include multi-MNO scenarios [5GPPP19]. This extended set includes roles for Network Slices as a Service and several layers of aggregators (Infrastructure, Datacenter, Network services, Spectrum…). Although fairly complete, the 5G PPP set of business roles largely exceed 5G-SMART's boundaries, i.e. non-public networks for industry.

In this report, we therefore restrict ourselves to six main roles:

NPN User: it is the end-user who uses the communication services offered by the NPN to run industrial services. Depending on the business pattern selected for the targeted services, the NPN User may or may not be the NPN owner.

NPN Operator: it operates and manages the NPN on a day-to-day basis. It is responsible for the smooth running of the network and it represents the single interface for NPN operations towards the NPN

User or any other vertical-specific service provider. The role of NPN Operator should not be confused with the MNO, which is defined as a stakeholder (Section 3.2).

Integrator: this role is about network design, installation, device integration, industrial-LAN adaptation and testing. For this report, we assume that this role encompasses both the role of industrial integrator and NPN integrator. Thus, the integrator has a double interface with the vertical players (e.g. OT industry) and the 5G provisioning players, in the sense that it both integrates the network components, or building blocks, and the industrial services running on top of them. As illustrated in Figure 3, it represents the single interface for the NPN User to deploy or reconfigure a network solution, which in general may not necessarily be a 5G NPN, but also Wi-Fi® or wired networks.

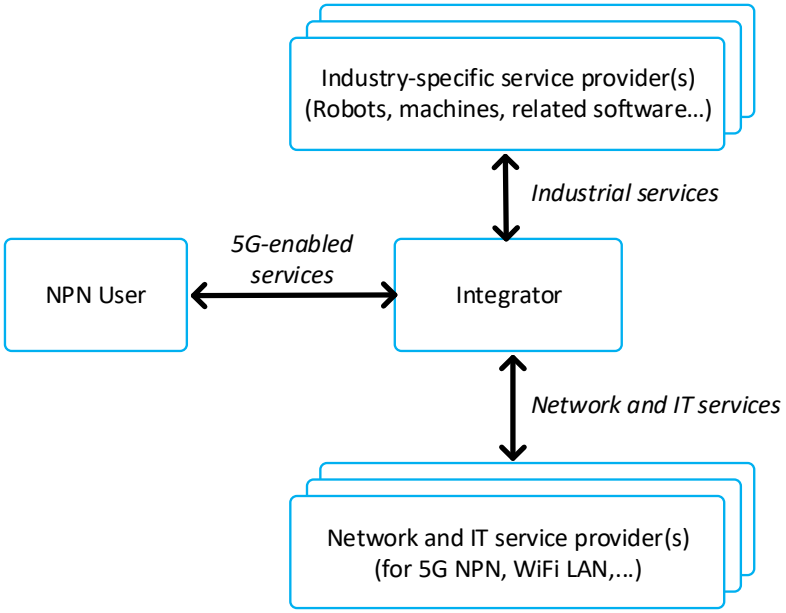

Figure 3: The role of Integrator, as defined in this deliverable

Spectrum Owner: this role includes spectrum license owners and owners of a leasing contract with a spectrum license owner.

NPN Owner: it owns the NPN infrastructure, including both the hardware and the software components.

A final note concerning the ubiquitous Edge Cloud computing platforms and solutions. They are undeniably useful, if not mandatory nowadays, for the successful and effective deployment and operation of an NPN network. There exists a wide range of business models around service provisioning for factory edge. However, we highlight that we do not consider mobile edge computing in this report. Involved roles and stakeholders depends more on the characteristics and design choices of this edge, than on the NPN deployment option, i.e. either SNPN, fully-hosted PNI-NPN or PNI-NPN with shared infrastructure. As a result, we neither list edge-related roles nor stakeholders in this report. Deliverable D5.2 [5GS20-D52] discusses this topic.

Remark: Business roles can be shared between different stakeholders, depending on business models and deployment options. For example, a split between local and central operator may be envisaged,

which would imply a sharing of functions for the NPN Operator. In a similar manner, given the various possibilities to deploy an NPN and to outsource part of the related functions, the role of NPN Owner may be assigned to a single stakeholder, or shared between several stakeholders.

3.2 Main stakeholders for NPN

5G-PPP [5GPPP19] provided a comprehensive list of the various stakeholders that are involved in the 5G ecosystem. As depicted in Figure 4:, these stakeholders are from the traditional cellular industry (i.e., those providing connectivity solutions, equipment, software) but also from verticals and a wide range of 5G-related organizations, which aim to support verticals' interests by standardization entities and policy makers. Within the telecom community, including these new parties, whose interests and development also seem to depend on 5G evolution, is a new approach. This also encompasses the IT industry and SMEs, who will likely play a key role as innovators.

Within the scope of 5G-SMART we focus on three main stakeholders:

Industrial party: a business entity that draws its economic benefits from the exploitation of one or more features or performances of 5G, applied to some of its business activities; such activities shall be in the industrial field (e.g. machinery, semiconductor manufacturing, etc.) and shall not include 5G or its ecosystem of services. The industrial party is always the consumer at the end of the value chain of 5G, even though it may take charge of other roles along the value chain.

Mobile Network Operator (MNO): a business entity whose core business is to provide wireless communications services and owns all the elements required to deliver such services, i.e. RAN, Core and Customer relationships services, as detailed in Section2.1.1. More particularly for this deliverable, the MNO is a stakeholder which aims to create value from the 5G technology, and which has knowledge and means covering the 5G ecosystem to a large extent. Traditionally, the MNO is the stakeholder who owns and manages a public land mobile network and owns a part of radio spectrum. Today, MNOs have largely broadened their offered services and they can take charge of one or many roles along the value chain; however, it is never the consumer at the end of it.

Third party: a business entity whose core business is the creation of value from the 5G technology, but which is positioned along the value chain of 5G and neither at the source, nor at the end of it. A third party typically focuses on a subset of the 5G ecosystem of services, either industry- or network-related, and it draws upon an established value with the purpose of increasing it, by complementing such services for the benefit of another entity.

Figure 4: 5G PPP Target Stakeholders [5GPPP19]

3.3 Methodology to analyze value creation around NPN

Definition for relationship model: for a given NPN architecture and deployment option (e.g. a standalone NPN), there exists a wide range of business models, depending on the sharing of activities, roles and responsibilities among the different stakeholders (e.g. the role of integrator can be delegated to a third party even in a standalone isolated NPN). We extend the definition of the operational model presented in deliverable D5.2 [5GS20-D52] and define the relationship model as a given combination of stakeholders, which undertake the various roles involved in designing, deploying and running an NPN, and which thereby establish business relationships.

Illustrating and analyzing relationship model: in order to illustrate business relationships, we propose to use the oriented graph of Figure 5:, where an arrow between a service provider and a service consumer depicts a business relationship, and whose direction represents the flow of the value proposition. Each node of the graph stands for a pair business role / stakeholder, where the business role is written in italics and the stakeholder is represented by an icon. In the example of Figure 5:, a Third party takes the role of Integrator, the Industrial party takes the role of NPN User, and the Third party provides integration services to the Industrial party.

For the analysis of relationship models, business relationships are split into two successive phases:

- In Phase 1 (Think, Build, Reconfigure), the NPN User expresses its needs and requirements, and the NPN is designed and deployed. This phase also includes the case when an existing NPN needs to be reconfigured, following new requirements from the NPN User.
- In Phase 2 (Run), the NPN is operational and used by the NPN User.

For each proposed relationship model:

- An overview is first provided, through the corresponding oriented graph and value proposition
- Pros and cons are then analyzed from the perspectives of the NPN User and of the MNO, using the value proposition criteria presented in the next subsection,
- Finally, we highlight the types of use cases and an NPN User that best suit this relationship model, discussing the interest of it and comparing to the others.

In remaining parts of this deliverable, relationship models are analyzed in Section 4 for Standalone (isolated) NPN, in Section 5 for Fully hosted PNI-NPN and in Section 6 for PNI-NPN with shared RAN / Core.

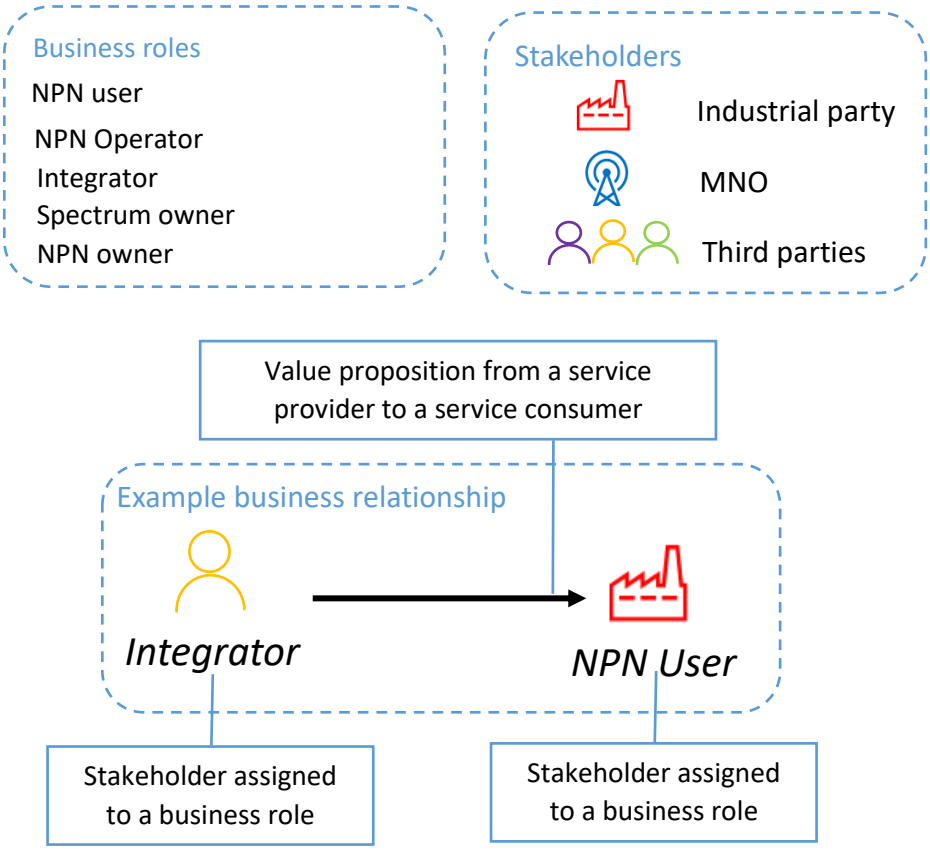

Figure 5: Legend for the relationship models, with an example value proposition.

Assumptions regarding technical performance: The combinations of possible relationships are numerous, especially if the highly flexible and customizable nature of the services offered by 5G is considered. Since our focus is on the comparison of different approaches in terms of value creation, we consider the three following assumption in this document.

First, we evaluate relationship models by considering a common set of minimum technical specifications so that:

- They are challenging enough so that only 5G can cope with it, among other wide-spread wireless communication technologies,
- Each of the considered NPN deployment options is assumed to be capable of satisfying all the technical requirements specified by the NPN User. If not, this option should be considered as not receivable and should be excluded, unless the NPN User decides to relax part of the technical requirements. As an example, if some particular performance must be optimized to its extreme capability (e.g. latency), then it is likely that only a subset or a single relationship model allows for it. However, discussing the actual values of KPIs is out of the scope of the present analysis.

For the benefit of the reader, we exemplify in Table 1 three general categories of use cases, with example values associated to each technical parameter, for which 5G is recommended, over other wireless communication technologies.

Technical KPI	Factory Automation	Process Monitoring	Logistics, Warehousing & Maintenance
Reliability	99,999%	99,999%	99,9%
Availability & Resilience	99,99%	99,999%	99,99%
Latency	<50ms	<20ms	-
Data rate (UL/DL)	10 / 100 Mbit/s	1 / 10 Mbit/s	1 Mbit / s
Time synchronization	100us	10us	-
Traffic patterns	Deterministic, Periodic	non-deterministic, periodic	non-deterministic, aperiodic
Packet size	1KB	<1KB	1KB
Number of 5G devices	<5 in 100m2	5-10 in 100m2	>10 in 100m2
Operating area	100m x 100m	10m x 10m	> 100m x 100m
Local coverage	Indoor	indoor	indoor/outdoor
Mobility of user equipment	slow, factory area	fixed, limited area	high, wide area

Table 1: Examples: KPIs for general categories of use cases

Second, we choose not to compare NPN deployment options based on their *optimal* technical performance, which can be hardly derived and would be out of the scope of this deliverable. Indeed, a Standalone NPN that is not well designed and deployed may show lower performance than a fully hosted PNI-NPN, even in terms of latency.

Finally, every implementation will surely provide some general capabilities, which are also left out from the analysis, despite of potentially being a key technical challenge of NPN deployments; an example of this is the support of heterogeneous traffic, with different levels of quality of service. The NPN optimization for all applications and related trade-offs is out of the scope of this deliverable.

3.4 Value creation criteria to evaluate relationship models

The demand for non-public networks is growing, together with the competition to deliver accompanying services. Each category of service suppliers – integrators, network equipment providers, operators– has different strengths and weaknesses and proposes different deployment options, which may fit some scenarios better than others. Understanding and specifying the needs of the NPN User is key to target the right NPN deployment option and develop profitable business with involved parties. This is about organizing who does what, understanding the strengths and weaknesses of each model and evaluating the balance between the required investment and the potential enhancement of the overall efficiency (e.g. increased flexibility, optimized maintenance, etc.), security, etc.

None of the potential business and technical options is able to satisfy all requirements; therefore, a trade-off has to be made. A first set of service attributes have been selected in [5GA19-NPN] to highlight the differences between NPN deployment scenarios, in particular device connectivity, network isolation, quality of service, NPN operation and management and security. As a complement,

this section presents the key value creation criteria that have been considered to analyze and compare relationship models from a business perspective. They are categorized as follows:

- Techno-related criteria to comply with performance requirements for industrial services,
- Business-related criteria facilitating the development of industrial activities,
- Technics- and Business-related criteria towards NPN coverage extension and scalability,
- Security and confidentiality criteria, to control risks and ensure data sovereignty,
- Economic criteria, to assess needed CAPEX and OPEX investments.

Rating criteria: The criteria defined below reflect both the perspective of OT partners and the perspective of ICT partners. Some of them relate more to the NPN User while some others present more the point of view of network stakeholders. In the analysis of SNPN (Section 4), Fully-hosted PNI-NPN (Section 5) and PNI-NPN with shared RAN and/or Core network (Section 6), we have provided a rating for each criterion, in the form of a High, Medium or Low grade. Yet, we highlight here that the proposed rating should be understood less as a technical evaluation of the considered criterion, and more as a **subjective perception** of involved stakeholders, and in particular the NPN User. We also highlight that some of the criteria have a double-grade, e.g. High / Medium. Indeed, most of criteria could be evaluated as "it depends" and encompass a wide range of factors which may not be easily balanced or "averaged" within a single grade.

3.4.1 Technical criteria: how to comply with performance requirements?

Previous-generation systems have been conceived essentially to support mobile broadband services running on public networks, with limited differentiation capabilities across use cases. A large part of services running on top of such networks was designed "afterwards", taking network capabilities as a basis. 5G technological innovations have completely reversed this trend and it is now the network architecture and configuration which can be designed as a function of services requirements (as long as they meet 5G technical limitations).

A large part of 5G-enabled services and use cases will still be developed later on, as a function of network capabilities. But an NPN user may also already have a clear view on targeted use cases and may wish that the NPN to be deployed meets very specific performance requirements, which may significantly differ from those typically targeted by public networks. This NPN User may thus be more interested in the NPN deployment option and related relationship model which offer the highest level of customization, such that the NPN is tailored to targeted use cases. However, such NPN may then lack "elasticity", in the sense that it may be harder for the NPN User to deploy additional services, which were not anticipated. For example, a NPN deployed for the sole purpose of eMBB or massive IoT may hardly suit URLLC services. On the contrary, a NPN User who prefers to develop services as a function of network capabilities may choose a NPN option which offers more elasticity, even if this comes at the cost of less flexibility to adapt to a particular use case. This trade-off is reflected in the two following criteria: "flexibility to adapt to different use cases" and "performance tuning".

Flexibility to adapt to different use cases: **This criterion evaluates the ability given by a relationship model to let an NPN User easily deploy a use case-tailored NPN solution in the design phase. It is a measure of how much the model can adapt to specific needs and of how broad its scope can be, regarding heterogeneous use cases.**

This ability, however, comes at a cost: the more flexibility is offered to design an NPN, the more the involved parties need a clear vision of both the use case characteristics and the NPN capabilities. This criterion is thus related to the trade-off between (1) the specificity of needs expressed by the industrial party, (2) the expertise required to translate those needs into a network architecture, and (3) the willingness (or economic risks) to invest in such architecture. An industrial party who is uncertain about the outcomes of such trade-off would rather select a relationship model with more "elasticity", where making a mistake in technical specifications is "affordable".

This criterion is mostly related to Phase 1 (Think & Build) and, from a technical perspective, to the 5G features which can be hardly modified once they have been decided, in particular during Phase 2 (Run), e.g. the antenna location and orientation, the TDD frame structure, etc. For example, an NPN deployed for the sole purpose of ultra-low latency (e.g. close-loop machine control) can be hardly tuned for higher throughput applications (e.g. adding augmented reality glasses for employees controlling machines). Thus, use case flexibility requires:

- A long-term vision of possible future use case changes to be deployed over the NPN,
- Expertise to translate industrial KPIs into network KPIs,
- Expertise to design and deploy the NPN configuration,
- Keeping up with 5G regulation and standards evolution to ensure interoperability and continuity of operations.

Depending on the selected relationship model and value proposition, use case flexibility can be achieved, for example, through the NPN User's own expertise in 5G technologies, through consulting by a third-party or a MNO, or through tight business relationships, where the NPN User expresses its needs and delegates effective NPN configuration to someone else.

Performance tuning: **This criterion evaluates the capability of a relationship model to let an NPN User express a need to further optimize some particular performance of interest at a later time and let the NPN Operator easily change NPN parameters in accordance with expressed needs. It is a measure of how rigid a relationship model is and of how autonomous the NPN User is with respect to network operations.**

Industrial services and applications may require very different QoS, implying several physical or virtual sub-networks, for example, one for measuring tools, one for monitoring systems, one for automated guided vehicles (AGVs), etc. Trade-offs may be needed between latency, bandwidth or reliability in order to optimize each application. However, the needs and situations may evolve along the time and performance fine-tuning may be required during NPN operations, without requiring any change in the fundamental characteristics of the deployed NPN. From a business perspective, a third-party acting as an intermediate between the NPN User and NPN Operator may slow down the fine-tuning process during NPN operations if customer relationships are not sufficiently developed.

This criterion is also about observability, i.e. the possibility given to an NPN User to have a dialog with the NPN Operator to control KPIs and eventually modify NPN parameters accordingly, thanks to dedicated APIs or network functions for example.

Ease of co-existence and provisions for managing interference: **This criterion relates to (1) the extra constraints required to protect an NPN from interference, which could impede performance, and**

(2) the sharing of responsibilities between a victim of such interference and its source, starting from Phase 1 (Think & Build) and during Phase 2 (Run).

Co-existence scenarios have been defined in deliverable D1.4 [5GS20-D14] as inter-network interference scenarios, i.e. scenarios where several neighboring networks (either public or non-public) may mutually interfere on each other, either in the uplink or in the downlink, depending on their radio network deployment option. Co-existence scenarios and interference are relevant topics both in the design phase, when NPN Owners' equipment is deployed, and later during network operations: a next-door neighbor entering the field can disrupt even the best design. In fact, deliverable D1.4 has shown that interferences can significantly affect the NPN performance, with all the negative effects induced on production and industrial processes. D1.4 investigated several scenarios, for both uplink and downlink transmissions, indoors and outdoors, macro UEs and NPN devices, macro networks and other neighboring non-public networks. Many industrial parties have already experienced the interference issue with Wi-Fi® and they will seriously consider this matter to properly design and deploy a new 5G NPN. Industrial parties should thus account for such challenge and a lack of anticipation, particularly in radio-challenging environment (e.g. an industrial campus with several neighboring factories), may result in longer deployment/configuration time (and thereby longer unproductive idle time), as well as extra cost, with no clear return on investment (compared to improving latency, for example).

Further analysis of challenges related to co-existence scenarios: Regulators impose restrictions to avoid detrimental effects in co-existence scenarios. However, the regulation differs from one country to another, and is still ongoing in some countries. Despite restrictions, there is always residual interference which can reduce the performance of a non-public network, even if unintentional [5GS20-D14, GSMA21]. This is particularly true for outdoors scenarios, within an industrial campus (with many neighboring stakeholders) or in an environment mixing industrial and commercial networks. Interference can also be generated within the industrial premises (For example, a macro UE located in the factory). Deliverable D1.4 [5GS20-D14] has investigated the NPN performance with interference for a wide range of scenarios. Several solutions can be envisaged to address this interference challenge, each with its own advantages and drawbacks.

While D1.4 focuses on technical features, we highlight here the business and non-technical aspects. Three parties are generally involved: the NPN User who receives interference (the "victim"), the party who generates this interference (the "source of interference"), and the regulator. From a business perspective, we thus distinguish three types of interference mitigation techniques:

- **Techniques which do not require coordination with another party:** for example, the victim chooses to better isolate a wall from electro-magnetic interference (for indoors use cases) or to ensure a separation distance (for outdoors). Such techniques bring higher business flexibility, as the NPN User is not subject to any commitment with respect to another stakeholder, but generally may have low efficiency from a business perspective. Indeed, the responsibilities and extra cost are borne solely by the victim. Next, uncoordinated interference management may prevent the NPN User to implement some services, such as the use of macro UE within the factory (c.f. deliverable D1.4 [5GS20-D14]).

- **Techniques which require an agreement between the source and the victim** (i.e., coordination between several NPN users or between an NPN user and an MNO). Such technics include, for example, network planning, selecting the same TDD scheme, etc. They are generally more efficient and bring some level of dynamicity. While coordination can be easily envisaged between two parties only, finding an agreement with more parties may require centralized coordination. In addition, such coordination could be easily achieved if the two (or more) NPN target the same level of performances (particularly latency) but may become tricky if one aims at very short latency while the other does not. Different balance between UL and DL load can be an issue as well.
- **Techniques involving an agreement through an external third-party:** When centralized coordination is needed, for example in an industrial campus gathering smaller-sized factories, the involvement of an intermediary may help provide a clear action plan and reach a fair equilibrium, that guarantees a good mutual protection at a balanced cost and shared responsibilities for all. This intermediary may be an MNO or MVNO.

From a business perspective, several other challenges remain. This is first a matter of responsibilities, i.e. avoiding being an interference source, avoiding being a victim, and detecting interference. Second, a good reactivity of involved parties (the victim, the interference source, the regulator) is required, as detecting that unusual low NPN performance is due to interference may take some time, during which the NPN user faces production loss and revenue reduction. Finally, it must also be highlighted that there is still a possibility that interference is intentional, e.g. from jamming or Denial of Service attacks, in which case the spectrum owner will likely get NRA involved, due to law infringement.

3.4.2 Business criteria: how to facilitate industrial activities?

Beyond functional requirements, the core business of industrial companies is to develop industrial services and industrial products, not to deploy and operate networks. Thus, an NPN relationship model should match the user willingness to gain expertise in 5G technologies, whether it be high or low. It should also provide the right balance in the *make or buy* decision the NPN User has to make. For example, should a turn-key NPN solution be bought from a single service provider? Should the NPN User select several service providers to compose a complete but multi-tenant NPN solution? Should the NPN user internally develop part of these services? Etc.

Providing a streamlined interface between stakeholders: **As the design, deployment and running of an NPN solution potentially involve various stakeholders, from various sectors (Industry, Equipment vendors, Operators, etc.), there is a need for a common understanding of requirements and for a common set of skills to ensure the seamless integration of complementary services provided by each of these stakeholders. This criterion thus evaluates the ability of a relationship model to facilitate the dialogue between these stakeholders. It is a measure of how easy or how smooth it is for the NPN user to buy a service rather than make it by itself.**

The industrial and network fields of work are both based on complex technologies, with their own terminology, way of working and objectives. Integrating 5G within industry thus requires a deep understanding of the other. In particular, such understanding can help ensure a good matching between the NPN User objectives and NPN effective operations.

For a successful NPN integration, the “Make it easy” approach is important, in order to minimize the need for highly specialized skills or training to

- Manage users and devices, integrate and operate the NPN,
- Express new needs or requirements, regarding operation and reconfiguration of the NPN
- Implement new solutions to support new requirements
- Manage potential failures (e.g. local support 24/7, service restoration).

Providing a single point of contact is critical if several partnerships with different stakeholders have been established to aggregate and integrate various services, i.e. if services are fragmented into a number of sub-services, each bought from a different stakeholder. Without a good interface between those sub-service providers, the NPN User would require the aggregation of many single-pieces of knowledge to build the desired service, out of these sub-services, and the advantage of such a “buy” option over the "make" option would quickly diminish.

Attractiveness of a 5G NPN solution: **This criterion evaluates the potential of a given relationship model to reach new customers and to facilitate 5G NPN adoption.**

From the perspective of an Industrial party, this criterion is related to the easiness to jump into 5G. Indeed, this jump may not be so easy for OT companies relying on radically different connectivity solutions (e.g. wired technologies) for their production lines. Many have now some expertise in the IT domain, e.g. Wi-Fi® connectivity or cloud security, but the technological complexity of 5G may be a hurdle and the jump too big. On the other extreme, jumping into 5G may not be so easy for OT companies having a Wi-Fi® solution running for a long time and for which expertise has been acquired, possibly thanks to a dedicated IT department. As 5G has not yet widely proven its full capabilities, the trade-off “promises vs reality” may be a significant hurdle. The extra investment to deploy a 5G NPN (or another new technology) is worth less and the bet may sound too risky.

In general, the industrial party’s previous expertise of network management (whether wireless or wired) is a true parameter that can facilitate (or not) the customer relationship between IT and OT partners. This is particularly true for customers already operating a wireless network (e.g. a Wi-Fi® solution). While it may be easier to specify needs and translate industrial KPIs into cellular KPIs, it may be harder to change habits and ways of conceiving networks and architectures.

From the perspective of MNOs, this criterion evaluates the ability of a relationship model to reach new customers.

Business agility vs customer loyalty: **This criterion evaluates the business adaptability of a given relationship model, for improved efficiency or better competition. It is a measure of how much an NPN User can control which stakeholders are involved in the relationship model and of how easily business relationships can be changed.**

Industry generally has longer time scale than 5G and some NPN Users may consider being locked in a long-lasting business commitment with another stakeholder as a risk. Flexibility in business relationships is two-fold:

- In the first phase (Think, Build, Reconfigure), the NPN User is likely to benefit from a greater choice of device, software, equipment, and network architecture options. The possibility for the NPN User to build a multi-vendor NPN solution and to integrate any industrial/network component that fits best to its needs and targeted use cases makes a given relationship model attractive.
- In the second phase (Run), the NPN User delegating NPN operations may enjoy the possibility to change its subscription at any time, for example because it is gaining expertise and wishes to have more autonomy and more control of its NPN solution.

A multi-vendor solution brings competition and generally leads to a cost reduction for the customer. It could also lead to a higher complexity, dilutes liabilities and requires a higher expertise from the NPN operator. However, business flexibility holds several drawbacks:

- A first trade-off needs to be found by NPN solution providers between innovation and profitability. Indeed, 5G is not yet mature, in particular for industrial use cases, and still requires large investment. A wide ecosystem, with many players, brings competition but at the same time, puts high pressure on NPN solution providers to decrease costs, resulting in reduced profitability for them. This may come at the cost of less innovation and may prevent smaller new entrants to step into the ecosystem and propose new solutions.
- A second trade-off needs to be found between NPN customization and device / equipment standardization. Indeed, giving the possibility for the NPN User to integrate any device / equipment in its NPN solution means that device / equipment providers should either propose a wide range of products to fit the various network architectures and regulations, or propose standardized device / equipment for larger interoperability.

3.4.3 Technical and Business criteria towards scalability and coverage extension

Scalability and coverage extension: **This criterion evaluates the capabilities offered by a relationship model, with a given NPN technical settings and geographical boundaries, to scale up or to extend to a wider coverage.**

Three cases are considered:

1. On-premises extension, e.g. the shop floor extension / reorganization, potentially with an increase in the device density for a new production line.
2. National extension, i.e., the industrial party wishes to open a second factory in another city and securely connect its NPN to the one of the first factory.
3. International extension.

First, on-premises coverage extension and scalability may come at a cost for the NPN Owner, as new antennas need to be deployed, together with additional cabling for power supply and backhauling. Performance does not linearly scale with the number of antennas and radio planning for interference management is generally a serious challenge. Expertise is thus required to properly orchestrate resources and maintain the desired level of network performance. This is key to avoid jeopardizing industrial services already running over the NPN.

Second, the closed-loop control of machines will probably remain within the NPN User premises only, but Industry 4.0 means that information is pervasive across the factory, independently from its physical size or location. For example, the process managers may want to monitor and optimize production parameters across the physical boundaries of the company, to squeeze out the maximum of "lean production" from the whole manufacturing capability. Other examples can be found in the additional forward-looking use cases, proposed in deliverable D1.1 [5GS20-D11]: UC8 - Enabled Remote Expert, UC9 - 5G Empowered Cross-domain and Intercompany Collaboration, or UC11 - 5G Enabled Metrology and Maintenance across Machine and Factory Boundaries.

To this end, connecting distant NPNs is required, but it is not straightforward to open to the Internet while guaranteeing quality of service and security. Enterprise may use MPLS and/or IPsec VPN networks, but also a Software-defined Wide Area Network (SD-WAN) solution for optimized multiple transport resource management, reduced cost of connectivity, faster deployment and automated real-time reconfiguration. The choice of relationship model (and particularly the selected NPN Operator) significantly impacts the technical solution for connecting NPNs, as well as its cost and business commitment.

Third, to grow internationally, an industrial stakeholder may want to develop services involving stakeholders located in different countries. In this case, inter-MNO roaming agreements are needed to ensure compatible level of performance and security.

Easiness to manage hosting sites: **This criterion rates the flexibility of physical antenna deployment and hosting sites, targeting particularly outdoors antennas.**

Creating and managing site hosting antennas may represent a huge amount of CAPEX, to bring both power supply and backhaul capabilities, even for on premise sites. In addition, sites may be subject to regulatory constraints, such as geographical restrictions or transmit power limitation.

3.4.4 Security risks and confidentiality, to control risks and ensure data sovereignty

In recent years, more and more end-users of communication systems became aware of information security risks; especially the industrial parties, who are potential NPN Users, are very sensitive to such matters.

Provisions for information security risks management: **This criterion relates to the availability of tools, methods and strategies for preventing adverse events, as well as for reacting to them.**

Within the broad definition of “information security”, we consider a number of different perspectives:

- Confidentiality during both transmission and storage of data, albeit temporarily for the technical need of the network; even the simplest production and process data are usually regarded as an industrial secret to be held.
- Integrity of data, which the end user may need to elaborate, with high confidence, at potentially remote locations in order to optimize production processes.
- Identity verification, which Industry 4.0 concepts like data fusion and digital twins have their foundation on; information must be clearly and unmistakably associated to its source.
- Intrusion and theft of information within the information system premises and along the communication channel.

- Aggressive actions resulting in disruption of a service, like DoS (Denial of Service) attacks.

Industrial parties nowadays expect that any service provider, not only in the field of communications, is actively considering the protection of their data, therefore provisions have to be part of the technical offer.

3.4.5 Cost criteria

There is a clear connection between techno-economic aspects and the feasibility of network deployment options. To deploy and operate the NPN some necessary functions require such high costs that not all stakeholders can afford to pay for them. Consequently, an NPN deployment option may be technically feasible but economically unreachable for an NPN User.

CAPEX: **Besides the industrial party's equipment like machines, robots, etc., the CAPEX of an NPN can be divided into several categories of cost items, which should be taken into consideration during NPN building.**

- **5G user devices.** 5G user devices allow the connectivity between the industrial party's equipment and the 5G network. They include 5G modems, 5G routers, 5G smart phones, and 5G SIM cards.
- **5G Radio Access Network.** The appropriate configuration of RAN and its dimensioning can be important factors affecting an NPN's total CAPEX. Multiple configuration options are available such as macro cell, small cell, base station configurations, Distributed Antenna System (DAS), positions and configurations of antenna system, virtualized Base Band Unit (BBU), etc. Concerning the RAN dimensioning, it is mainly determined by the coverage area, the number of 5G users, their density and traffic profiles, as well as the available spectrum. Deliverable D1.4 [5GS20-D14] describes and analyzes in detail these options.
- **5G spectrum.** See Section 2.4.
- **Front-haul network.** In case a BBU and the radio units are not co-located, the front-haul network cost should be taken into consideration. The front-haul network consists of the cabling on the industry site between the 5G radio nodes and the centralized BBU. It normally comprises an optical fiber network.
- **5G Core network.** The different 5G Core User Plane and Control Plane functions can be distributed either on a local private Core network or on a Core network shared by several industry sites. Under the conditions that the technical and security requirements are satisfied, the choice of Core architecture has an undeniable impact on the NPN CAPEX. It is noted that since there are commonly less users in a private core network, the CAPEX per user in a private Core network is considerable higher than in a public core network. Furthermore, the cost of a Core network in local private Core configuration could be higher than RAN's cost.
- **Backhaul network.** The backhaul network refers to the connection between the RAN and the core network. For an NPN, a backhaul network only exists when its Core part is situated outside of the industry premises. The backhaul network is usually supported by either optical fiber or microwave. It can be built, so the backhaul cost is consequently a CAPEX item; or it can be leased, thus the backhaul cost is mainly an OPEX item.
- **Edge cloud.** An Edge cloud may host industry applications, data storage, BBU of RAN in case of virtualized RAN, core network functions in case of virtualized core network, etc.

- **Network management system.** The network management system refers to the hardware and software destined for network monitoring, operation, maintenance, collecting and analyzing the network performance data. Building a private network management system for an industry site could be expensive.
- Switches, Routers and Firewalls.

OPEX: **Apart from the industrial party's equipment OPEX, the operation expenditure of an NPN has the similar structure to other mobile network services.**

- **Operation and Maintenance.** The maintenance covers a wide range of activities, such as industry site infrastructure maintenance, radio site caretaking, RAN, Core, transport network, Edge Cloud maintenance, etc. From a labor point of view, they include the labor cost of staff who works for operation, maintenance and supervision of an NPN from end to end.
- **Rent.** The rent of the space occupied by the equipment inside the industrial party premises is generally at the expense of the industrial party.
- **Energy consumption.** The energy consumption of the equipment inside the industrial party premises are generally at the expense of the industrial party, while that of the equipment located in other parties' premises is in their charge.
- **Lease of Backhaul network.** This OPEX item only exists if the backhaul is leased.

Note that local survivability is a real cost driver. This term is used in telecom to describe the capability of a local NPN to continue to function even if all connections out from the premises (e.g. a factory site) go down (even if there is redundancy for outgoing cables, e.g. fiber).

Going further with a tech-eco analysis: The work proposed in this deliverable could be pursued by a quantitative technical-economic analysis. However, such analysis exceeds the scope of this deliverable. Indeed, it requires data which can be confidential, sensitive, or even unavailable. Such data would include, for example, the cost of each single device and of equipment, of cabling (for networking and power supply), of software development, of operation and maintenance services, of expert consulting, etc. 5G is not mature enough and some of the devices and equipment are not yet widely available or still in a prototype state; this condition may imply atypically high prices and making assumptions on unknown costs would be speculative. Next, 5G-SMART trialed use cases are largely research-oriented (Technology readiness level (TRL) level 5) and not for operational phase. While assumptions could have been possible on the investment necessary to design and deploy a NPN, assumptions on the costs of operations could be hardly made. Indeed, daily NPN operations would require numerous additional services that are not considered within 5G SMART, for example device identity and SIM card management, day-to-day network maintenance or expert consulting in case of a failure. Given the technological breakthroughs and business innovations brought by 5G, OPEX models from 4G, or other technologies, hardly apply.

4 SNPN - Standalone NPN

There may be a multitude of reasons and needs that drives an industrial company to want to invest in a Standalone NPN [5GA19-NPN]. A SNPN is deployed as an independent, standalone network. It is physically isolated from the public network. It contains dedicated RAN, 5G core network and local management located inside the premises. In deliverable D5.2 [5GS20-D52], it is described as deployment model NPN 1.

There are cost benefits to gain for the NPN User from relaxing the requirement on a physically isolated network for different parts of the SNPN. The MNO can in this case make additional value propositions. Section 6 explores this possibility further.

Three SNPN options regarding the involved Stakeholders are chosen from a lager set of possibilities and are selected to be the more plausible options. The selected options have the same Stakeholder as Integrator and Operator, which is more plausible than having different actors in those two roles. In this section, the SNPN is considered the same for all options, but the stakeholders play different roles in each option:

- Option 1: The Industrial party takes the role of Integrator and NPN Operator
- Option 2: The Third-party takes the role of Integrator and NPN Operator
- Option 3: The MNO takes the role of Integrator and NPN Operator, assuming that the spectrum is owned by the Industrial party (option 3a) or by the MNO (option 3b).

For options 1, 2 and 3a, the Industrial party always assumes the role of the Spectrum Owner. An Industrial party can appear as Spectrum Owner in two ways, as explained in Section 2.4. There are countries in which the Industrial party can get his own local spectrum license. If this possibility does not exist, the Industrial party might have the possibility to lease spectrum from an MNO. If both allocations from the regulator and leasing from an MNO are available, the Industrial party can make a choice. If neither exist or if the Industrial party does not wish to acquire and manage spectrum, the Industrial party does not appear as Spectrum Owner but can still deploy a SNPN, using Option 3b.

4.1 SNPN Option 1: The Industrial party as NPN Integrator and Operator

In this first option for SNPN, the industrial party undertakes all business roles defined in Section 3.1. Although the MNO is not a stakeholder in this option, we consider it as a basis for analysis.

4.1.1 Overview and Value proposition

Relationship model: The relationship model has been divided into two phases to capture the different tasks needed, see Figure 6. The relationship model illustrates how the Industrial party holds, apart from being the NPN Owner and NPN User, the roles of the Integrator, the NPN Operator and the Spectrum Owner for SNPN Option 1.

The reader is reminded that SNPN Option 1 cannot appear in countries where neither local spectrum licenses nor leasing is available, since the Industrial party then cannot appear as Spectrum Owner. For details see Spectrum section 2.4.

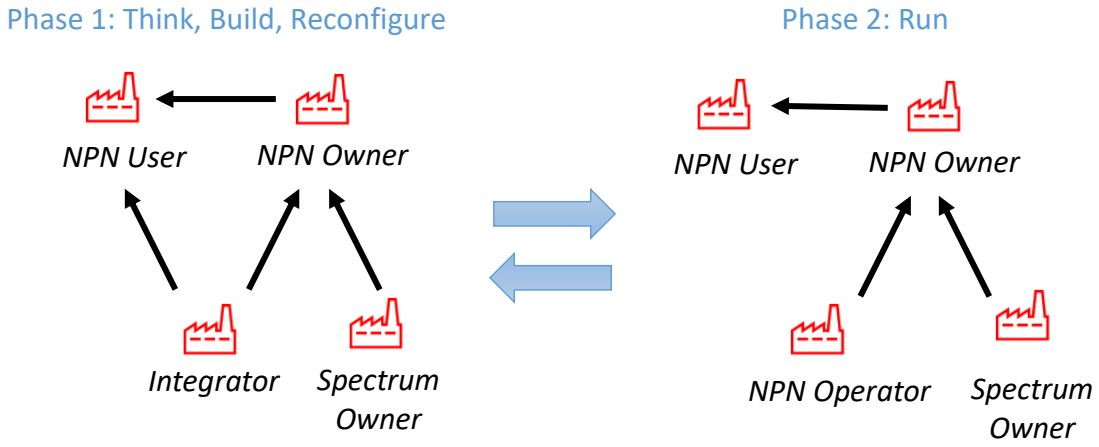

Figure 6: SNPN Option 1, the Industrial party takes all roles in the relationship model.

Value proposition from MNO: The value proposition could be:

- In countries where leasing is allowed, the MNO can be a spectrum lessee of licensed (national) spectrum. This could mean leasing additional spectrum on top of an awarded local license. The MNO should then provide a spectrum lease administrative system supporting the internal "process" used by the MNO.
- The Industrial party might use consultancy services from subcontractors for example regarding spectrum regulation, integration and operation. The MNO has the competence to perform such consultancy services.
- The Industrial party needs to buy NPN network solution equipment. The MNO can take the role of a reseller of such equipment and should provide an NPN network solution equipment organization and re-sell process (business support systems, etc.).
- The MNO can offer public (non-NPN) services to the Industrial party from his public network, such as voice, wireless broadband access to the external world, etc.
- Finally, the MNO can offer roaming services via its public network for services/applications, to ensure service continuity and seamless service provisioning/connection.

4.1.2 Advantages and disadvantages of this relationship model

The MNO can offer the services described above to the Stakeholders of the SNPN, in this case the sole Industrial party.

Pros & cons for the NPN User: This relationship model gives the NPN User full control of the spectrum (provided that it meets the restrictions stated by the regulator), the integration and management of the 5G network. The price to pay is the needed competence and resources.

- **Flexibility to adapt to different use cases:** ● High. The Industrial party is in control of the integration and deployment processes, and is free to adapt its SNPN to its specific needs. However, this calls for competence and organization in the areas of spectrum regulation,

network integration and network operation in order to set up and run the NPN. Such high expertise usually requires several years and significant investment to acquire. Another important aspect is the support for mixed IIoT services, for example the simultaneous support of URLLC and M-MTC services. The general conclusion of D1.4 (section 3.2.2 [5GS20-D14]) is that a single TDD band (typical case for local licensed band) can hardly support both at the same time (mostly because a single TDD pattern cannot be optimal simultaneously for both URLLC and M-MTC services). Multi-band use is recommended, which is not easily achievable for an Industrial party. However, even is the NPN User may perceive this relationship model as offering high flexibility and customization, this model also holds high risk and leaves little room for errors. Once the SNPN has been deployed, it may be hard, time-consuming and costly to radically change its properties to support other types of use cases, if not accounted for, at initial deployment. That's why SNPN option 1 also requires confidence and a long-term vision of use cases to be deployed in the long-term.

- **Performance tuning:** ● High. The NPN User is in control of the network but expertise is needed, as well as dedicated API for simplified tuning.
- **Ease of co-existence and provisions for managing interference:** ● Low. As detailed in Section 3.4.1, the case of using local licensed band requires an agreement between the source of interference and the victim, or requires an agreement through an external third-party. Indeed, two NPN users need to agree on appropriate emission limits, or if an agreement cannot be reached, the NRA should define the emission limits, as stated in D1.4 [5GS20-D14].
- **Providing a streamlined interface between stakeholders:** ● Medium. The Industrial party undertakes most roles (NPN owner, NPN integrator, NPN operator, etc.), which implies that there is no intermediate between him and his suppliers. However, the NPN User must handle all contacts and should ensure that subscribed services and selected devices are compatible all together. If a minimal level of expertise is not acquired internally, the NPN User should handle multiple interfaces, towards each supplier, to run the SNPN, and solve potential issues and network failures.
- **Attractiveness of a relationship model:** ● Medium. Given the required high level of expertise and high investment, this option may attract only customers which are already convinced by 5G. Customers with low level of experience of 5G networks or with a strong experience with another solution (e.g. WiFi) may consider such option as highly risky. Yet, in Germany, this solution is quite popular in particular for research purpose or trials due the spectrum situation and thanks to the high level of autonomy given to the NPN User.
- **Business agility vs customer loyalty:** ● Medium. This option is very agile, since the NPN User is independent of solution equipment and services suppliers. Yet, once suppliers have been selected, the NPN User is engaged in a long business relationship.
- **Scalability and coverage extension:** ● Medium. The NPN user is free to extend coverage within the industrial premises, as long as efficient radio planning is performed to maintain the

high level of performance of its SNPN. For national coverage extension, dual subscription with NPN and PLMN is possible. The NPN User needs to make necessary arrangements with an MNO outside of the site. Regarding internal extension, the NPN User should ensure service compatibility, as the regulation may change from one country to another and make arrangement with a MNO.

- **Easiness to manage hosting sites:** ● High. The NPN User is the owner of the site or entitled to use the site. However, specific restrictions may exist for outdoors antennas, for example on sector orientation or transmit power.
- **Provisions for information security risks management:** ● High. Isolated SNPN guarantees network isolation in the form of a physical isolation. Data does not physically leave the industrial premises. However, the NPN User shall manage security and device management (identity, authorization, authentication, etc.) on its own. Strict physical isolation may also prevent an NPN User to implement some use cases requiring opening to the Internet, such as the UC8 Enabled Remote Expert, presented in D1.1 [5GS20-D11].
- **Reducing the required CAPEX / OPEX:** ● Low. This may be the most expensive alternative, requiring all the needed competence available in the company. No economy of scale can be reached. There could be an advantage in buying network equipment from an MNO because MNOs can get wholesale prices. Network equipment can also be bought from network equipment vendors. Need to purchase or rent all network hardware and software from end to end. Leasing parts of a MNOs national spectrum will increase CAPEX. It will be more expensive than leasing mandatory leasing spectrum, or having a local license, which both have pre-set price. Local survivability is a potential cost driver.

Pros & cons for the MNO: Implementing this relationship model requires the MNO to take a role as a consultant and re-seller of hardware and provider of spectrum (leasing).

4.1.3 Discussion on type of customer and use cases the option is suitable for

Targeted use cases: This option has the advantage that it can be tailored to any use case not requiring remote access/operation. It is suitable for NPN Users that have high performance use cases, with very specific technical requirements (latency throughput, reliability, etc.). Given the high investment needed, it should be envisioned rather for high density of devices / production lines or high number of use cases running on the NPN, so as to secure a faster return on investment and make good profit. However, the NPN User may require different spectrum bands to do so, which is typically not available for private players, as shown in D1.4 [5GS20-D14].

Targeted NPN users: Typically, very large companies that decide and can afford to invest in own expertise and operation organization. Automotive and aerospace manufacturers are examples. Furthermore, this option (and other standalone deployment options, as well as some PNI-NPN with shared RAN / CORE options) more specifically targets NPN users who do not permit production data to leave premises. Only suitable for companies with sites in countries where industry spectrum is available (either directly, or through leasing from MNOs).

4.2 SNPN Option 2: A Third party as NPN Integrator and Operator

In the second option, the NPN User outsource the Integrator and the NPN Operator roles to the Third party. The MNO can still be indirectly involved, so we also consider this scenario a basis for analysis.

4.2.1 Overview and Value proposition

Relationship model: The relationship model for SNPN Option 2 illustrates how the Industrial party holds the roles of NPN Owner and NPN User. Recalling that, as defined in Section 3.1, the integrator has a double interface with the vertical players and the 5G provisioning players, this role is now shared between the Third-Party for the network components (NPN integrator) and Industrial party, for the industrial services running on top of them (Industrial integrator). In Phase 2, the third-party operates the network. This means that the Industrial party does not need the same amount of in-house competence. The Industrial party still needs competence in spectrum regulation. It also needs competence in the areas of network integration and network operation to be able to outsource these tasks, in order to specify correctly the needed services. A business opportunity is available for competent third parties.

It is worth noting that SNPN Option 2 cannot appear in countries where neither local spectrum licenses nor leasing is available, since the Industrial party then cannot appear as Spectrum Owner.

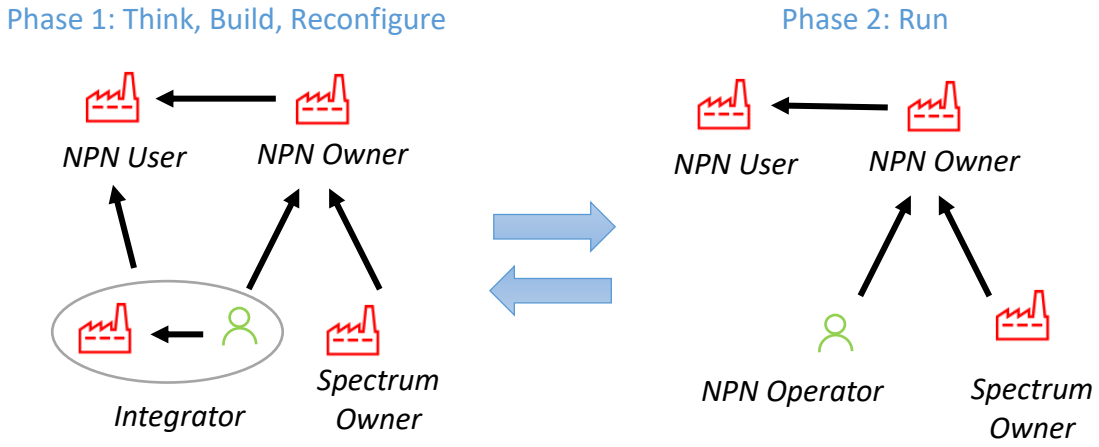

Figure 7: SNPN Option 2, the Industrial party outsources the Integrator and the NPN Operator roles in the relationship model to a Third party.

Value proposition from MNO: The value proposition is:

- In countries where leasing is allowed, the MNO can be a spectrum lessee of licensed (national) spectrum. This could mean leasing additional spectrum on top of an awarded local license. The MNO should then provide a spectrum lease administrative system supporting the internal "process" used by the MNO.
- The Industrial party might use consultancy services from subcontractors, for example regarding spectrum regulation. The MNO has the competence to perform such consultancy

services. Note that the MNO value proposition is the same as in Option 1 in this case, with the difference that the MNO could partner with the Third party regarding consultancy services in integration and operation, and thus reduce the number of interfaces compared to selling directly to the NPN User. It would instead require partner management with the Third party.

- The Industrial party need to buy NPN network solution equipment. The MNO can take the role of a reseller of such equipment and should provide an NPN network solution equipment organization and re-sell process (business support systems, etc.).
- The MNO can offer public (non-NPN) services to the Industrial party from his public network, such as voice, wireless broadband access to the external world, etc.
- Finally, the MNO can offer roaming services via its public network for services/applications, to ensure service continuity and seamless service provisioning/connection.

4.2.2 Advantages and disadvantages of this relationship model

The MNO can offer the services described above to the Stakeholders of the SNPN.

Pros & cons for the NPN user: This relationship model gives the NPN User full control of the spectrum but relaxes the responsibility and competence in integration and management of the 5G network. The price to pay is less flexibility in integration.

- **Flexibility to adapt to different use cases:** ● High ● Medium, depending on the NPN user confidence in the use cases to target in the long-term and on the customer relationship with the Third-Party, which can bring in return some performance tuning expertise
- **Performance tuning:** ● High, as the NPN User needs to interact with the Third party, which can bring in return some performance tuning expertise.
- **Ease of co-existence and provisions for managing interference:** ● Low. As detailed in Section 3.4.1, the case of using local licensed band requires an agreement between the source of interference and the victim, or requires an agreement through an external third-party. Indeed, two NPN users need to agree on appropriate emission limits, or if an agreement cannot be reached, the NRA should define the emission limits, as stated in D1.4 [5GS20-D14].
- **Providing a streamlined interface between stakeholders:** ● High. The Third party is a single point of contact for integration and operation. A big advantage would be if the Third party were also industry application supplier.
- **Attractiveness of a relationship model:** ● High. This alternative is probably very attractive for customers looking for SNPN and ready to significant investment in such technologies (see targeted customers in Section 4.2.3), but also accepting outsourcing of integration and operation, especially if the Third party has domain knowledge. It requires a medium level of expertise for the NPN user, compared to Option 1.

- **Business agility vs customer loyalty:** Medium. Medium on flexibility, there are some restriction on vendors. The NPN User is independent of solution equipment suppliers. Yet, once suppliers have been selected, the NPN User is engaged in a long business relationships.
- **Scalability and coverage extension:** Medium. The NPN User need to make necessary arrangements with an MNO for external coverage extension. Dual subscription with NPN and PLMN is possible.
- **Easiness to manage hosting sites:** High. The NPN User is owner of the site or entitled to use the site. However, specific restrictions may exist for outdoors antennas, for example on sector orientation or transmit power. Some restriction may apply for outdoors sites.
- **Provisions for information security risks management:** High Medium, depending on the level of trust between the NPN User and the Third-Party. An isolated SNPN guarantees data isolation and physical isolation, but an external party is present, in this case. There is a trust issue when outsourcing to the Third party (criteria on security etc.). Strict physical isolation may also prevent an NPN User to implement some use cases requiring opening to the Internet, such as the UC8 Enabled Remote Expert, presented in D1.1 [5GS20-D11].
- **Reducing the required CAPEX / OPEX:** Medium. This is the average alternative for SNPN options, requiring competence available in the company but outsourcing some vital parts, which depends on the scale factor in the Third parties offering.

Pros & cons for the MNO: Implementing this relationship model requires the MNO to take a role as a consultant and re-seller of hardware. Given that the MNO is only indirectly involved in this relationship model, the key value creation criteria are not evaluated for the MNO for this option.

4.2.3 Discussion on type of customer and use cases the option is suitable for

Targeted use cases: Similarly as for SNPN option 1, this option has the advantage that it can be tailored to any use case not requiring remote access/operation, even the most demanding ones, as long as the NPN is adequately designed and fine-tuned. It is suitable for NPN Users that have high performance use cases, with very specific technical requirements (e.g., latency throughput, reliability, etc.). It could be envisioned for higher density of devices / production lines or higher number of use cases running on the NPN, to secure a faster return on investment. However, the NPN User may require different spectrum bands to do so, which is typically not available for private players, as shown in D1.4 [5GS20-D14].

Targeted NPN users: Typically, very large companies that decide and can afford to invest in own expertise and operation organization. Automotive and aerospace manufacturers are examples. Furthermore, this option (and other standalone deployment options, as well as some PNI-NPN with shared RAN / CORE options) more specifically targets NPN users who do not permit production data to leave premises. Only suitable for companies with sites in countries where industry spectrum is available (either directly, or through leasing from MNOs).

4.3 SNPN Option 3: The MNO as NPN Integrator and Operator

4.3.1 Overview and Value Proposition

The relationship model for SNPN Option 3 incorporates two variants of spectrum ownership, which may apply depending on the spectrum regulation and on the choice of the NPN User:

a. The Industrial party is the Spectrum Owner: this option may be considered only in countries where local spectrum licenses or leasing is available. The MNO can be granted right to use the local spectrum license, thereby not having to use his nationally licensed spectrum
    i. leasing can be used for increased bandwidth (or vice versa)
    ii. the MNOs national spectrum could be added for increased bandwidth
b. The MNO is the Spectrum Owner: this option has to be considered in countries where neither local spectrum licenses nor leasing is available, and may also be considered in countries where local spectrum licenses or leasing is available, if chosen by the Industrial party.

As a consequence, two relationship models can be derived for Option 3, depending on the spectrum ownership.

Value proposition from MNO: In Option 3a, illustrated in Figure 8, the Industrial party is the Spectrum owner and the MNO takes the role of Integrator and NPN Operator. A direct parallel can be made with Option 2, as the MNO can offer the same services as the Third Party of Option 2. We thus refer the reader to Option 2 for the analysis of Pros & Cons for the User and for the discussion of suitable use cases and NPN Users.

Yet, a MNO can bring several additional advantages. It has more spectrum options, notably FDD mid-band, and is in position to potentially dedicate multiple bands (including local licensed, which are typically TDD bands) in order to simultaneously support multiple services with very different requirements, as further discussed in D1.4 [5GS20-D14]. Then, a wide range of additional services may be provided in a simplified manner thanks to the direct interface between the MNO and the NPN User, in particular for services based on roaming, or offered to distant sites. Examples of such services have been proposed in deliverable D1.1 [5GS20-D11]: UC8 - Enabled Remote Expert, UC9 - 5G Empowered Cross-domain and Intercompany Collaboration, or UC11 - 5G Enabled Metrology and Maintenance across Machine and Factory Boundaries.

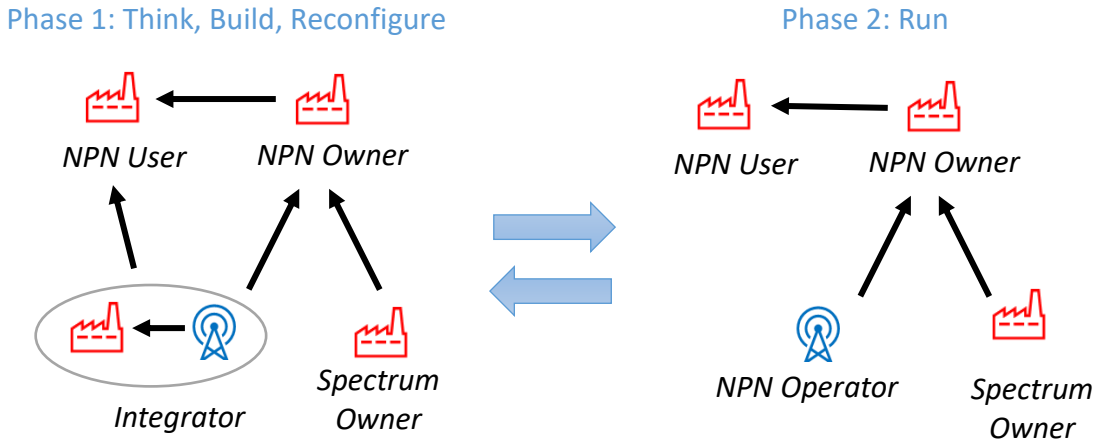

Figure 8: SNPN Option 3a, the Industrial party outsources the Integrator and the NPN Operator roles in the relationship model to a MNO, the spectrum is owned by the industrial party

In the following, we focus on Option 3b, illustrated in Figure 9, in which the MNO takes the role of Integrator and NPN Operator and uses its own Spectrum to run the NPN. As for Option 3a, the MNO is responsible for the development and integration of the infrastructure (Phase 1) and for the NPN operations.

From technical and business criteria perspective, if the NPN Owner does not know or does not have Spectrum Owner properties, the Spectrum must be obtained elsewhere. However, its task is further complicated because, in this case, the NPN Owner is not expected to own any telecommunications equipment either, based on the regulation in many countries. In this situation, the MNO can act as a mobile network operator and build and operate a service for the NPN User. Building and/or operating a NPN may also be affected if the MNO has to use other Operator's Spectrum instead of its own Spectrum during integration and operation.

When integrating and operating an NPN network, the MNO starts with an advantage based on its existing experience, for both residential customers and business customers for which they already provide dedicated coverage solutions for shopping malls, airports, business buildings, etc. An advantage may be the already described years of experience in the entire field of service. A MNO is also likely to have years of experience in UE, RAN, Core, IP and IT systems. In terms of organization and resources, it is ready to achieve low prices and good quality by comparing products from different manufacturers. The MNO has experience with spectrum regulation processes and formal relationship with NRA.

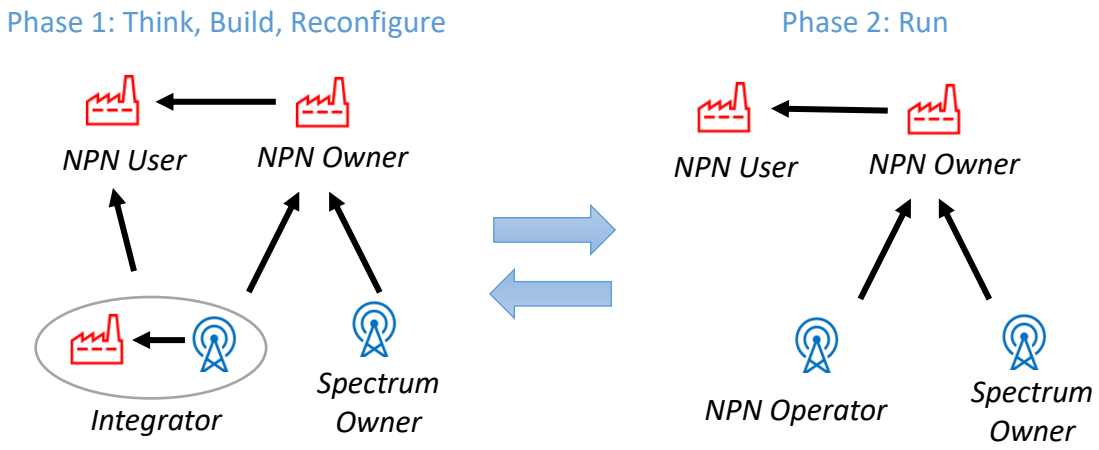

Figure 9: SNPN Option 3b, the NPN User outsources the Integrator and the NPN Operator roles in the relationship model to a MNO, the spectrum is owned by the MNO

Based on specialized experience:

- MNO can ensure native indoor/outdoor/WAN service continuity
- MNO is well placed to resolve coexistence issues with the public network
- MNO has experience in operating a network in the run phase, particularly in troubleshooting
- MNO may offer a fallback coverage (albeit with degraded performance) using the public network in case of NPN outage, if relevant.

MNO can use its existing architecture to build the new NPN in a good case, giving the NPN User an advantage over new entrants. A MNO usually has rural area coverage based on already existing Wide Area Network. MNO also has a lot experience in installing base stations optimizing radio planning, quality of service and availability. However, it could be a disadvantage to overturn the policy of an existing business. In addition to the current retail and wholesale services, the acquisition of industrial relations and industry standards is a novelty for the MNO. The new NPN Operator must start new directions in addition to or instead of existing processes or operating routes.

Furthermore, MNO is that it has experience in selling, operating, regulation in that country. There are several MNOs who are also present internationally. Thus, they can transfer a solution in one country to a franchise system. And even if the MNO is does not have international footprint, it has vast experience on roaming agreements with other national MNOs and can benefit from this experience to provide international solutions. This may also be true for operational tasks. They can transfer the solution and architecture laid out in one country to another, so they can move fast and reliable. Operational workforce training and possibly resource sharing between MNO's national companies (NatCos) also fit this pattern. Large manufacturers love shared resources solutions and want to use as few local specialties or local needs as possible. It is generally true that a system is economical if it is produced in good quality once and then copied many times.

4.3.2 Advantages and disadvantages of this relationship model

The pros & cons for the NPN User and the MNO regarding option 3a can be derived from Option 2. Regarding option 3b, we have the following.

Pros & cons for the NPN User:

- **Flexibility to adapt to different use cases:** ● High ● Medium, depending on the customer relationship with the NPN User, as for Options 2 and 3a. Interacting with the MNO (or Third-Party in Option 2) may be perceived as a reduction in the control of the NPN solution design, but at the same time, expertise may be brought by the MNO (or Third-Party in Option 2). The customized solution shall be delivered by the MNO. For the NPN User, this NPN-Option is one of the most flexible opportunities. There is no need to invest for spectrum (and infrastructure) and maintain the network, keeping up with the latest regulations. MNO has all the knowledge and experiences to design, build and run networks. It takes all the risks and responsibility to operate the radio network without any bigger outage due to the commitments made in the frequency tender and MNO's general terms and conditions. It has all resources to analyze the root cause of any radio malfunction and intervene if needed. Even In some cases (mainly in mission critical use cases) after stopping the whole radio network (due to any emergency cases) the MNO usually still operates the network, because emergency services are also running on the NPN solution. Based on MNO daily operation MNO gains experiences from development and operation of industrial use cases (incl. own internal best practices) and they serve as inputs for next implementations or fine tunings. This kind of consultancy can help for NPN User to define exact specifications (e.g. max. latency in operation flow).
- **Performance tuning:** ● High. The NPN user currently has medium autonomy with respect to performance tuning, as for SNPN Options 2 and 3a. In case a configuration change is needed, it shall refer to the MNO to effectively make the required change. However, SD-LAN principles could enable customer-friendly interfaces to control some more elements of the network.
- **Ease of co-existence and provisions for managing interference:** ● High. The MNO owned spectrum largest advantage is the Interference management and the Coverage extension. Interference management can be a very big advantage, because the MNO has long experience with spectrum allocation methodology and history with working on interference issues.
- **Providing a streamlined interface between stakeholders:** ● High. As for Options 2 and 3a, the MNO is the unique point of contact for the NPN User, simplifying contract management and customer relationships.
- **Attractiveness of a relationship model:** ● High. MNOs are already largely trusted in the provisioning of connectivity for the society's mission critical services such as emergency services, police or firefighters. Besides, contracts aim to guarantee the execution of the negotiated service and financial penalties can be planned in case of failure to compensate for the production impact. If the NPN user deploys and operates the network itself, as in Option 1, all the cost impact of a failure has to be supported by the sole NPN User.

- **Business agility vs customer loyalty:** Medium. As for other SNPN options, the business relationship between the NPN user and the MNO (or Third-party in Option 2) is a relatively long-term business commitment, given the high required CAPEX / OPEX.
- **Scalability and coverage extension:** High. The coverage area of the solution in the level of physical coverage and also in services can be well extended to the MNO other service areas.
- **Easiness to manage hosting sites:** High. As for other SNPN options, the radio equipment shall be installed at the NPN Owner's site.
- **Provisions for information security risks management:** High Medium. As for other SNPN options, the NPN Owner negotiates about security polices and encryption mechanism, and trust is required.
- **Reducing the required CAPEX / OPEX:** Medium, as for other SNPN option 2 and 3a. Nevertheless, the cost may be further decreased due to the large buying power of the MNO enabling economies of scale. Depending on the business model between MNO and NPN user the financial part is flexible; full CAPEX, full OPEX or mixed model can be used. On the other hand in this scenario the MNO only needs to focus on its core business with a well-known and easy to plan or forecast cost structure; developing and operating the network.

Pros & cons for the MNO:

- **Flexibility to adapt to different use cases:** High. The partnership with an Industrial party allows the MNO to gain in flexibility and expertise in this sector of activities.
- **Performance tuning:** High. As for Option 2, the MNO has the knowledge and experience to manage this task and to harmonize with NPN User's demands.
- **Ease of co-existence and provisions for managing interference:** High. The knowledge and experience to manage this issue is part of the MNO's daily business operations.
- **Providing a streamlined interface between stakeholders:** High. In this model MNO only needs to interact with NPN User
- **Attractiveness of a relationship model:** High. Easy to communicate and understand for the market.
- **Business agility vs customer loyalty:** Medium, depending on the business relationship and on the agreed contract.
- **Easiness to manage hosting site:** High. The MNO does not manage hosting sites, which are located in the industrial premises.

- **Scalability and coverage extension:** ● High. As a MNO usually has national coverage, extending coverage is quite straightforward from a technical perspective.
- **Provisions for information security risks management:** ● High. An isolated solution cannot be a challenge for MNO, as it is the part of its daily operation.
- **Reducing the required CAPEX / OPEX:** ● Medium. MNO made financial investments for spectrum it has to make revenues in order to decrease the payback period. For MNO the spectrum is an available (but finite) resource so no additional investment is needed to serve NPN User / NPN Owner.

4.3.3 Validity of this relationship model: discussion

Targeted use cases: As for other SNPN options, this alternative has the advantage that it can be tailored to any use case, even the most demanding ones. It is suitable for NPN Users that have high performance use cases, with very specific technical requirements (latency throughput, reliability, etc.). Given the high investment needed, it should be envisioned rather for high density of devices / production lines or high number of use cases running on the NPN, so as to secure a faster return on investment and make good profit. The partnership with a MNO may allow the NPN User to use different spectrum bands to do so.

Targeted NPN Users: Mandatory for companies with many sites in countries where industry spectrum cannot be acquired or leased. Attractive for companies that do not have the strength or do not want to have internal expertise and organization for handling the 5G network but still need an ultra-high performing network.

The European regulatory environment is not uniform for 3GPP standards that can be issued for private purposes. In Germany, the industry has already been allocated own frequency bands, but it has not yet happened in southern and eastern Europe. Thus, the industry with international production has to coordinate its implementation plans with several national regulations and several national MNOs. It is expected that solutions will change as the NPN solutions evolve which will also offer a wide range of opportunities. Until the technology is consolidated, both NPN User and national MNOs will need to be prepared to work together on different architectures.

4.4 Summary on Standalone NPN

Whatever the selected relationship model, SNPN options may hold today the highest potential in terms of performance and customization and may be able to fulfill most of technical requirements, even the most stringent or the most specific ones, provided that they do not exceed 5G technical capabilities. These options generally provide the NPN User a high level of autonomy with respect to NPN operations. These may be considered as key technical advantages for the NPN User.

From a business perspective, the SNPN options would attract very large companies that decide and can afford to invest in such network deployment, as well as related expertise and operation organization. The required level of expertise can be reduced thanks to the outsourcing to a Third-Party (Option 2) or to a MNO (Option 3a), which may attract companies that can afford to invest in SNPN

and develop expertise and for which outsourcing part of services is considered as strategically acceptable. Given the high CAPEX / OPEX they require, such options are generally synonym of longer-term business relationships and slower return on investment, but it could be envisioned for a very high density of devices/production lines or high number of use cases running on the NPN, to secure a faster return on investment, provided that the SNPN is designed to handle such heterogeneity of use cases.

While the choice between Option 1, Option 2 and Option 3a belongs to the NPN User, these options all assume that the Industrial party is the spectrum owner and are, in practice, not possible in all countries. For the cases of SNPN with a non-MNOs in the role of integrator/operator, the value proposition from the MNO remains low, e.g. consultancy services and re-seller of equipment, but they provide an opportunity for the MNO to address and get expertise in domain-specific needs.

Option 3b shows that SNPN deployment is also feasible when the Industrial party cannot be the Spectrum owner. As highlighted in Section 2.4, the non-harmonized spectrum landscape could potentially be a burden for international market growth and scalability. In this case, a key value proposition from MNO is to use their multinational scale to protect industrial users from these effects. Also this option is the one that enables the most flexible spectrum availability as the MNO can use its various spectrum bands (FDD and TDD, low and high) in order to meet the requirements of any use cases, while at the same time providing the easiest interference management with the public network and other NPN in the area managed by the same operator. Finally, this option facilitates service continuity between the private coverage and the public coverage as the same MNO would offer both, including fallback operation on the public network in case of outage (with degraded performance).

5 Fully hosted PNI-NPN

For this NPN deployment option, all network functions, for both the user plane and the control plane, are fully hosted by the public network. It corresponds to the technical option NPN 4 in D5.2 [5GS20-D52] or to the "NPN deployed in public network" in [5GA19-NPN, figure 4]. The MNO has the sole responsibility for the network infrastructure and its operations. The NPN user is a subscriber to the public land mobile network (PLMN), operated by the MNO, but have privileged access to resources thanks to **network slicing or Data Network (DNN) functionalities**, which virtually separates the NPN from the public network. We recall that a network slice provides a logical network that runs on a common physical infrastructure (in this case, the public network) and satisfies the service level agreement (SLA) for a certain category of service, e.g. URLLC or eMBB.

From a business perspective, fully hosted PNI-NPN can be implemented following several relationship models, each one providing different network services better suited to different industrial scenarios. In this section, we detail two options:

- Option 1: Fully hosted PNI-NPN in which the MNO only acts as a connectivity provider, as illustrated in Figure 2a.
- Option 2: Fully hosted PNI-NPN in which a third-party and a MNO establish a partnership for an enhanced integration of industrial services and network services, potentially with reselling facility.

Remark: Note that these two options do not consider additional on-premises antenna deployment, which is further investigated within Section 6.4 (PNI-NPN with Control plane, UDM and User Plane hosted in public). For Section 5, the prospective user shall be located in an area where 5G is available. In case 5G is not deployed yet, specific coverage (involving the deployment of a new 5G radio site) can be negotiated with the MNO as part of the contract, potentially with various ownership models (including shared).

5.1 Fully hosted PNI-NPN Option 1: MNO as connectivity provider only

This first option may be the simplest business pattern that a MNO can use to provide Fully hosted PNI-NPN services to an industrial end-user.

5.1.1 Overview and Value proposition

Directly inspired from the historical business model illustrated in Figure 2:a of Section 2.1, the NPN user contracts with a MNO for NPN services and simultaneously (but separately) contracts with the chosen third parties to access services not related to network. Typically, the MNO offers **generic slicing offers ("catalog sales")**, the NPN user then just has to subscribe to one of them to get its own Fully hosted PNI-NPN and be able to run industrial services on it. In this case, the MNO does not have any particular knowledge on the industrial services, run by the NPN user, and the NPN user has to integrate and configure industrial services by himself. The relationship between the MNO and the NPN user is essentially economical, rather than technical.

Relationship model: In a "make or buy" decision, SNPN Option 1 represents the "make" decision, while PNI-1 represents the "buy" decision. The NPN user does not take any responsibility for roles or

activities related to the NPN design, deployment and operations. As illustrated in Fig. 10, in Phase 1 (Think, build, Reconfigure), the NPN user holds several separate contracts, with the MNO for connectivity and with one or several third-parties for other services, like provisioning and integration of industrial services. In Phase 2 (Run), NPN operations are solely supported by the MNO and the industrial stakeholder does not undertake any role other than NPN user.

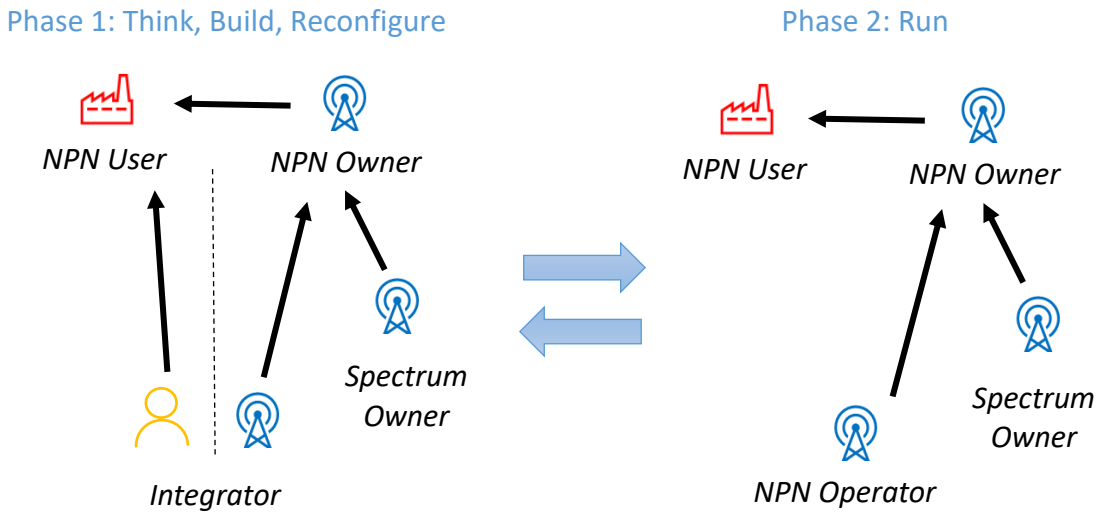

Figure 10: Fully hosted PNI- NPN, Option 1: MNO as connectivity provider for non-public networks

Business roles are here split into industry-related and network-related functions. More particularly, in Phase 1 (Think, Build, Reconfigure), the role of **Integrator** is shared between the MNO and a third-party, with no dedicated business relationships. The MNO undertakes the role of network integrator, as defined in 3GPP [3GPP20-28807] or in D5.2 [5GS20-D52], i.e. deploys and configures the NPN according to a chosen architecture and makes it ready to use. The third party undertakes the role of industrial integrator, i.e. it deploys, configures and runs industrial services on top of the provided NPN. In this case, the NPN User manages two interfaces, one with the MNO for network related activities, one with the Third-party for industry-related activities. Note that the role of industrial integrator can also be taken by the industrial party itself, as in Figure 11.

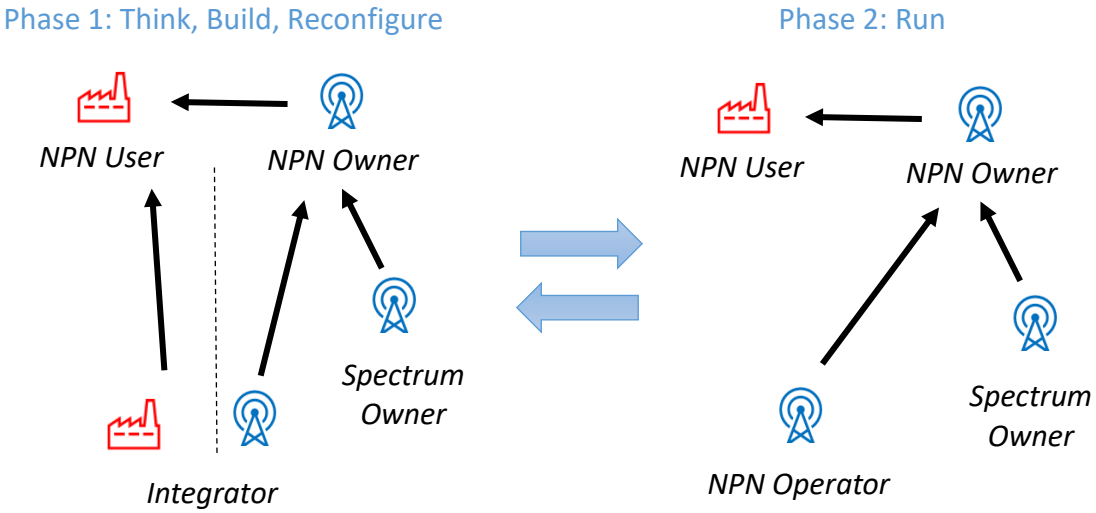

Figure 11: Fully hosted PNI- NPN, Option 1: MNO as connectivity provider, without third-party

Value proposition from MNO: Typically, the MNO proposes generic slicing offers, to provide fully hosted PNI-NPN services to industrial end-users. The business agreement concerns one or several dedicated slice(s), with functionalities isolated from other slices, and a user equipment may access multiple slices that are linked to the NPN where it is registered. As discussed in D1.4 [5GS20-D14], the real advantage of an MNO is that it has more spectrum options, notably FDD mid-band, and is in position to potentially dedicate multiple bands (including local licensed, which are typically TDD bands) in order to simultaneously support multiple services with very different requirements.

As further detailed in D5.2 [5GS20-D52], the subscribed slices are associated to a given Service-level Agreement (SLA) based on bit rate, latency and packet loss, to meet the required quality of services. In this relationship model, the MNO keeps control over the whole network value chain in Phase 2 and is able to deliver end-to-end network services to NPN users. This pattern sets the MNO essentially as a **"connectivity provider"**, i.e. agnostic to the industrial application.

5.1.2 Advantages and disadvantages of this relationship model

We analyze this relationship model based on the criteria presented in Section 3.4, from both the NPN User and the MNO perspective.

Pros & cons for the NPN user: for the NPN user this relationship model is synonym of simplicity, as a very limited expertise in 5G technologies is needed; it also potentially corresponds to low expenditure overall, requiring no dedicated infrastructure. It also reduces the build-up time to get a non-public network ready for use, implying a faster time to market for industrial services or products relying on this NPN.

- **Flexibility to adapt to different use cases:** ● Low ● Medium, depending on the MNO portfolio**.** The NPN user is limited to the offers proposed by the MNO ("length of the catalog") but it may select several slices to manage heterogeneous traffic. It is then easy to create virtual

independent sub-networks to run services with very different technical properties (ex: low latency / low bandwidth and high bandwidth traffic streams). Even if flexibility is low, this relationship model offers minimal risk to invest in a non-public network. Nevertheless, such relationship model may offer more possibilities for the NPN user to radically change NPN deployment options, for example, moving from an eMBB-oriented NPN to a URLLC-oriented NPN.

- **Performance tuning:** 🔴 Low. The NPN user has low autonomy with respect to performance tuning. In case a configuration change is needed, it shall refer to the MNO to effectively make the required change, potentially resulting in a new contract, and limited to the "catalog".
- **Ease of co-existence and provisions for managing interference:** 🟢 High**.** The MNO is the sole responsible for interference management. Related decision-making and all actions that may be taken are transparent to the NPN user.
- **Providing a streamlined interface between stakeholders:** 🔴 Low**.** Since in this case the role of integrator is split, the NPN user has to manage two distinct interfaces, one with the MNO for network-related functions and one with the third party for industry-related functions. The third party should also ensure that the services and devices expected to be used on the Fully hosted PNI-NPN are compatible with the subscribed slice. A minimum expertise in 5G is required by the NPN User in order to be able to understand and select the MNO offering.
- **Attractiveness of a relationship model:** 🟢 High 🟠 Medium, depending on the MNO portfolio. Because minimal CAPEX is required for this relationship model and because deployment is quick and easy, choosing a Fully hosted PNI-NPN shows minimal risk for an industrial party to jump into 5G and to make use of 5G capabilities without the need for developing internal skills to master this technology and operate the NPN. However, attractiveness depends on the good matching between the MNO portfolio and the industrial needs.
- **Business agility vs customer loyalty:** 🟢 High. Even if it depends on the subscribed slicing offer for Fully hosted PNI-NPN, the business relationship between the NPN user and the MNO is a relatively short-term business commitment, especially compared to a SNPN deployment. Given the low CAPEX, this relationship model leaves great freedom to the NPN User.
- **Scalability and coverage extension:** 🟠 Medium. As a MNO usually has national coverage, therefore extending the NPN User coverage across different sites is quite straightforward from a technical perspective. For international extension, the MNO may take the responsibility to negotiate roaming agreements, so that performance is guaranteed abroad as well. However, as the NPN User does not have control of sites hosting antennas, there may be some limitation in case scaling up is needed (e.g. higher number of devices) or if a wider coverage is required.
- **Easiness to manage hosting sites:** 🟠 Medium. The NPN user does not manage the hosting site, but it is limited to the areas where 5G is already deployed. In case 5G is not deployed, then specific coverage (involving the deployment of a new 5G radio site) can be negotiated

with the MNO as part of the contract, potentially with various ownership models (including shared).

- **Provisions for information security risks management** ● Medium**.** No expertise is required, and security level and risk management is considered at industrial market-standard level. Depending on the NPN User choice, the data may leave the industrial premises. In this case, the MNO ensures virtual network isolation, which can offer very high level of security [5GA21-Secu, GSMA20]. Indeed, private and public data are processed separately, and even the MNO providing the network Infrastructure can't access the data. If data should not leave the NPN user's premises, the MNO could deploy an edge server in the premises, as in Fully hosted PNI-NPN Option 2.
- **Reducing the required CAPEX / OPEX:** ● High. It requires close to zero CAPEX for the NPN User, and it has the potential to be the option with the lowest expenditure for the NPN user. Nevertheless, charging aspects (billing, price per month, per day, per use…) have to be analyzed deeply in order to ensure this and to match the minimum CAPEX with an optimized OPEX.

Pros & cons for the MNO: This relationship model allows to benefit from the economy of scale. It may help reach new customers and open new opportunities. Regarding the technical criteria detailed in Section 3.4:

- **Flexibility to adapt to different use cases:** ● Low ● Medium, depending on the MNO knowledge of industrial needs. To create a sustainable demand, the MNO should create a valuable portfolio, targeting the right use cases and the right potential customers. Besides, the MNO requires an accurate understanding of industrial needs in order to design generic slicing offerings and to achieve a satisfying tradeoff between customization and standardization, properly including new technical requirements.
- **Performance tuning:** ● Medium. The MNO should propose adequate customer services to facilitate the dialog with the NPN User and to ensure their needs are fulfilled within short delay. Regarding observability, the MNO can log some KPIs and inform the NPN User of relevant network events, for example through dedicated APIs.
- **Ease of co-existence and provisions for managing interference:** ● High. The MNO is in charge of interference management, as part of its daily business.
- **Providing a streamlined interface between stakeholders:** ● Medium. This relationship model is fairly MNO-centric as the MNO controls all resources related to the provisioning of NPN functions. However, it must be aware of industrial services and devices available on the market to ensure a good compatibility with provided NPN offers and give the NPN user a large choice.
- **Attractiveness of a relationship model:** ● High. Thanks to its simplicity, this relationship model allows reaching new customers.

- **Business agility vs customer loyalty:** Medium. It mostly depends on the subscription contract, but the MNO needs to take action in order to ensure its customer's loyalty.
- **Scalability and coverage extension:** High. As a MNO usually has national coverage, extending coverage is quite straightforward from a technical perspective.
- **Easiness to manage hosting sites:** Medium. Creating and managing site hosting antennas represent a huge amount of CAPEX for the MNO, which is also subject to authorization by the relevant authorities. The MNO can then lease hosting sites to facility managers or urban furniture managers, which are expected to have a larger role in future network access.
- **Provisions for information security risks management:** High. If the NPN user allow data to leave its premises, the MNO is expected to provide security at the highest standards level, but that is common business practice and therefore not an additional burden. In addition, the MNO could deploy an edge server in the premises, as in Fully hosted PNI-NPN Option 2.
- **Reducing the required CAPEX / OPEX:** Medium, by adopting a suitable strategy and careful planning, the MNO can quite easily leverage its network design. Even if a lower use case customization would generate lower revenue per NPN deployed (compared to SNPN options), revenues are expected to come more from a higher number of subscription.

5.1.3 Discussion on type of customer and use cases the option is suitable for

Targeted use cases: First, as no on-premises antenna is assumed, this option may show reduced performance for indoors / deep indoors use cases, depending on the radio propagation conditions, but it easily meets requirements for outdoors use cases [5GA19-UC], potentially with a wide coverage area, for example logistics and warehousing, monitoring of large industrial sites or storage sites thanks to massive IoT, surveillance cameras, AGV or patrolling drones, for harbors, open-pit mines, power plants, oil and gas industries, maritime- and aeronautic-related industry, etc.

Second, this option is interesting to a large base of use cases, except for those with very stringent requirements on some technical performances (for example latency), or characteristics specific to one single customer, for which a slice of general interest cannot be easily defined. For example, this option is particularly suitable for services including AR glasses or AGV not moving in highly-constrained environments. Yet, this is likely to evolve with time and dynamic on-demand slices creation, expected around 2025, should bring additional flexibility and allow a NPN User to design a fully-tailored slice.

Targeted NPN Users: Users that are not willing to gain expertise in 5G, and that are not willing to invest a lot or cannot afford it (SMEs, start-ups...), users with "classic needs" and who want fast time to market. The prospective user shall be located in a convenient area, where 5G is available, or negotiate the supplemental 5G coverage with the MNO.

5.2 Fully hosted PNI-NPN Option 2: A partnership between the Third-Party and the MNO

A fruitful evolution of MNOs' business models lies on collaborations between the stakeholders within the industrial ecosystem, in order to deliver the required level of service, while allowing customers to benefit of a better-tailored offering. From a technical point of view, this option is also based on network slices.

5.2.1 Overview and value proposition

Figure 12 illustrates this relationship model. In Phase I, the MNO and a third party share the Integrator role, with a business relationship between them. In contrast to PNI-NPN Option 1, in which the industrial party was simply aware of the MNO offering and capabilities to design its NPN, the core concept of this alternative model is that a third party acts as an intermediate between the industrial party and the MNO. This third-party hides the network and business complexities of the MNO from the view of the NPN User, and conversely, it hides the industrial and business complexities of the NPN user from the view of the MNO. In this role of Integrator, we envisage an industrial third party with a direct and solid knowledge of the field of the NPN User, who therefore needs no expertise in 5G at all.

During Phase II, while the MNO is the operator, the same partnership would hold with reversed flow of value: the industrial party may provide consulting services to the MNO, for example in the case of requests from the NPN User.

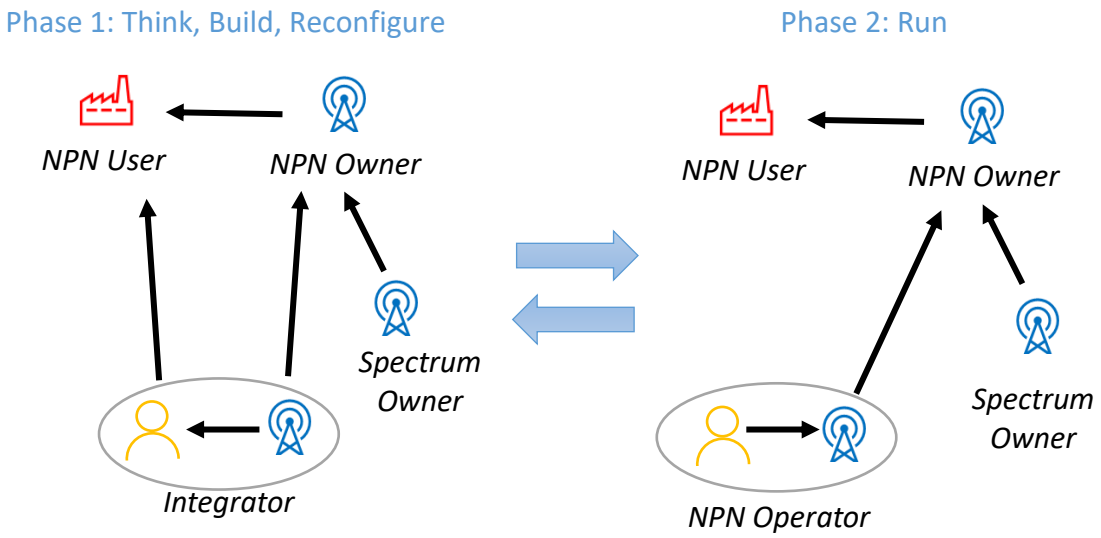

Figure 12: Fully hosted PNI- NPN, Option 2: Partnership between a Third-Party and a MNO

The relationship might be at different levels, up to that of a partnership, depending on the specific market segment. In Figure 12, the Third-party consults the MNO in Phase 1 and interfaces with the NPN User. But the dual model is possible as well, i.e. with the MNO interfacing with the NPN User and consulting the industrial third-Party, who provides the expertise in the specific field of the NPN User.

Value proposition from the MNO: The MNO provides the network services (in particular slicing offers), and eventually consulting services, to the third party, who is therefore the single interface to the NPN User. As for Fully hosted PNI-NPN Option 1, the MNO keeps control over the whole network value chain (equipment providers, network services providers, etc.) and is able to deliver end-to-end network services to the Third-Party. These network services can be designed for different spectrum options which help support multiple services with very different requirements. The main difference in the value proposed by the MNO lies in the type of SLA which are offered and which are specifically designed for the use cases provided by the Third-Party, which ensure a good matching between the MNO's network capabilities and the industrial products or services.

Potential value proposition from a third party: the third party is providing the 5G service to the market, eventually reselling the MNO's connectivity and network services, and adding the value of its knowledge and competence in the specific industrial field of the NPN User.

We assume here that the NPN user directly signs a contract with the MNO for connectivity offers in Phase I and that the partnership between the Third-Party and the MNO concerns the role of Integrator. Such relationship model allows a win-win relationships between the NPN user, the Third-party and the MNO. There is more transparency with respect to the role and responsibilities of each stakeholder. In particular, the Third-Party does not hold responsibilities in case of a network failure and faster reactivity can be reach as the MNO has a direct business relationship with the NPN User. The NPN User has a clearer view on the network services that he has subscribed. By having a tighter relationship with the NPN User, the MNO can use its own expertise and data analytics to propose new added-value services to be developed with the Third-Party.

5.2.2 Advantages and disadvantages of this relationship model

Pros & cons for the NPN user: for the NPN user this relationship model is the simplest and most straightforward path to entering the 5G ecosystem, because no expertise in 5G technologies is needed at all. By requiring no dedicated infrastructure, this model also offers a low expenditure overall, which is expected to be slightly higher than fully hosted PNI-NPN Option 1 only due to the mediation of the third party on the MNO's connectivity and network services. However, this mediation allows to design an NPN better tailored to industrial services. The NPN User may also expect a fast time to market for its industrial services, due to the fact that its sole interface belongs to the same industrial field: they "speak the same language", so to say.

- **Flexibility to adapt to different use cases:** ● Medium, similarly to fully hosted PNI-NPN Option 1, the NPN user (through the Third-Party) is limited to the offers proposed by the MNO ("length of the catalog"). However, the mediation of the industrial third party allows the MNO to have a better knowledge of industrial needs and to design a wider and more specific catalog of services, which can be proposed to Industrial parties with similar requirements. In addition, future on-demand slice creation will bring increased use case customization.
- **Performance tuning:** ● Medium, depending on the services designed by the partnership between the MNO and the Third Party. The NPN user has lower autonomy with respect to performance tuning than for a SNPN, and has to refer to the third party. There is however a

benefit in terms of reduced knowledge required and a tight collaboration between the MNO and the Third-Party could lead, for example, to the design of dedicated API for improved performance tuning and observability.

- **Interference management in co-existence scenarios:** ● High. As in the previous fully hosted PNI-NPN Option 1, the MNO is the sole responsible for interference management and it takes all the decisions and actions without involving the NPN user.
- **Providing a streamlined interface between stakeholders:** ● High. This model provides the most simplified relationship and it is one of the strongest factor for adopting this model. The mediation of the Third-party brings trust in this relationship model and helps ease the communication between stakeholders.
- **Attractiveness of a relationship model:** ● High. As in the previous fully hosted PNI-NPN Option 1, because minimal CAPEX is required for this relationship model and because deployment is quick and easy, choosing a Fully hosted PNI-NPN shows minimal risk for an industrial party to jump into 5G. Contrary to Option 1, the partnership between the MNO and the Third-Party can ensure a better matching between the MNO portfolio and the industrial requirements.
- **Business agility vs customer loyalty:** ● Medium, since the NPN User relies completely on the expertise of the third party Integrator, a medium-term relationship would be typical for this scenario, intermediate between SNPN deployments and the fully hosted PNI-NPN Option 1.
- **Scalability and coverage extension:** ● Medium. As in the previous fully hosted PNI-NPN Option 1, the NPN User has straightforward access to the national, and eventually international, capabilities of the MNO.
- **Easiness to manage hosting sites:** ● Medium, as in the previous PNI-NPN Option 1, the NPN user does not manage the hosting site, but it is limited to the areas where 5G is already deployed or should negotiate with the MNO for specific additional coverage.
- **Provisions for information security risks management:** ● Medium ● High, depending on the MNO's edge computing offering. No expertise is required; security level and risk management is expected at market-standard level. As for Option 1, data may leave premises but virtual network isolation can offer the same level of security as physical network isolation. Furthermore, tailored edge solutions, designed with the Third-Party, can bring additional trust with respect to Fully hosted PNI-NPN.
- **Reducing the required CAPEX / OPEX:** ● High. This model requires substantially no CAPEX of the NPN user, who can also match the OPEX to the actual needs, and who can therefore keep them very close to the minimum value. Even though in fully-hosted PNI-NPN Option 1 there is the possibility for the NPN User to tune the OPEX by relating directly to the MNO from the beginning, it is very likely that a bulk offers agreement between the MNO and the industrial third party can guarantee an overall better price to the NPN User, even after considering the

margins of both the MNO and the third party. Further overall savings can also be due to the lower internal costs of managing a single supplier.

Pros & cons for the MNO: The interest of this relationship model from the perspective of a MNO highly depends on its market penetration and its brand relevance with respect to the targeted use cases and NPN users. If the MNO already has strong knowledge of the use case, it may expect a reduced revenue stream using this relationship model; however, in contrast to fully hosted PNI-NPN Option 1, a higher return is possible thanks to mediation of the industrial third party who effectively reduces the MNO's operating costs. On the other side, if the MNO already has less knowledge of the targeted use case, a partnership with a third-party helps open new business perspectives and reach new customers.

- **Flexibility to adapt to different use cases:** Medium. As for the previous Option 1, the MNO needs to create a valuable portfolio to generate a sustainable demand. However, the applied expertise of the industrial third party as an integrator facilitates the design of such portfolio and ensures to reach customers. This criterion is rated as Medium and not High because the needs expressed by the third party should however be aligned with the MNO's internal capabilities, given the NPN is fully hosted in the public network.
- **Performance tuning:** Medium. This is comparable to fully hosted PNI-NPN Option 1, even though the NPN User may enjoy an even better responsiveness and focus if the industrial third party is somewhat involved during Phase II as well.
- **Ease of co-existence and provisions for managing interference:** High. The MNO is in charge of interference management, as part of its daily business.
- **Providing a streamlined interface between stakeholders:** Medium. The MNO is hidden by the third party during Phase I and it is the sole interface to the NPN User during operation. This challenge may be improved by a tight and long-standing partnership between the MNO and the Third-Party.
- **Attractiveness of a relationship model:** High. The MNO can greatly benefit from a partnership in order to enter every market where it does not already have expertise and/or established brand.
- **Business agility vs customer loyalty:** Low. Compared to other NPN solutions, there is a higher risk of substitution for the MNO.
- **Scalability and coverage extension:** High. Like in fully hosted PNI-NPN Option 1, a MNO usually has national coverage, therefore extending coverage is quite straightforward from a technical perspective. International extension is enabled by MNO agreements.
- **Easiness to manage hosting sites:** Medium. This operational model shows the same challenges as for PNI-NPN Option 1.

- **Provisions for information security risks management:** ● High. The MNO is expected to provide security at the highest standards level, but that is common business practice and therefore not an additional burden. Contrary to option 1, the partnership with the Third-Party brings trust and may help design security and privacy services tailored to the use cases. In addition, the MNO could deploy an edge server in the premises.
- **Reducing the required CAPEX / OPEX:** ● Medium, by adopting a suitable strategy and careful planning, the MNO can quite easily leverage its network design, so that the NPN offering is substantially integrated with its general public offering.

5.2.3 Discussion on type of customer and use cases the option is suitable for

Targeted use cases: As for the fully hosted PNI-NPN Option 1, this option targets mostly outdoors use cases, potentially with a wide coverage area, and use cases showing characteristics common to several customers (yet, future on-demand slicing should allow increased use case customization).

Targeted NPN Users: Users that are not willing to gain expertise in 5G, and that are not willing to invest a lot or cannot afford it (SMEs, start-ups...), users with ”classic needs” and who want fast time to market. The prospective user shall be located a convenient area, where 5G is available, or supplemental 5G coverage should be negotiated with the MNO. In comparison to fully hosted PNI-NPN Option 1, this second model might be preferred by those NPN User who give particular value to having a single interface with knowledge of their own industrial field.

5.3 Summary on Fully hosted PNI-NPN

Even if Fully hosted PNI-NPN options may show some technical limitations compared to other options, e.g. for use cases with very stringent latency requirements, they hold several key advantages for the NPN User which make them worth considering. From a technical perspective, these options inherently hold services to facilitate spectrum management, interference mitigation in co-existence scenarios and coverage extension, for both national and international scales. From a business perspective, such options allow the NPN Users to focus on their core business, while relying on an industrial Third-Party and/or a MNO for the design and operation of its 5G NPN. As less CAPEX is required, an Industrial party takes much less risk in selecting a fully hosted PNI-NPN deployment option.

Fully hosted PNI-NPN options allow MNOs to create significant value out of their network capabilities and to reach new customers, provided that a portfolio meeting NPN User’s requirement is offered. Dynamic on-demand slices creation, expected around 2025, should bring additional flexibility and allow a NPN User to design a fully-tailored slice.

While the choice of the SNPN relationship model highly depends on the spectrum regulation framework in the considered country and on the choice of the NPN user, the choice of the relationship model for fully hosted PNI-NPN (Option 1 or 2) rather belongs to the MNO. This choice should be made based on the knowledge the MNO has on targeted use cases, on its market penetration and brand relevance, but also on trust.

For use cases already mastered by MNOs, and for which it is possible to design generic slicing offers, the MNO is fully able to own the customer relationship and Option 1 can be considered. Otherwise, the partnership between a Third-Party and the MNO (Option 2) is possible. It allows the MNO to step in new use cases and reach new customers, and allows the Third-Party to develop novel 5G-enabled products and services, thereby creating new business opportunities. Option 2 can also be considered for use cases already mastered by MNOs as it brings a good emulation and may be a relevant driver for innovation.

6 PNI-NPN with shared RAN / CORE

While a Fully hosted PNI-NPN service from the MNO may be the most attractive option for some industrial players, some would still like to make sure parts of the network and operation are fully dedicated and run on-premises, which means that some parts belong to the private NPN and some of the dedicated functions are hosted in the public network. These combinations of PNI-NPN are sometimes referred to as *shared models* and, in essence, the scenarios differ depending on how much functionality is hosted on the infrastructure in the public network. In the same way as with SNPN, there are many possible combinations and levels of functional split between private (on-premises) and public, but in this document, we analyze four different network deployment options for running shared networks, as well as the consequences they will have for the NPN User and MNO. Both business patterns described in chapter 5 can still be used. Note that in contrast to chapters 4 and 5, where the network deployment stays the same in each option and only the business roles changes, in this chapter it is the network deployment that changes between the options. The relationship model stays the same for all options in this chapter i.e. the MNO is both network integrator and operator.

- Option 1: PNI-NPN with only parts of the Operation & Maintenance[1] (O&M) in the public network
- Option 2: PNI-NPN Shared RAN
- Option 3: PNI-NPN Shared RAN plus Private Control Plane and User Management hosted in public network
- Option 4: PNI-NPN Shared RAN plus Private Control Plane, User Management and User Plane hosted in public network. In the following subchapters, we will provide an overview of the value proposition from the MNO and the advantages and disadvantages the different deployment options will have for both the MNO and the NPN User. For all the options the MNO is responsible for the integration (possibly together with a third party integrator) and operation, since it is integrated into the public network and thus they will also use MNO spectrum, possibly in combination with local industry spectrum if that is available and it is legal in the specific country to combine.

[1] Operation & Maintenance – An umbrella term used in telecom to describe processes, activities, tools involved for operating, administering, managing and maintaining a network.

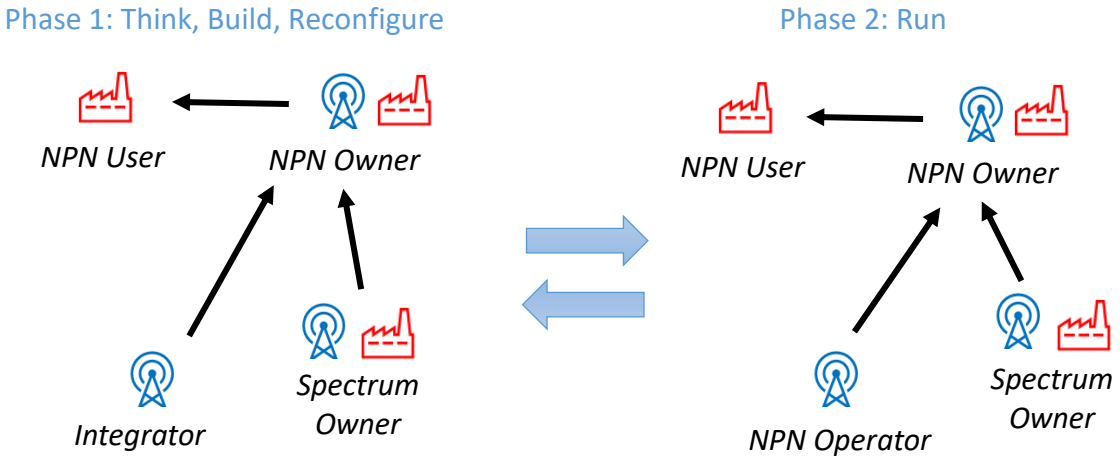

Figure 13: PNI-NPN with shared O&M/RAN/Core

6.1 Option 1 – PNI-NPN with part of O&M hosted in public network

6.1.1 Overview and value proposition

Note that this option is not explicitly mentioned in 5G-ACIA [5GA19-NPN]. Operating an NPN entirely on-premises is resource consuming and costly, thus an expensive option. If an MNO instead is allowed to open a secure connection to its Network Operation Centers (NOC) and sites and are allowed to run at least parts of the operations from the public network, resources and expertise can be shared between several NPNs and better economy of scale can be reached. Each customer and use case may lead to moving different functionalities; however, configuration, integration, optimization, software management, advanced trouble shooting is typically handled by the MNO NOC. The NPN can still be designed so that it can have local survivability in case the connection to the public network goes down, with different level of functionality available, depending on what is installed in local OSS [2] and what is only available from public hosted OSS. If all functionalities resides on-premises, and the connection is only a secure tunnel for remote access to the local OSS functionality through the network of a MNO, we consider it still being an SNPN. All private traffic still stays on site and no public traffic is allowed in the PNI-NPN. Typically, normal daily operation like monitoring, subscriber management, basic troubleshooting, replacing, and restarting faulty nodes is handled locally, supported by a local OSS, likely by the industrial NPN User's own IT team.

Value proposition from the MNO: The MNO provides the same pre-tested fully on-premise deployed NPN solution as for a SNPN, i.e. with local survivability, but with a more cost-efficient operation setup compared to an isolated SNPN, by re-using expertise, functionality, and shared infrastructure from their centralized NOCs and OSS and having maintenance field engineers that can be shared between multiple sites in a geographical area.

[2] OSS – Operations Support System is a term in telecom describing the set of tools used to support management functions such as network inventory, service provisioning, network configuration and fault management.

6.1.2 Advantages and disadvantages of this relationship model

The main benefit of this setup is to make operation more cost efficient and avoid having dedicated personnel on each customer site compared to a fully isolated SNPN. Field personnel can cover multiple sites and SLAs for service restoration can be solved by redundant deployment. This setup requires the industrial player to trust the MNO and open up to securely connect O&M data (all private data traffic stays on the private network). To enable this, a split OSS architecture and SW is required. Local operation personnel is still required to run the daily operations if the NPN User selects to do it themselves, but it could also be offered by an MNO.

Pros & cons for the NPN user: In general, this relationship model provides all the benefits of having a SNPN and at the same time get the advantage of having an MNO taking care of some of the management activities and thus get better economy of scale. “Best of two worlds”.

- **Flexibility to adapt to different use cases:** ● High, since from a traffic perspective this is the same as a SNPN.
- **Performance tuning:** ● High, since from a traffic perspective this is the same as a SNPN.
- **Ease of co-existence and provisions for managing interference** ● High, the MNO will take responsibility and thus the NPN User does not need to have expertise in this field**.**
- **Providing a streamlined interface between stakeholders:** ● High. Same as in SNPN, the MNO is the sole interface, since it is responsible for operations and network integration (the only difference is that some of the O&M is handled from off-site e.g. in a NOC).
- **Attractiveness of a relationship model:** ● High, this option requires a low level of expertise since the MNO is responsible for both operation and integration. Depending on how much the NPN User wants to manage themselves, different levels of competence need to be invested in, but should be easy for local IT teams to learn.
- **Business agility vs customer loyalty:** ● Medium. If the NPN User owns (whole or parts of) the on-premise network they can change MNO. The more functions that are hosted on the MNO sites, the harder it will be to change.
- **Scalability and coverage extension:** ● High. No difference from all other scenarios/options where the MNO is involved.
- **Easiness to manage hosting sites:** ● High, since the private part is on-premise, the only cost is to provide server room where the core functions of the on-premise NPN can be hosted. However, specific restrictions may exist for outdoors antennas, for example on sector orientation or transmit power. Extra cost, borne by the sole NPN user, may be necessary to provide the hosting site with power supply and backhauling capabilities.

- **Provisions for information security risks management:** ● High. No production traffic is leaving the premises. The MNO must though be trusted to handle the selected (which is case-by-case) O&M traffic off-premise.
- **Reducing the required CAPEX / OPEX:** ● Low. The whole network is still on-premise like a SNPN. Some cost optimization can though be obtained by centralizing part of the O&M functionality. The ratio between CAPEX and OPEX is dependent on the pricing structure of the supplier of the PNI-NPN. Depending of the selected ownership model, possibilities for scaling and re-use of equipment can differ. An MNO can more easily move equipment between different customers if they own the infrastructure.

Pros & cons for the MNO: In general, this option provides a good way for an operator to meet the NPN Users' concern about not trusting to run services hosted in a public network. It creates a good opportunity to use assets and economy of scale from existing NOCs and sites and both learn about industry customer needs and build trust that enable to expand and tune the portfolio, grow business by taking over more of the networking and IT-related functionality from the industry player.

- **Flexibility to adapt to different use cases:** ● Medium, a balance should be found between the high level of customization of the NPN and the economy of scale.
- **Performance tuning:** ● Medium, a balance should be found between the high level of customization of the NPN and the economy of scale.
- **Ease of co-existence and provisions for managing interference:** ● High, The MNO have the responsibility to manage interference and is in full control.
- **Providing a streamlined interface between stakeholders:** ● High. Same as in SNPN, the MNO is the sole interface and may gain expertise in industrial needs and requirements.
- **Attractiveness of a relationship model:** ● High. MNO needs to understand industry processes and the application requirements as well as the device eco-system.
- **Business agility vs customer loyalty:** ● Medium. Good opportunity to create a strong customer relationship.
- **Scalability and coverage extension:** ● High. This is MNO normal business (also for indoor)
- **Easiness to manage hosting sites:** ● High. Low cost site acquisition and operation if the NPN User hosts the network.
- **Provisions for information security risks management:** ● High. No production traffic is leaving the premises.

- **Reducing the required CAPEX / OPEX:** ● Medium. Opportunity to get lower OPEX by utilizing NOC and other existing resources for O&M. The ratio between CAPEX and OPEX is dependent on the pricing structure of the network equipment and OSS provider. The cost structure is the same as for a SNPN but the MNO also need to take care of the cost of the split OSS architecture and integrate the local OSS installation at the NPN User sites with the MNO sites and NOCs and secure field personnel dimensioned to serve selected geographical areas.

6.1.3 Discussion on type of customer and use cases the option is suitable for

This setup is suitable for NPN Users who want to have a lot of control and do not want data from the NPN to move into the public network but still want to benefit from a more cost efficient relationship model and trusts an MNO to have part of the O&M data being handled from the public network (NOC). This setup can support all use cases.

6.2 Option 2 – PNI-NPN with Shared RAN

6.2.1 Overview and value proposition

Many industrial players also have a need for non-critical mobile communication inside their buildings i.e. regular MBB e.g. for own personnel, entrepreneurs working inside the facility or public safety personnel such as fire fighters and ambulance personnel, or for logistics in and out of the premises. Still, they do not want this traffic to run on the private network (due to trust or capacity). In this case a shared RAN setup can be an interesting option. This means that the same RAN infrastructure can be used by the MNO to also offer public services. Devices and end users are provisioned separately on the private UDM and the public UDM[3]; public traffic terminates in the public network, while private traffic stays on the private on-premise NPN. The RAN can be configured to either use the same spectrum or separate spectrum for the private and public. An alternative is to have a parallel public in-house RAN infrastructure and to use dual-SIM for relevant devices, if there is concern about the dimensioning and that the public traffic may consume resources from the private NPN.

Value proposition from the MNO: The MNO can offer public services over the same RAN infrastructure with clear traffic separation. Devices (temporary users, material and products i.e. logistics) that enter and leave the building can benefit from the coverage and roaming of the public network. Voice services could be offered from the public network (note: in that case without local survivability). If the NPN User does not trust temporary public users (e.g. machine suppliers) to be provisioned and connected directly to the private network, the MNO can provide connectivity for these users through the public network (the users need a subscription in the public network).

6.2.2 Advantages and disadvantages of this relationship model

In addition to the benefits from option 1 (part of O&M allowed from public network) public MBB traffic can be offered in the buildings and still have private and public traffic completely separated. If the

[3] UDM – Unified Data Management. The UDM manages data for access authorization, user registration, and data network profiles.

same resources can be used, a more sustainable setup can be provided utilizing the same RAN infrastructure also for MBB coverage.

Pros & cons for the NPN user: In general, this relationship model provides all the benefits of having a SNPN and at the same time get the advantage of having an MNO taking care of some of the management activities and offer public services on the same RAN infrastructure. Again, "Best of two worlds".

- **Flexibility to adapt to different use cases:** ● High, since from a traffic perspective this is the same as a SNPN (given that the MNO are flexible).
- **Performance tuning:** ● High, since from a traffic perspective this is the same as a SNPN (given that the MNO are flexible).
- **Ease of co-existence and provisions for managing interference:** ● High. Since MNO spectrum is utilized, the MNO will take responsibility and thus the NPN User do not need to have expertise in this field**.**
- **Providing a streamlined interface between stakeholders:** ● High. Same as in SNPN, the MNO is the single point of contact since they are responsible for operations and network integration.
- **Attractiveness of a relationship model:** ● High. Low level of expertise required since the MNO is responsible for both operation and integration. Depending on how much the NPN User wants to manage themselves, different levels of competence need to be invested in but should be easy for local IT teams to learn.
- **Business agility vs customer loyalty:** ● Medium. If the NPN User owns (whole or parts of) the on-premise network they can change MNO. However, if they also use public MBB services, NPN User is limited to the MNOs covering the area.
- **Scalability and coverage extension:** ● High. No difference in-door from other scenarios where the MNO is involved. Outdoor coverage could potentially be served by the public network if the requirements can be met. Otherwise, it can be built as part of the SNPN with outdoor hardware.
- **Easiness to manage hosting sites:** ● High. Since the private part is on-premise the only cost is to provide server room where the core functions of the on-premise NPN can be hosted. Backhaul to public core needs to be hosted.
- **Provisions for information security risks management:** ● High. No production traffic is leaving the premises. The MNO must be trusted to handle the selected O&M traffic off-premises and the NPN User need to trust that the public services served over the same RAN infrastructure on-premise do not affect the private network.

- **Reducing the required CAPEX / OPEX:** 🔴 Low. The network is still on-premise like a SNPN. Some cost optimization can be met by centralizing some of the O&M functionality. Utilizing public MBB for non-critical services could be more cost efficient, especially for outdoor coverage, but depending on the use cases, indoor coverage from outdoor antennas using sub-6GHz bands could be sufficient. The ratio between CAPEX and OPEX is dependent on the pricing structure of the supplier of the PNI-NPN.

Pros & cons for the MNO: In general, this option provides a good way for an operator to meet the NPN Users' concern about trusting to run services in a public network and at the same time offer public services on-premise. It creates a good opportunity to use assets and economy of scale from existing NOCs and RAN sharing. MNO can learn about industry customer needs and build trust that enable to grow business and take over more from the NPN User. The MNO also gets increased coverage/extension for the public network virtually for free (low or no site acquisition cost).

- **Flexibility to adapt to different use cases:** 🟠 Medium, a balance should be found between the high level of customization of the NPN and the economy of scale.
- **Performance tuning:** 🟠 Medium, a balance should be found between the high level of customization of the NPN and the economy of scale.
- **Ease of co-existence and provisions for managing interference:** 🟢 High, since the MNO has the responsibility to manage interference, both for private and public services, but can at the same time be in full control.
- **Providing a streamlined interface between stakeholders:** 🟢 High. Same as in SNPN, the MNO is the sole interface and may gain expertise in industrial needs and requirements.
- **Attractiveness of a relationship model:** 🟢 High, since the MNO needs to understand industry processes and the application requirements as well as the device eco-system.
- **Business agility vs customer loyalty:** 🟢 High. Good opportunity to create a strong customer relationship including public services.
- **Scalability and coverage extension:** 🟢 High. MNO normal business (also for indoor) with an opportunity to use public network for non-critical service coverage.
- **Easiness to manage hosting sites:** 🟢 High. Low cost site acquisition and operation if the NPN User hosts the network. MNO needs to get access to their backhaul and RAN resources used for public services.
- **Provisions for information security risks management:** 🟢 High, since no production traffic is leaving the premises.

- **Reducing the required CAPEX / OPEX:** ● Medium. Opportunity to get lower OPEX and CAPEX by utilizing NOC and shared local, and if access points can be mutualized between public and private service. The ratio between CAPEX and OPEX is dependent on the pricing structure of the network equipment and OSS provider.

6.2.3 Discussion on type of customer and use cases the option is suitable for

This setup is equally suitable as an SNPN for industrial players that requires full control and local survivability for the private traffic, but also want access to public services. It requires that the NPN User trust the MNO (and the Third party integrator in case they are used) to design, dimension, and deploy the network so that defined SLAs can be met. This setup supports all private use cases plus optional public services on-premise.

6.3 Option 3 – PNI-NPN Shared RAN plus Private Control Plane and UDM hosted in public

6.3.1 Overview and value proposition

If the industrial player does not have a strict requirement for full local survivability (the NPN works with full functionality even if redundant connections to the public network is broken) it will be an even more cost efficient alternative to host the control and UDM (HSS) functionalities in the public network to benefit from economy of scale. The user plane functions still stay on premise and make sure private traffic do not leave premises. This may be necessary for performance and/or trust issues on e.g. data sovereignty/confidentiality. Full local survivability will not be supported as control functions are hosted in the public network.

Value proposition from the MNO: In addition to offer public services as in option 2, the MNO can also host the core control functions and user and device management leading to less investment for the NPN User due to the MNO having economy of scale from utilizing their existing sites and personnel. The NPN User will also need less investment in competence for operating a mobile core.

6.3.2 Advantages and disadvantages of this relationship model

With this option the NPN User will not need to invest in competence for running a mobile core and can benefit from the advantage of economy of scale for the control functions since the MNO can utilize the same infrastructure for multiple customers. Since User and Data Management is hosted in the public network, the NPN User may have some concern about trust and depending on the MNO offering there can be limitations in what the NPN User is allowed to do.

Pros & cons for the NPN user: In general, this relationship model provides some of the benefits of having a SNPN and get the advantage of having an MNO taking care of some of the management activities and core control functions. Private traffic still stays on-premise however since core control functions are hosted in the public network full local survivability cannot be offered, but depending on the specific split of functionality in the Operating Support System the local network could still continue to run although some functions like e.g. software upgrades cannot be made.

- **Flexibility to adapt to different use cases:** ● Medium, depending on how much customization the MNO will allow to still benefit from economy of scale.
- **Performance tuning:** ● Medium, depending on how much customization the MNO will allow to still benefit from economy of scale.
- **Ease of co-existence and provisions for managing interference:** ● High. Since MNO spectrum is utilized the MNO will take responsibility and thus the NPN User do not need to have expertise in this field**.**
- **Providing a streamlined interface between stakeholders:** ● High. Same as in SNPN, the MNO is the single point of contact since they are responsible for operations and integration (the only difference is that some of the O&M, control plane and UDM is running hosted off-site).
- **Attractiveness of a relationship model:** ● High. Low level of expertise required since the MNO is responsible for both operation and integration. Depending on how much the NPN User wants to manage themselves different levels of competence need to be invested in but should be easy for local IT teams to learn for basic operation.
- **Business agility vs customer loyalty:** ● Medium. Radio part and user plane is still on-premise but the lock-in due to using an MNO hosted core control is rather strong.
- **Scalability and coverage extension:** ● High. No difference in-door from other scenarios where the MNO is involved. Outdoor coverage could be served by the public network if the requirements are reached.
- **Easiness to manage hosting sites:** ● High. Server room to host RAN and core user plane needs to be provided. Backhaul to both the public core and to the private core control plane needs to be hosted.
- **Provisions for information security risks management:** ● Medium. No production traffic is leaving the premises. The MNO must be trusted to handle some of the O&M traffic, UDM and control plane data off-prem. Public services must be trusted to be served over the same RAN infrastructure on-premise.
- **Reducing the required CAPEX / OPEX:** ● Medium. Cost optimization can be met by centralizing some of the O&M functionality, core control plane and UDM. However, RAN and core user plane is still required on-premise. Utilizing public MBB for non-critical services could be more cost efficient. The ratio between CAPEX and OPEX is dependent on the pricing structure of the supplier of the PNI-NPN.

Pros & cons for the MNO: In general, this option provides a good way for an operator to meet the NPN Users' concern about trusting to run services in a public network and at the same time offer public services on-premise. It creates a good opportunity to use assets and economy of scale from existing

NOCs, core/VNF hosting sites and RAN sharing. MNO can learn about industry customer needs and build trust that enable to grow business and take over more from the NPN User.

- **Flexibility to adapt to different use cases:** Medium, a balance should be found between the high level of customization of the NPN and the economy of scale.
- **Performance tuning:** Medium, a balance should be found between the high level of customization of the NPN and the economy of scale.
- **Ease of co-existence and provisions for managing interference:** High. The MNO have the responsibility to manage interference, both for private and public services, and is in full control.
- **Providing a streamlined interface between stakeholders:** High. Independent of deployment models where the MNO is the main contact.
- **Attractiveness of a relationship model:** High. MNO needs some understanding of industry processes and the application requirements to create scalable offerings.
- **Business agility vs customer loyalty:** High. Good opportunity to create a strong customer relationship including public services and by also running core control functions.
- **Scalability and coverage extension:** High. MNO normal business (also for indoor) with an opportunity to use public network for non-critical service coverage.
- **Easiness to manage hosting sites:** High. Low cost site acquisition and operation if the NPN User hosts the network. MNO needs to get access to their backhaul and RAN resources used for public services.
- **Provisions for information security risks management:** Medium. No production traffic is leaving the premises. Control plane data supported from off-prem sites. API for secure provisioning in the UDM for the daily operations need to be provided.
- **Reducing the required CAPEX / OPEX:** Medium. Opportunity to get lower OPEX by utilizing NOC and shared local RAN as well as the core/VNF sites. Investment to provide secure APIs for provisioning in the hosted UDM for the daily operations. Multitenant support for the core functions required. The ratio between CAPEX and OPEX is dependent on the pricing structure of the network equipment and OSS provider.

6.3.3 Discussion on type of customer and use cases the option is suitable for

This option is more suitable for NPN Users that trust an MNO to host control plane and UDM functions but still have high performance demanding use cases and/or do not want production data to leave premises which means that the user plane functions needs to stay on-premise. Full local survivability will not be supported. It is likely that an MNO will limit the flexibility for customization to some extent. All use cases can still be supported with this option.

6.4 Option 4 – PNI-NPN Shared RAN plus Private Control plane, UDM and User Plane hosted in public

6.4.1 Overview and value proposition

If the industrial players trust private data to be routed to dedicated network functions hosted in the public network and do not have ultra-low latency requirements, they can consider to host the user plane of the core network in the public domain. All traffic to on-premise servers (e.g. running on a local on-premise edge cloud server) will then be routed out via the public network and back again. The traffic is still separated by means of e.g. a slice or DNN and resources can be virtually dedicated on the public site. In this scenario all core functionality is hosted in the public network and only the RAN is on the customer premises. The NPN User (industrial player) may still want to own the RAN for different reasons (e.g. a mining company must own it for legal reasons).

Value proposition from the MNO: The MNO takes care of everything and the NPN User only needs to host the RAN on-premise and will get "industry communication as-a-Service".

This option has some similarities with the fully hosted PNI-NPN options, presented in Section 5, but contrary to them, the NPN User enjoys additional on-premises antennas.

6.4.2 Advantages and disadvantages of this relationship model

With this option, given that the NPN User trusts the MNO to manage all data they can get the benefits of economy of scale also for the user plane functions and does not need to host any core equipment on-premise. All traffic to local servers now needs to go via the user plane hosted in the public network which adds additional delay and means that the most performance requiring use cases may not be supported.

Pros & cons for the NPN user: In general, this relationship model provides the benefits of having an MNO taking care of everything but hosting the RAN.

- **Flexibility to adapt to different use cases:** ● Medium, depending on how much customization the MNO will allow to still benefit from economy of scale.
- **Performance tuning:** ● Medium, depending on how much customization the MNO will allow to still benefit from economy of scale.
- **Ease of co-existence and provisions for managing interference:** ● High. Since MNO spectrum is utilized, the MNO will take responsibility and thus the NPN User do not need to have expertise in this field**.**
- **Providing a streamlined interface between stakeholders:** ● High. Same as in SNPN, the MNO is the single point of contact since they are responsible for operations and integration (the only difference is that O&M, core and UDM is handled from off-site e.g. in a NOC).
- **Attractiveness of a relationship model:** ● High. Low level of expertise required since the MNO is responsible for both operation and integration. Depending on how much the NPN

User wants to manage themselves different levels of competence need to be invested in but should be easy for local IT teams to learn for basic operators.

- **Business agility vs customer loyalty:** ● High. Radio part is still on-premise but the lock-in due to using an MNO hosted core and UDM is rather strong.
- **Scalability and coverage extension:** ● High. Outdoor coverage could be served by the public network if the requirements are reached, but compared to fully hosted PNI-NPN options, the NPN User enjoys additional on-premises antennas which increase the possibilities to scale up.
- **Easiness to manage hosting sites:** ● High Standalone server room to host the RAN needs to be provided. Backhaul to both the public core and to the private core needs to be hosted.
- **Provisions for information security risks management:** ● Medium. The MNO must be trusted to handle all traffic off-premise which they are well equipped to do. Public services must be trusted to be served over the same RAN infrastructure on-premise.
- **Reducing the required CAPEX / OPEX:** ● High. Cost optimization can be met by centralizing all the core functionality. However, RAN is still required on-premise. Utilizing public MBB for non-critical services could be more cost efficient. The ratio between CAPEX and OPEX is dependent on the pricing structure of the supplier of the PNI-NPN.

Pros & cons for the MNO: In general, this option provides a more cost-efficient way for an operator to create good on-premise coverage while still using public hosted core. It thus creates a better opportunity to use assets and economy of scale from existing NOCs, core/VNF hosting sites and RAN sharing. MNO can learn about industry customer needs and expand on services.

- **Flexibility to adapt to different use cases:** ● Medium. To keep economy of scale the MNO should be careful to allow too much service customization.
- **Performance tuning:** ● Medium. To keep economy of scale the MNO should be careful to allow too much customized tuning.
- **Ease of co-existence and provisions for managing interference:** ● High. The MNO have the responsibility to manage interference, both for private and public services, but is in full control.
- **Providing a streamlined interface between stakeholders:** ● High. The MNO represents the single point of contact for the NPN User.
- **Attractiveness of a relationship model:** ● High. MNO needs some understanding of industry processes and the application requirements to create scalable offerings and need to convince NPN Users that they can be trusted to meet their needs.

- **Business agility vs customer loyalty:** Medium. Good opportunity to create a strong customer relationship including public services and by also running core functions.
- **Scalability and coverage extension:** High. MNO normal business (also for indoor) with an opportunity to use public network for non-critical service coverage.
- **Easiness to manage hosting sites:** High. Low cost site acquisition and operation if the NPN User hosts the RAN network. MNO needs to get access to backhaul and RAN resources.
- **Provisions for information security risks management:** Medium. All traffic is handled from off-premise sites and security precautions need to be taken.
- **Reducing the required CAPEX / OPEX:** Medium. Opportunity to get lower OPEX by utilizing NOC and shared local RAN as well as the MNO sites hosting core functions (e.g. Virtual Network Functions). Multitenant support for the core functions required (also for user plane functions). The ratio between CAPEX and OPEX is dependent on the pricing structure of the network equipment and OSS provider.

6.4.3 Discussion on type of customer and use cases the option is suitable for

This option is most suitable for industrial players that have full trust in an MNO and do not need to customize so frequently. Since all the traffic to local servers now “trombones”, or make round-trip, into the public network some of the most performance demanding use cases may not be possible to run, depending on the distance between on-premise and MNO core/VNF sites. From the seven trialed use cases described in D1.1 [5GS20-D11] only the use case “Visualization of factory floor” can be supported. “Cloud steered AGV” and “5G Connected robot” could potentially be supported depending on how the MNO network is designed and deployed.

Even if it is over a very secure infrastructure, data will now also leave the customers’ premises. Since an MNO can utilize economy of scale best in this option it is likely also the option with the lowest TCO for the industrial player (however, this is case-by-case and dependent on how the MNO organize and select pricing model).

6.5 Summary on PNI-NPN with shared infrastructure

Shared PNI-NPN could potentially develop from something very close to SNPN, with substantial NPN user control, to something that is much more MNO-controlled, with the increasing trust. It could combine the required performance, security, and sense of control for the NPN user with the potential economy of scale benefits to the MNO, supporting multiple industry customer from one operations center and integrated with the public network. Although this will differ case-by-case, in general, the more functionality that is moved to be hosted on a public infrastructure the higher potential of reaching economy of scale and at the same time the level of control for the industrial player may decrease. Therefore, trust on the MNO needs to be higher and customer relationships between the Industrial party and the MNO needs to be tighter, to ensure a sufficient level of autonomy for the customer. It will in the end be a tradeoff to be made by each industrial player regarding the level of control required. For the MNO it will be a trade-off of how much customization and tuning to allow

when they design their offering to keep cost under control while at the same time meet the needs of all targeted segments.

7 Summary on relationship models

We review the different criteria for the proposed relationship models in Table 2: for the NPN User perspective and Table 3: for the MNO perspective. Given the number of aspects and how they affect each other, the contributors to this deliverable wish to warn the reader that these tables **do not claim to provide a comprehensive guide or handbook to the "best" option.** Rather, it summarizes various important aspects that industrial players need to consider to an informed decision, and for MNOs to identify key resources required to be able to offer high valued services.

Each rating needs to be viewed in the context of the related explanation provided for each option and depends on the country (e.g. spectrum regulation, existing ecosystem), the industrial end user (e.g. large enterprise, SMEs, willingness to invest in 5G expertise, etc.), as well as the individual use case portfolio of this industrial end user, which is out of the scope of this document. We also highlight that the proposed rating should be understood less as a technical evaluation of the considered criterion, and more as a **subjective perception** of involved stakeholders, and in particular the NPN User.

The perspective of the NPN user (Table 2:): The following aspects can be raised:

- **Flexibility to adapt to different use cases:** For SNPN options, the High or Medium evaluation depends on the level of control of the NPN given to the industrial user. Interacting with an intermediary may result in less control of the NPN for the industrial end-user. Yet, this intermediary can also bring support and expertise for NPN Users less familiar with 5G technologies. For fully-hosted PNI-NPN, limitations depend on the MNO portfolio. For PNI-NPN with shared RAN and / or core networks, the control of the NPN given to the industrial user depends on the level of sharing. The proposed rating may reflect more the perception of the NPN User, than a technical evaluation.
- **Performance tuning:** This criterion evaluates the autonomy of the NPN User with respect to network KPIs observability and monitoring. Hosting part of network functions in the public network may be perceived as less convenient by an industrial user looking for full NPN control.
- **Ease of co-existence and provisions for managing interference:** Some challenges may exist between neighboring networks, or regarding the use of macro UE within factory. Anticipation is required.
- **Providing a streamlined interface between stakeholders:** Two factors are highlighted here: (1) the amount of contracts the NPN User must handle with different stakeholders when going for a home-made NPN solution (SNPN option 1) and (2) the benefit brought by having an integrator which can encompass both the industrial services and the network-related services (Fully-hosted PNI-PNP option 1).
- **Attractiveness of a relationship model:** An NPN option may sound more or less attractive for potential new customers depending on the required level of expertise and the risks related to high investment and not immediate return on investment, but also if the NPN offering does not sufficiently match the end-user needs.
- **Business agility vs customer loyalty:** This criterion encompasses a wide range of factors which have to be balanced, in particular the length of business relationships, the independence of the NPN User with respect to solution equipment & service providers, the restriction of

vendors. Low CAPEX is required for NPN Users to deploy a NPN solution largely / fully hosted in the public network, this may offer high business agility for the NPN User.

- **Scalability and coverage extension:** Some additional partnerships, and thus additional contracts, may be required by the NPN User if coverage extension is required.
- **Easiness to manage hosting sites:** This criterion focuses on potential 5G coverage issues if there is no on-premise antenna.
- **Provisions for information security risks management:** This mostly depends on (1) the trust placed by the industrial party in the stakeholders involved in the NPN design and operations, and (2) the perception of network isolation and risks incurred if data leaves the factory. Here too, the proposed rating reflects more the perception of the NPN User than a technical evaluation.
- **Reducing the required CAPEX / OPEX:** This may be achieved by sharing infrastructure or by involving more stakeholders in the NPN design, deployment and operations.

The perspective of the MNO (Table 3:Table 2:): The following aspects can be raised:

- **Flexibility to adapt to different use cases and Performance tuning (two first criteria):** A potential rating has been proposed to balancing different factors: (1) the expertise in a particular industrial sector that is gained by the MNO through a partnership with the NPN User, (2) the need for the MNO to design adequate customer services or dedicated API to facilitate the dialogue and ensure the NPN user's needs are met and (3) the balance to be found between the economy of scale and the service customization.
- **Ease of co-existence and provision for managing interference:** This is part of MNO's daily job.
- **Providing a streamlined interface between stakeholders:** A lack of direct contact with the NPN User may be considered as not optimal regarding the design of the NPN solution (e.g. Fully-hosted PNI-NPN options).
- **Attractiveness of a relationship model:** Each NPN solution may be considered as beneficial for a MNO, whether it be because of the gained expertise (e.g. through SNPN options) or because of already mastered technologies and customer relationships (e.g. through Fully-hosted PNI-NPN).
- **Business agility vs customer loyalty:** The MNO should ensure a good customer relationship with the NPN User for long-lasting business. When more functions are hosted within the public network, higher competition may exist between MNOs.
- **Scalability and coverage extension:** This is part of MNO's daily business.
- **Easiness to manage hosting sites:** For PNI-NPN options fully or partially hosted in the public network, the MNO should ensure sufficient resources are provided, for both RAN and Core network. This can go through negotiating additional 5G radio sites deployment, potentially with shared ownership models.
- **Provisions for information security risks management:** From a technical perspective, security and privacy requirements can be met also if the NPN is fully / partially hosted in the public network. However, some NPN Users may still perceive as a risk if some data leaves the industrial premises, even though private edge servers can be deployed. Trust must be built between the MNO and the NPN User.

- **Reducing the required CAPEX / OPEX:** Different factors have been presented in Sections 4, 5 and 6, and finding a good trade-off between the economy of scale and the level of service customization is essential.

The NPN User perspective	SNPN				Fully-hosted PNI-NPN		PNI-NPN with shared infrastructure			
Option	1	2	3a	3b	1	2	1	2	3	4
Section	4.1	4.2	4.3	4.3	5.1	5.2	6.1	6.2	6.3	6.4
Flexibility to adapt to different UC	●H	●H ●M	●H ●M	●H ●M	●L ●M	●M	●H	●H	●M	●M
Performance tuning	●H	●H	●H	●H	●L	●M	●H	●H	●M	●M
Co-existence and interference	●L	●L	●H	●H	●H	●H	●H	●H	●H	●H
Streamlined interface between stakeholders	●M	●H	●H	●H	●L	●H	●H	●H	●H	●H
Attractiveness of a relationship model	●M	●H	●H	●H	●H ●M	●H	●H	●H	●H	●H
Business agility vs customer loyalty	●M	●M	●M	●M	●H	●M	●M	●M	●M	●H
Scalability and coverage extension	●M	●M	●H	●H	●H	●H	●H	● H	● H	●H
Easiness to manage hosting sites	●H	●H	●H	●H	●M	●M	●H	● H	● H	●H
Information security risks	●H	●H ●M	●H ●M	●H ●M	●M	●H ●M	●H	● H	●M	●M
Reducing CAPEX / OPEX	●L	●M	●M	●M	●H	●H	●L	●L	●M	●H

Table 2: Summary of criteria and NPN deployment option: the NPN user perspective

The MNO perspective	SNPN				Fully-hosted PNI-NPN		PNI-NPN with shared infrastructure			
Option	1	2	3a	3b	1	2	1	2	3	4
Section	4.1	4.2	4.3	4.3	5.1	5.2	6.1	6.2	6.3	6.4
Flexibility to adapt to different UC	-	-	●H	●H	●L ●M	●M	●M	●M	●M	●M
Performance tuning	-	-	●H	●H	●M	●M	●M	●M	●M	●M
Co-existence and interference	-	-	●H	●H	●H	●H	●H	●H	●H	●H
Streamlined interface between stakeholders	-	-	●H	●H	●M	●M	●H	●H	●H	●H
Attractiveness of a relationship model	-	-	●H	●H	●H	●H	●H	●H	●H	●H
Business agility vs customer loyalty	-	-	●M	●M	●M	●L	●M	●H	●H	●M
Scalability and coverage extension	-	-	●H	●H	●H	●H	●H	●H	●H	●H
Easiness to manage hosting sites	-	-	●H	●H	●M	●M	●H	●H	●H	●H
Information security risks	-	-	●H	●H	●H	●H	●H	●H	●M	●M
Reducing CAPEX / OPEX	-	-	●M	●M	●M	●M	●M	●M	●M	●M

Table 3: Summary of criteria and NPN deployment option: the MNO perspective

8 Conclusion

First of all, it is important to acknowledge that 5G for Industries, and more specifically 5G supporting smart manufacturing, is a market under development and is still immature. This report has explored how business relationships and role sharing between stakeholders affects the responsibilities and the cost items that industrial users need to bear to deploy and run non-public networks. To this end, an analysis of the industry ecosystem transformation with 5G has been performed, looking at historical MNO business models. The technical breakthroughs have been identified that have challenged the traditional business models and initiated the transformation. This document has developed a common understanding of roles, stakeholders and business models related to Non-Public Networks (NPN) and NPN design principles are formulated as a list of criteria. These include (1) technical criteria, (2) business criteria, (3) criteria with respect to coverage extension and scalability, (4) security risks and confidentiality and (5) cost criteria. All relationship models discussed in this deliverable are evaluated against these criteria and advantages and disadvantages of these models are highlighted. This document does not claim to provide a comprehensive guide or handbook to the "best" option. Rather, it summarizes various important aspects that industrial players need to consider to an informed decision, and for MNOs to identify key resources required to be able to offer high valued services.

There is no relationship model, for which all criteria can be optimized with respect to technical KPIs, business needs, privacy or cost aspects. As a consequence, industrial players need to have a clear strategic direction of what they want to do on top of the NPN and how much control or customization they actually require, to find the best trade-off. On their side, MNOs need to construct a suitable portfolio of offerings, ranging from more complex fully customized NPN deployments, e.g. for large industries, to more standardized cost-efficient solutions, targeting in particular smaller companies.

Among the alternatives that 5G NPNs offer, both in terms of technical solution and in terms of business model, a baseline for an evaluation of which model one may adopt, is related to the level of expertise in 5G. A potential adopter needs to evaluate and decide how much effort it is willing to invest in acquiring the required knowledge, as an alternative to delegating it. In the different business model, a possibility emerges for third parties to support or complement MNOs, both in the design phase and in the operating phase, as a trait d'union between the industrial field and the telecom one. And this trait d'union primarily goes through the sharing of a common terminology and the understanding of each other's perspective. 5G-SMART's work on use cases and KPIs showed the necessity to have common definitions for technical terms, such as KPIs between all involved parties. In particular, the work behind this deliverable highlighted that this need was also essential when addressing business opportunities, and more specifically, to characterize roles and responsibilities taken by the various stakeholders.

However, a number of key challenges are yet to be addressed. From a sustainability perspective, the project could also be beneficial to reuse assets already in place from MNOs and increase the utilization of these to minimize the use of energy and thus lower the carbon footprint. It is also important to recognize that the end-to-end solution does not only include the industry use cases and the 5G network solutions, but also the OT solutions, the integration of industry application to 5G, and suitable industry devices to support 5G. Engaging representatives from every part of the ecosystem, as in this project, assists in establishing and developing the ecosystem.

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Appendix

List of abbreviations

3GPP	3rd Generation Partnership Project
AGV	Automated guided vehicle
API	Application Programming Interface
AR	Augmented reality
BBU	Baseband Unit
CN	Core Network
CAPEX	Capital expenditure
DL	Downlink
eMBB	Enhanced Mobile Broadband
EU	European Union
FDD	Frequency division duplex
GPS	Global Positioning System
HW	Hardware
ICT	Information and Communication Technologies
KPI	Key Parameter Indicator
LTE	Long Term Evolution
LTE-M	LTE Category 1 cellular technologies designed for low data rate applications and requiring low power consumption
M-MTC	Massive Machine Type Communications
MNO	Mobile Network Operator
MPLS	Multiprotocol Label Switching
MVNO	Mobile Virtual Network Operator
NB-IOT	Narrowband Internet of Things

NOC	Network Operation Center
NPN	Non-Public Network
NRA	National Regulatory Authorities
OSS	Operations Support System
OT	Operational Technology
OTT	Over-the-top
OPEX	Operating expenses
PLMN	Public land mobile network
PMR	Private Mobile Radio
PNI-NPN	Public Network Integrated -NPN
QoS	Quality of Service
RAN	Radio Access Network
SD-WAN	Software-defined Wide Area Network
SIM	Subscriber Identification Module
SLA	Service Level Agreement
SME	Small and medium-sized enterprises
SNPN	Standalone NPN
SW	Software
TCO	Total Cost of Ownership
TDD	Time division duplex
UC	Use Case
UDM	Unified Data Management
UE	User Equipment
UL	Uplink
URLLC	Ultra-reliable low latency communications

VNF	Virtualized Network Function
VPN	Virtual Private Network

Table 4: List of abbreviations