ICRIER AND VODAFONE IDEA CENTRE FOR TELECOM

5G CAPTIVE NON-PUBLIC NETWORKS: BUILDING A FLEXIBLE AND INCLUSIVE POLICY REGIME IN INDIA

Policy Brief

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Abstract

Captive Non-Public Networks (CNPNs) are expected to play a valuable role in leveraging the secure, reliable, and ultra-low latency characteristics of 5G technology. The main findings of this policy brief are that the 5G CNPNs are designed to meet specific bespoke requirements of an enterprise and that 5G's unique features enable CNPNs to support the implementation of innovative and highly specialised use cases/applications (such as remote healthcare, remote surgery, robotics, autonomous transport, self-driving cars, independent drone-enabled delivery services, etc.). Private captive networks can be through a telco-led model or through the direct allocation of spectrum to enterprises. As both 5G public networks and private networks will play a critical role in building the next-generation mobile networks in India, this policy brief recommends a flexible and inclusive policy regime that promotes a fair and equitable ecosystem in implementing 5G CNPNs. The policy framework should include important issues like spectrum management policy for the availability of a dedicated and interference-free spectrum, flexibility in technical and financial options for enterprises for building their 5G CNPNs, support for innovation and capacity building for 5G, and fostering collaboration among enterprises, telcos, and telecom equipment and service providers, for strengthening the implementation of Industry 4.0 use cases in India.

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CONTENTS

1. Background 1
2. Global experience 1
3. Developments in India 4
4. Policy Recommendations 7
References 11

List of Tables

Table 1: Cross-country comparison 2
Table 2: TRAI Recommendations for setting up 5G PCNs 4
Table 3: Comparison of PCN options in India 6

5G Captive Non-Public Networks: Building a flexible and inclusive policy regime in India

1. Background

5G (or the 5th generation) is a new global wireless standard (after 1G, 2G, 3G, and 4G networks) designed to connect virtually everyone, including machines, objects, and devices. According to GSMA's recent 5G economic benefits study, 5G technology and services will generate an additional value of about $960 billion globally.[1] In addition, the measurable socio-economic impact will include further benefits, such as improved access to healthcare and education, increased public security and response times, safer driving conditions, and reduced pollution. It has a unified and more capable air interface designed with an expanded capacity to enable next-generation user experiences, empower new deployment models, and deliver new services. With high speeds, superior reliability, and negligible latency, 5G will expand the mobile ecosystem into new spheres. Therefore, country governments need to carefully plan their 5G-related policies to strengthen the country's mobile ecosystem. In addition to benefits from enhanced mobile broadband (eMBB) and improved fixed wireless access (FWA) services related to public networks, significant advantages are expected from more specialised and complex use cases of 5G. These special applications will require ultra-reliability and low latency (URLLC) through dedicated and specially designed networks that enterprises can privately own or operate (known as **Captive Non-Public Networks).**

Why 5G Private Captive Networks

- 5G PCNs help leverage IR 4.0 technologies (e.g., IoT, A.I. and ML, V.R., robotics, data analytics, virtual reality, etc.) into interesting and impactful use cases.
- 5G PCNs are secure and mitigate risks from cyber threats by limiting exposure to public interfaces.
- 5G PCNs are scalable and adaptable networks for economies of scale and efficiencies.
- 5G PCNs have the potential to transform and redefine sectors.

Unlike the current 3G/4G networks, which have primarily been designed as public mobile networks to support wide-area network requirements, 5G Captive Non-Public Networks (CNPNs) are designed to meet the specific needs and bespoke requirements of an enterprise. For example, many Fourth Industrial Revolution (IR 4.0) technologies, including IoT, machine learning and artificial intelligence, data analytics, virtual reality, etc., use cases/applications need a secure, ultra-reliable, and low-latency communication (URLLC) network that can be made possible only through private captive networks.

PCNs are usually deployed on a single site/premises – for example, in a manufacturing assembly line, factory, or industry campus. They can also address specialised requirements, such as a smart city's water utility or energy transmission network, remote healthcare, remote surgery, robotics, autonomous transport (self-driving cars), independent drone-enabled delivery services, etc. 5G private networks will play an essential role in building the foundation of the new digital economy.

2. Global experience

Traditionally, governments have either allocated spectrum to licensed telecom companies (telcos) or reserved bandwidth for the armed forces and other government agencies. With the advent of 5G, some countries across the globe (refer to the table below) are considering or have already set aside mobile spectrum for non-telcos (enterprises) to deploy private captive networks. These dedicated networks act as a local area network (LAN) to provide secure connectivity. Some popular spectrum allocation and use models adopted worldwide are the licensed mobile spectrum held by telcos, shared access spectrum (such as CBRS spectrum in the USA),[2] or local access licences (direct allocation).

Most of the 5G CNPNs globally (as of June 2021) have been using licensed mobile spectrum, i.e., spectrum

1 Study on Socio-Economic Benefits of 5G services Provided in mmWave Bands. GSMA (2018). Retrieved from: https://www.gsma.com/spectrum/wp-content/uploads/2019/10/mmWave-5G-benefits.pdf (Accessed: October 28, 2022)

2 5G, Private Spectrum and CBRS. Celona (2021). Retrieved from: https://www.celona.io/cbrs/cbrs-5g (Accessed: October 28, 2022)

licensed to telecom companies. However, there are also examples of organisations with directly allocated/locally licensed spectrum. Common dedicated bands have been assigned for 5G – for example, the 2570-2620 MHz band in France, 3.7-3.8 GHz in Germany, the 3.8-4.2 GHz in the UK, etc. Similarly, the US has made the CBRS spectrum in the 3.5 to 3.7 GHz band available for shared access.

USA's Citizen Broadband Radio Service (CBRS) has designated 150 MHz in the 3.5 – 3.7 GHz range for allocation to priority access licence (PAL) users. It has also designated a GAA (General Authorised Access) tier for unlicensed spectrum that users can access for free.

For PAL users, FCC auctions 10 MHz blocks in a county; licence terms are for 10 years.

CBRS also supports spectrum sharing through its Spectrum Access System (SAS). A user can put a request in SAS to use the CBRS band; if the spectrum is free in the desired geographic location, the SAS grants the request.

Global experience confirms that wider channels under the new 5G spectrum are better suited to low-latency applications. Instead of using a fixed cable network, 5G wireless seems to be a better option for more demanding factory-based applications. In addition, wireless technology provides users with a range of benefits, such as superior scalability and flexibility to configure/re-configure devices or machines without the restrictions of wired connections. The spectrum bands in the 3.4-4.2 GHz frequency range provide wider channels that are unavailable within the commonly used bands (1800 MHz and 2.6 GHz used for LTE networks).

Due to the increasing complexity of 5G technology and the more demanding factory and industrial use-applications, telcos/MNOs are becoming the preferred deployment partners (either as network providers or delivery partners). As a result, telcos across the globe are forming partnerships with equipment suppliers, specialist network service providers, and systems integrators to provide 5G private network services. For example, in Germany, the private captive network deployed by Mercedes-Benz was in partnership with Ericsson, the network vendor, and Telefonica, which played the project leader role in implementing, integrating, and maintaining the private network.

Table 1: Cross-country comparison

Countries	[3]5G Diffusion[4]	Use Cases	Spectrum Reserved for Private Captive Network	Spectrum Ownership and Licensing
Germany	**Cities with 5G:** 58 **5G availability:** 4.2%[5]	Used in **manufacturing**, **agriculture,** and **forestry**. Companies deploying 5G PCN include Mercedes Benz and Lufthansa.	**100 MHz** in **3.7-3.8 GHz** and **10 MHz** in **26 GHz** band (24.25 GHz-27.5 GHz) range reserved for private companies. **201 spectrum licences** were awarded in the 3.7-3.8GHz band and 10 in the 26 GHz band.[6]	Enterprises and the telecom sector can **own the spectrum**. **Private firms can deploy** their own network by acquiring a licence directly from the regulator.[7]
France	**Cities with 5G:** 20 **5G availability:** 10.4%	Used by **manufacturing**, **logistics**, **health,** and **energy**. Companies deploying 5G include ADP Group and Hub One (airport operator), EDF (French electricity company), and TransDev (mobility company).	**310 MHz** in the **3.4-3.8 GHz** band allocated. **3.8 certain industrial sectors can use 3.8 GHz-4.0 GHz** [8] Vertical sectors are permitted to use **2.6 GHz** and **26 GHz** band frequencies.	**Local enterprises can apply** for 3.8 GHz to 4.0 GHz to Arcep (telecom service regulator).[9]

3 Since the presence of 5G is not a robust indicator measuring coverage and adoption, here OOKLA uses 5G availability to calculate the percentage of users on 5G capable devices spending most of their time on 5G during Q3 2021.

4 European 5G Observatory (2021). Retrieved from: https://5gobservatory.eu/info-deployments/5g-cities/ (Accessed: October 28, 2022).

5 McKetta, I. (2022) Growing and slowing: The state of 5G Worldwide in 2021, Ookla. Ookla. Retrieved from: https://www.ookla.com/articles/state-of-worldwide-5g-2021 (Accessed: October 28, 2022).

6 Numerous Frequency Assignments for 5G Campus Networks. (2020) Bundesnetzagentur. Retrieved from: https://www.bundesnetzagentur.de/SharedDocs/Downloads/EN/BNetzA/PressSection/PressReleases/2020/202009021_5GCampusNetworks.pdf?__blob=publicationFile&v=2 (Accessed: October 28, 2022)

7 Taneja, M. (2022). Private Networks in a 5G World. ETTelecom. Retrieved from: https://telecom.economictimes.indiatimes.com/amp/news/private-networks-in-a-5g-world/93098998 (Accessed: October 28, 2022).

8 Morris, A. (2022). France Offers up More Spectrum for Industrial 5G. LightReading. Retrieved from: https://www.lightreading.com/5g/france-offers-up-more-spectrum-for-industrial-5g/d/d-id/776084 (Accessed: October 28, 2022).

9 Tomas, J. (2022). France Launches New Measures to Boost Industrial 5G Adoption. EnterpriseIOT. Retrieved from: https://enterpriseiotinsights.com/20220317/5g/france-launches-new-measures-boost-industrial-5g-adoption (Accessed: October 28, 2022).

Countries	5G Diffusion	Use Cases	Spectrum Reserved for Private Captive Network	Spectrum Ownership and Licensing
Italy	**Cities with 5G:** 65 **5G availability:** 7.3%	**122 5G projects** are in the trial phase, including the one underway in Livorno.	**700 MHz, 26.5-27.5 GHz**, and 3.6-3.8 GHz bands have been auctioned.[10]	Bands **obtained by telecom** operators. Licensees have certain **obligations to grant** other companies access to their 5G network.[11]
Netherlands	**Cities with 5G:** 10 **5G availability:** 45.1%	The **first industrial applications** of the novel 5G technology have been tested in Rotterdam harbour by Shell, Huawei, KPN, ABB, and ExRobotics. **KPN, Vodafone, Ziggo, and T-Mobile** Netherlands have **launched 5G networks**.	**0.7 GHz**, **1.4 GHz,** and **2.1 GHz** spectrum bands were auctioned.[12] **3400-3450 MHz** and 3750-3800 MHz are reserved for enterprises.[13]	Mobile operators like KPN and T-Mobile **own frequency bands** through bidding in auctions.[14]
United Kingdom	**Cities with 5G:** 57 **5G availability:** 11.7%	**EE, O2,** and **Vodafone**, through the 3.4 GHz band, are the backbone of the UK's 5G networks. **Vodafone** and the Ford Motor Company have set up a 5G private mobile network. **Non-Standalone 5G New Radio** is deployed in the UK.[15]	3.8 to 4.2 GHz exclusive for local private and shared networks.[16] The **lower 26 GHz** band will also be reserved for private and shared access.[17]	National operators to relinquish unused licensed spectrum to enterprises. Local shared access in 26 GHz, 1800 MHz and 2300 MHz, which are licensed in sections to telcos 3.8 to 4.2 GHz for PCNs
United States of America	**Cities with 5G:** 296 **5G availability:** 49.2%	Domains of use include **healthcare**, **automotive industry**, **retail**, **public safety,** and **surveillance**. Companies using the 5G network in the USA include **Verizon Communications Inc.**, **Digital Realty Trust**, **SBA Communications Corp.,** and so on. Verizon 5G Ultra-Wideband is used by companies that aim to jointly build a 5G factory for the future	Mid band spectrum - 5 GHz and 3.5 GHz mmWave band – patches between 24.25 to 48.2 GHz[18]	Private 5G networks can operate on licensed, unlicensed, and shared spectrum.

10 Tomas, J. (2018). Italian Government Raises $ 7.5 Billion in 5G Auction. RCRWirelessNews. Retrieved from: https://www.rcrwireless.com/20181003/business/italian-government-raises-billion-5g-auction (Accessed: October 28, 2022).

11 Feo, I. (2020). 5G Regulation and Law in Italy. CMS. Retrieved from: https://cms.law/en/int/expert-guides/cms-expert-guide-to-5g-regulation-and-law/italy (Accessed: October 28, 2022).

12 Netherland's multi-band 5G auction raises 1.23 billion EUR. (2020). European 5G Observatory. Retrieved from: https://5gobservatory.eu/netherlands-multi-band-5g-auction-raises-1-23-billion-eur/ (Accessed: October 28, 2022).

13 5G Private Licences Spectrum in Europe. (2020). European 5G Observatory. Retrieved from: https://5gobservatory.eu/5g-private-licences-spectrum-in-europe/. (Accessed: October 28, 2022).

14 Wieland, K. (2020). T-Mobile, KPN Play 5G Catch-up with VodafoneZiggo. TelcoTitans. Retrieved from: https://www.telcotitans.com/deutsche-telekomwatch/t-mobile-kpn-play-5g-catch-up-with-vodafoneziggo/1948.article. (Accessed: October 28, 2022).

15 Watson, C and Goddard, I. (2020). 5G Regulation and Law in United Kingdom. CMS. Retrieved from: https://cms.law/en/int/expert-guides/cms-expert-guide-to-5g-regulation-and-law/united-kingdom (Accessed: October 28, 2022).

16 5G Private Licences Spectrum in Europe. (2020). European 5G Observatory. Retrieved from: https://5gobservatory.eu/5g-private-licences-spectrum-in-europe/. (Accessed: October 28, 2022).

17 Blackman, J. (2019). UK Releases Masses of Spectrum for Private, Shared Usage; Squeezes Operators. Retrieved from: https://enterpriseiotinsights.com/20190725/channels/news/uk-releases-masses-of-spectrum (Accessed: October 28, 2022).

18 U.S. Private LTE & 5G Network Market Size, Share & Trends Analysis Report By Vertical (Oil & Gas, Mining), By Component (Hardware, Services), By Frequency (MmWave, Sub-6 GHz), By Spectrum, And Segment Forecasts, 2022 – 2030. (2020). Grand View Research. Retrieved from: https://www.grandviewresearch.com/industry-analysis/us-private-lte-5g-network-market. (Accessed: October 28, 2022).

Countries	5G Diffusion	Use Cases	Spectrum Reserved for Private Captive Network	Spectrum Ownership and Licensing
China	**Cities with 5G:** 356 **5G availability:** 20.1%	More than 5325 PCNs built by telcos across 20,000 use cases and 40 sectors.[19] **China Mobile** is integrating 5G with **BeiDou Navigation Satellite System.** Yangquan Coal Group has built a 534-metre deep, 5G **underground coalmine network.** **5G infrastructure for airports** – AeroMACS system is being planned by the Civil Aviation Administration of China (CAAC).	**700 MHz, 2.6 GHz,** and **4.9 GHz** are reserved for nationwide use. No assignment of high band spectrum	Spectrum allocation and deployment of private networks by telcos.

Globally, the interest in 5G private networks is growing. A report from the GSA suggests that about 37 per cent of private networks use 5G. Governments have used different licensing models for spectrum management, where 5G CNPNs can either use spectrum already assigned to mobile operators or rely on dedicated spectrum licences issued by governments. The spectrum management policy needs to be carefully planned to avoid the risk of fragmenting scarce 5G spectrum resources. For example, the failure to achieve contiguous blocks may result in reduced speeds, quality of service (QoS), and the inability to dynamically reallocate frequencies to accommodate fluctuations in traffic.[20]

3. Developments in India

With the culmination of spectrum auctions in July 2022, India is all set to roll out its 5G networks. To facilitate the setting up of 5G captive non-public networks, the Indian cabinet has approved the operation of CNPNs through various models. These models include the telco-led model through network splicing, setting up an isolated network for enterprises, setting up a network through leasing of spectrum to enterprises, and setting up an independent network through direct spectrum allocation to private enterprises. The Union Cabinet has approved[21] the proposal of the Department of Telecommunications to allow CNPN licensees to acquire spectrum and to set up isolated networks. Enterprises having operations at multiple locations will require only one CNPN licence; however, for any new location, the geo-coordinates of the location will have to be updated in the DoT's portal.

As per TRAI's recommendations,[22] enterprises in India should have the following four options to set up their own 5G private networks. The four options are presented in the following table:

Table 2: TRAI Recommendations for setting up 5G PCNs

Option 1 – PCN as a service on its public land/mobile network (PLMN) • Telecom Service Provider (TSP) to provide 'PCN as a service' by using its own PLMN public network (through network slicing).
Option 2 – Isolated PCN using licensed spectrum • TSP to use its spectrum to establish an 'isolated CNPN' at client enterprise premises
Option 3 – Obtain CNPN licence and lease spectrum from TSPs • Obtain spectrum on lease for each location/premises from TSP(s) • Comply with 'Guidelines for leasing of Spectrum to CNPN Licences', dated June 27, 2022
Option 4 – Obtain CNPN licence and spectrum directly from DoT • DoT will undertake a demand study • DoT will seek TRAI's recommendation for direct allocation

19 Clark, R. (2022). China Has More Than 5K 5G Private Networks. LightReading. Retrieved from: https://www.lightreading.com/asia/china-has-more-than-5-5g-private-networks/d/d-id/778434. (Accessed: October 28, 2022).

20 5G Observatory Quarterly Report 16 (2022). European Commission. Retrieved from: https://5gobservatory.eu/wp-content/uploads/2022/08/QR-16_Final_PDF.pdf (Accessed: October 28, 2022).

21 DoT issues Notice Inviting Applications (NIA) for Auction of Spectrum for IMT/5G Telecom Services. Ministry of Communications. Retrieved from: https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1834137 (Accessed: October 28, 2022).

22 Recommendations on Auction of Spectrum in Frequency Bands Identified for IMT/5G. (2022). Telecom Regulatory Authority of India. Retrieved from: https://trai.gov.in/sites/default/files/Recommendations_11042022_0.pdf. (Accessed: October 28, 2022).

DoT has approved all four options and issued guidelines for the leasing options[23]. For the fourth option involving direct spectrum allocation, DoT plans to have a demand assessment study and thereafter, seek TRAI's recommendations for direct assignment of spectrum to enterprises.

An enterprise may obtain the **5G PCN 'as a service'** from the telecom service provider. The 5G technology supports network-slicing that can subdivide network bandwidth into multiple virtual networks to handle different types of traffic simultaneously. For example, it will enable the enterprise to route its internet network data traffic from office phones and laptops via Network Slice-1. At the same time, it will help operate another Slice -2 to handle traffic from its factory operations, medical devices operations, machine-to-machine communication, etc. The importance of 'network slicing' is hard to overemphasise. It will be critical for organisations that need the native capability to have control and need insight into what and how applications are performing on each slice, as well as those coping with data traversing multiple networks.

Enterprises requiring a fully secured and interference-free network may opt for an isolated network. In this option, the telco builds the **'isolated network'** for the enterprise using its licensed spectrum. As the spectrum bandwidth is shared from the TSP's public network, isolation is required to ensure 'interference-free' access to the enterprise's private network. Bandwidth is achieved through physical isolation in specific premises/campus/project areas or designed and architected through slicing to ensure that there is no interference or overlap in spectrum bands. 5G deployments are typically quite dense and, therefore, can become highly capital intensive. Using a TSP's licensed spectrum ensures shared/lower costs, quick access to the desired spectrum, and access to the TSP's expertise in setting up and operating the network efficiently.

The 'operational isolation' provides independent monitoring, control, configuration, and full operational capability. This is considered adequate for the requirements of most enterprises. However, some enterprises require 'network-level isolation' and do not want to share any hardware or software infrastructure with other enterprises (let alone competitors).

Enterprises requiring a **dedicated spectrum can take a CNPN licence and lease** it from TSPs. More and more manufacturing/industrial houses are deploying highly sophisticated sensor-enabled applications and industrial robotics to achieve superior operational efficiency and productivity. These applications will require ultra-reliability and low latency (URLLC) through seamless and secure connectivity. In addition, the demand for time-sensitive networking (TSN) and real time-based networking is rapidly increasing for several mission-critical applications across many industries, including aerospace, railways, specialised manufacturing, oil and gas, and transportation.

In the fourth option, the enterprise obtains a **licence from DoT and then directly acquires the spectrum** based on the government's policy. The enterprise can then set up a wholly owned and operated (i.e., all the equipment, private cloud, and spectrum) private 5G network. This alternative will require high levels of in-house capabilities within the enterprise. Typically, this option may be preferred by large IT companies and high-technology companies working on digital products and solutions that require full network configuration capabilities and where the network is a crucial component of the application/solution. This option helps deliver complete control and end-to-end security with no interference from any third-party, ensuring protection of mission-critical information and sensitive infrastructure. It may, however, be noted that the telco may be involved as a delivery partner even in enterprise-led models.

A comparative analysis of the four options provided by TRAI is set out in Table 3 below:

Table 3: Comparison of PCN options in India

CNPN deployed on TSP's PLMN network	Independent Isolated CNPN offered by TSP	Using Spectrum on Lease from TSPs	Using spectrum directly allocated by DoT
Description: Telcos offer a ready-to-use private 5G platform to address the requirements of client enterprises. For example, NTT, a global telecom service provider, offers turnkey private 5G network partnerships. Their private 5G-as-a-service platform is a full stack solution delivering on-premises, at the edge, or as a cloud service, with flexible deployment options. **Advantages:** Enterprises benefit from the TSP's competence to deliver novel technology solutions that can be adaptable and resilient, reducing costs and security risks for an enterprise. **Disadvantages:** Having to choose only from TSPs, enterprises are left with few options. Market power to negotiate a desirable solution remains with TSPs, which can be limiting if the total number of service providers in the market is few.	**Description**: Telco builds the 'isolated network' for the client enterprise using its licensed spectrum. As the spectrum bandwidth is shared from the telco's public network, isolation is required to ensure 'interference free' access to the enterprise's private network. Bandwidth is achieved through physical isolation in specific premises/campus/project areas. **Advantages:** Enterprises that require 'interference-free' bandwidth can still go with telcos, benefit from their expertise, and reduce costs and security risks. **Disadvantages:** Isolated areas may further restrict the choice of TSPs, and provide limited power to negotiate the price and costs of the desired solution; the control over bandwidth remains with the TSPs.	**Description**: The enterprise obtains a licence to build its own network and leases dedicated bandwidth from a telco. The telco/licensee retains the *de jure* control and agrees to transfer the *de facto* control of the leased spectrum to the lessee for a defined period (short-term or long-term). **Advantages:** This gives the enterprise full operational control over the spectrum leased and ensures 'interference-free' bandwidth. Useful for mission-critical applications. **Disadvantages:** The market power to negotiate a desirable solution still remains with TSP. Limited flexibility as the 'de jure' control continues to be with the TSP.	**Description**: Enterprise obtains a licence from DoT and then directly acquires the spectrum based on the government's policy. The network is wholly owned and operated by the enterprise, providing full control. **Advantages:** Allows the enterprise to have full ownership and control over the network. Ensures complete flexibility, cost control, end-to-end security, and risk management to design and implement the optimum solution. **Disadvantages:** High levels of in-house capabilities are required within the enterprise. Licence costs are much higher; telco expertise is not used, legal compliances and licence conditions, etc., are the enterprise's responsibility.

Private 5G will undoubtedly have a huge impact on the industry and promote the overall growth of the country

- *Potential Impact for the Telecom Sector.* India is expected to follow global trends in the telecom sector. IDC's latest market research estimates that the worldwide LTE/5G private network market will be about $8.3 billion by 2026 (from $1.7 billion in 2021). Another report by ResearchAndMarkets.com estimates that the global private network market for 5G will reach US$36 billion by the year 2030 (at a CAGR of 47% from 2022 to 2030). In India, the demand for 5G private networks is expected to be driven by big corporates in the IT and manufacturing sectors. The new use cases enabled by IR 4.0 technologies and the enabling 5G communication infrastructure are expected to transform several industries. Besides, in addition to the increased deployment of core networks and backhaul equipment for 5G implementation, the CNPN implementation by corporates will drive the demand for telecom components, i.e., hardware equipment (radio access network, core network, backhaul and transport), software, and services for installation, integration, and support and maintenance.

- *Growing security needs and cyber threats.* As Indian organisations adopt digitization, they are exposed to increasing levels of risks from cybercrimes, malware, and data thefts. 5G private networks, with their capabilities to deliver end-to-end security in a network that is not connected to the internet, help ensure that the enterprise information and infrastructure

are protected from cyber threats. As a result, 5G private networks will emerge as a crucial decision for enterprises where the confidentiality of information is critical. In addition to the demand for CNPNs from enterprises, high demand is expected from government and public safety agencies.

- *Verticals will be the drivers of growth.* As national flagship programmes like Make in India, Digital India, Smart Cities, Gati Shakti (Logistics), etc., implement more sophisticated digital strategies, the 5G CNPN demand will steadily increase. Globally, manufacturing industry led the 5G private networks market with a 15% market share. Digitization of the manufacturing sector requires seamless connectivity to several devices, such as ultra-HD cameras, extended reality headsets, automated guided vehicles (AGVs), and robotics. Similarly, in several other industries, the 5G private network is a preferred option for enterprise communication networks, e.g., transportation, logistics, energy, oil and gas, smart utilities, aerospace, defence, government, and public safety. Several governments and public safety agencies that deal with sensitive data, or require real-time/emergency response, will be opting for 5G private networks.

4. Policy Recommendations

Enabling a flexible and inclusive policy framework for 5G private networks will go a long way to strengthen the ecosystem. Some key policy interventions are set out below.

Agile Regulation – 5G will need a flexible ecosystem to evolve

The global experience with 5G private networks emphasises the need for a flexible ecosystem in which they can evolve. 5G and other new IR 4.0 technologies (also called disruptive technologies) will cause severe disruptions in the status quo. Therefore, governments should prepare to deal with these disruptions and build a flexible and agile policy framework that encompasses all options whether telco-led or enterprise-led. The telecom sector should be prepared for a new paradigm where enterprises could have a range of demands that best suit their own individual business cases. Government policies and initiatives have played a crucial role in the deployment of private networks in developed countries (like the US, the UK, Germany, France, and Japan) across highly secure, flexible, and customisable applications. China has been supporting CNPNs (refer to box) through national-level programmes to build 5G private networks and use cases across almost all sectors of its economy. Many countries have made dedicated spectrum available to enterprises through flexible policies that make spectrum affordable and easily usable. Such agility in policy and regulation will be foundational for the success of private 5G.

Germany's Federal Network Agency provides spectrum in the 3.7-3.8 GHz range for private networks for IR 4.0 applications in priority sectors. The agency has approved over 200 licences for 5G private networks for manufacturing companies (like Audi, BMW, Mercedes, Porsche), telcos (Like Deutsche Telecom, NTT, LS Telecom, Telefonica, etc.), and universities and research organisations. Fees are charged based on bandwidth requested and area covered, and the assignment terms ensure optimal use and efficient use of the spectrum. The spectrum allocation prioritises start-ups, research and innovation, medium-sized enterprises, and agriculture enterprises.

As 5G private networks stabilise and develop as a proven solution for IR 4.0 use cases in India, more and more enterprises will join the 5G private network market. As a result, telcos will emerge as the most crucial player in the private network market value chain. Unlike the initial demand from a few ICT sector enterprises, the 'second wave enterprises' will comprise a large number of enterprises in manufacturing, transport, storage and logistics, hospitals and health care, smart city power/water utilities, etc. These enterprises will need technical support and services for 5G CNPNs from telcos. With their expertise in setting up wireless networks, telcos will have a substantial comparative advantage in core network deployment and management. Enabling a flexible and affordable 5G private network regime where enterprises have technical and financial options will go a long way in strengthening the 5G CNPN market in India. The flexibility should provide choice to enterprises; e.g., directly acquiring spectrum and building their own network; partnering with a telco to build an on-premises fully enterprise owned and operated, or enterprise owned and telco-operated network, etc.

Inclusive Policy Framework

The current policy framework laid down by the government is flexible and supports options for enterprises to buy or build private captive networks. However, some provisions seem restrictive and exclude the needs of MSMEs and start-ups that will drive new ideas and innovations. For example, the

eligibility criteria in the current guidelines announced on June 27, 2022, require that the applicant's net worth shall not be less than Rs.100 crore. This makes MSMEs ineligible to apply for a licence for a private network.

The need for a captive non-public network is defined by its use case, not the enterprise size or its net worth. For example, Germany's Federal Network Agency prioritises the 5G spectrum allocation to research organisations, start-ups, and medium-sized enterprises. Similarly, US's CBRS supports access to free, unlicensed spectrum through an online SAS system. Enterprises running mission-critical applications would like to own their network and have full control. Sharing the network functions makes it impossible to have full control or to customise the network for their specific needs. Even where traffic has been separated (slicing or isolation), problems from one user can affect all others. Therefore, enterprises with mission use cases (e.g., critical public safety, disaster management, mission-critical assets, etc.) may not benefit from the current policy framework. A more open and inclusive policy, with necessary safeguards, that supports wider access will be beneficial in promoting CNPNs.

Fair competition and level playing field

Direct allocation of set aside spectrum: Many countries have set aside the 5G spectrum for direct administrative allocation. Over the last few decades, spectrum assignment is done through open auctions. This ensures that the spectrum assigned is used efficiently and its public value is maximised. The practice of setting aside spectrum for direct administrative allocation undermines this principle and raises concerns on optimum use of scarce national spectrum. The risks include the inability of the selected enterprise to use the spectrum fully/efficiently and depriving other valuable users of the allocated spectrum. Most selected enterprises will operate in a small number of fixed locations; so the spectrum allocated is likely to go unused in parts of the city and/or in rural areas.

A prudent and carefully crafted policy for direct spectrum allocation will be critical for India. It will be important to clearly define the allocation criteria, e.g., market failure, national security, national mission-critical applications, etc. In most cases, only 'operational isolation' is required where the enterprise is able to monitor and even fully control a network slice independently. However, in exceptional cases where administrative allocation is required, it is a good practice to undertake a 'cost-benefit analysis' to verify that the benefits outweigh the costs of such allocation. The analysis should also examine why other alternative options are unsuitable. It is also recommended that the allocation policy should include conditions and options to minimise the costs and adverse effects of the set aside allocations, e.g., periodic review to ensure usage is as per target levels, make the set aside spectrum available for use in other areas/locations, minimise the size of set aside spectrum to a basic minimum as per identified demand, increasing efficiency by exploring synergies between private networks so that similar spectrum use and technologies can be clubbed together for multiple uses, policy measures to avoid hoarding of spectrum, 'use it or lose it' rules, etc.

Portugal's 5G Hub has the first 'private standalone 5G core network' to be implemented in the country and is considered to be the next step in the evolution of 5G technology. With an investment of 1.8 million euros, the new NOS 5G innovation centre has been designed as an area for brainstorming, experimentation, and technological transformation. Located in the Parque das Nações building in Lisbon, the NOS 5G Hub will be an area to empower companies, start-ups, universities, and partners, and provide the most advanced technical capabilities, teams, and resources.

(https://tecknexus.com/5gusecase/portugals-nos-opens-5g-hub-with-standalone-5g-private-network/)

Spectrum pricing: India will also need a balanced spectrum pricing policy to enable a fair and level playing field for spectrum allocation. In options 1 to 3 (in Table 2 above), the enterprise uses the spectrum allocated to a telco through a commercial arrangement. However, option 4 provides for the direct allocation of spectrum for the 5G CNPN network to a licensee enterprise. For telcos, the price of the spectrum is determined both through auctions and by market conditions. However, for CNPN spectrum allocation, the auction is not a viable option. The CNPN licence will typically be a local licence that only covers the area of a single factory, mine, hospital, etc. It is also very specific to an enterprise and specific location(s), which means that the licence has only one potential buyer. Benchmarking can be another market-based approach for spectrum pricing; however, markets for local 5G licences do not exist currently. Therefore, benchmarking is not a viable option in the early stages of 5G, but pricing under options 1, 2, and 3 may provide a benchmark after a few years.

From the enterprise demand perspective, the value of the CNPN spectrum will be determined by the expected additional future cash flows that the licence generates for the enterprise. These benefits/cash flows may be realised through increases in revenues or reductions in costs. Therefore, for CNPNs, spectrum pricing in the initial years will be dependent on the willingness to pay and demand for licences based on expected future benefits to the licensee. DoT's demand assessment study, therefore, is a step in the right direction.

Role of unlicensed spectrum

Unlicensed spectrum plays a valuable role by enabling enterprises to build their 5G networks – or outsource the network service to third-party providers. These networks can be very similar to Wi-Fi-based high-speed connectivity that is designed for enterprise-grade deployment. For example, through USA's CBRS unlicensed bands, a private network can be deployed entirely using an unlicensed spectrum to support a wide variety of use cases ranging from high-speed broadband to low-power IoT connectivity.

For enterprises that operate in controlled and isolated environments (for example, factory premises in a remote area), a network using an unlicensed spectrum can be relied upon to deliver high-quality connectivity with minimal interference. DoT may consider providing a suitable option to use a reserved band of unlicensed spectrum that is free to use for all. However, it is important to emphasise that the unlicensed spectrum cannot support all use cases, especially where the enterprise's application requires the highest level of network quality, latency, and reliability, and the network environment is difficult to control (e.g., in areas like ports, railway stations, etc.).

5G Private Network Innovation Hubs

The current government policy supports and acknowledges the role of 5G private networks. However, benefits from 5G and new IR 4.0 technologies will not be realised only through an enabling policy for spectrum use. Many countries across the globe (China, Germany, Portugal, etc.) are setting up innovation and training centres to build internal capacities and to support start-ups, research centres, universities, etc., to support the development of new products, ideas, and solutions using 5G and IR 4.0 technologies. Further, the current policy will enable only large enterprises that have the financial and technical capacity to implement these privately owned and operated networks. Many smaller innovators and start-ups (prospective unicorns) will not have access to fully independent 5G private networks and, therefore, will be unable to contribute to new and innovative use cases critical to India's digital economy targets.

To address this challenge, it is suggested that DoT launches a national capacity-building initiative as a business model and sets up '5G network innovation hubs' in partnership with telcos and other telecom industry players. DoT may plan to set up 5G private network innovation hubs across India to provide 5G ecosystem access (for 2-3 years) to start-ups and MSME enterprises. These 5G innovation hubs will be like incubation centres for IR4.0 technology use cases. The one trillion digital economy target[24] will require hundreds of 'unicorns' and start-ups having access to 5G rather than just a handful of large industrial houses.

National Flagship/High Priority Programmes

5G private captive networks are being strategically used by many countries to drive high-priority national initiatives and to support their digital economy goals. For example, China has systematically built over 5,300 CNPNs[25] (refer to box) through a national-level initiative for 5G private networks. It will be useful to have a government policy and a national-level intervention that supports collaboration and partnership between telcos and non-telco service

As per China's Ministry of Industry and IT, the country's three state-owned operators have built 5,325 5G private networks with a total of more than 20,000 use cases across sectors. China Telecom has built more than 2,500 5G custom network projects, China Mobile claims to have built 2,300 5G private network projects and China Unicom built 1,500 5G industrial 5G network projects. These Telcos are targeting 40 economic sectors including key industries including power grids, mining, ports, and manufacturing.

24 India's Trillion-Dollar Digital Opportunity. Ministry of Electronics and Information Technology. Government of India. Retrieved from: https://www.meity.gov.in/writereaddata/files/india_trillion-dollar_digital_opportunity.pdf (Accessed: October 28, 2022).

25 Clark, R. (2022). China Has More Than 5K 5G Private Networks. LightReading. Retrieved from: https://www.lightreading.com/asia/china-has-more-than-5-5g-private-networks/d/d-id/778434. (Accessed: October 28, 2022).

providers in developing 5G private networks for large national flagship programmes. The consortiums (telco and non-telco telecom service providers) will then have access to a vast new market for specialised 5G networks and applications for federal programmes like smart cities (e.g., smart utilities for power/ water/sewerage, smart city command and control centres etc.), railway station private networks, ports, custom private networks, river and inland waterway programmes, etc. In addition, telcos can support capabilities for building and operating specialised 5G private networks for highly specialised agencies like disaster management, public safety agencies (police, fire services), etc. Telcos in countries like the US are already building these partnerships rather than competing among themselves. In addition, a mature 5G private network market will open up new markets and revenue streams, including new sector applications like education campuses, hospitals, warehouses, malls etc.

From a policy perspective, it is important to acknowledge the critical role of both 5G public networks and private networks (CNPNs) in building next-generation mobile networks in India. CNPNs and public networks will serve different use cases and requirements of citizens and enterprises. Globally, CNPNs have already established their value based on Wi-Fi or 4GLTE networks, and during the 5G era, their adoption is expected to increase manifold as new use cases emerge and stabilise over time across several sectors. Most CNPNs will be implemented with the support of telcos as they will be able to provide the expertise necessary to design, construct, and operate dedicated CNPN networks, and provide access outside the campus/ premises through their public network.

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