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Original Article

The Regulatory Landscape for Private Wireless Spectrum Allocation across Different Regions

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Abstract *- The global telecommunications landscape is experiencing a fundamental change, driven by the democratization of wireless spectrum access. As Industry 4.0, the Internet of Things (IoT), and mission-critical industrial applications grow, the traditional model of exclusive, nationwide spectrum licensing held by Mobile Network Operators (MNOs) is becoming inadequate to meet the complex needs of "vertical" industries—manufacturing, logistics, healthcare, energy, and utilities. In response, regulators across North America, Europe, and the Asia-Pacific have developed diverse regulatory frameworks to enable Private 5G (P5G) and Private LTE (PLTE) networks. This paper offers a comprehensive comparative analysis of these regulatory systems. It examines the three-tiered dynamic sharing model of the United States' Citizens Broadband Radio Service (CBRS), Germany's BNetzA's administrative "campus network' licensing, the hybrid Shared Access License (SAL) system of the United Kingdom's Ofcom, and the dedicated "Local 5G" and "e-Um 5G" programs in Japan and South Korea, respectively. By analyzing spectrum bands (especially the differences among bands n78, n77, n79, and n48), licensing economics, device ecosystem maturity, and deployment data, this paper highlights the tension between policy goals and market realities. It concludes that although regulatory approaches vary—from market-driven auctions to nominal administrative fees—the overall trend worldwide is clearly toward localized, enterprise-controlled spectrum.*

Keywords *- Private 5G, Spectrum Allocation, CBRS, Local 5G, Campus Networks, Industrial IoT, Telecommunications Policy, 5G NR, Spectrum Sharing, Industry 4.0.*

1. Introduction

1.1. The Imperative for Private Spectrum

The arrival of the fifth generation of mobile technology (5G) promised a revolution not just in consumer broadband but also in the operational technology (OT) of physical industries. Technologies like Ultra-Reliable Low Latency Communications (URLLC) and Massive Machine Type Communications (mMTC) are designed to support use cases that require performance benchmarks far beyond the "best-effort" service levels of public networks [1].

Autonomous Mobile Robots (AMRs) in "lights-out" factories, real-time digital twins of complex aerospace components, and remote telesurgery all need guaranteed uplink throughput, millisecond latency, and, importantly, data sovereignty [1] [2].

However, deploying these technologies has faced a significant obstacle: spectrum access. Historically, high-quality cellular spectrum was exclusively controlled by national MNOs, acquired through multi-billion-dollar auctions. Enterprises looking to deploy cellular technology had to rely on MNO services, which often lacked the flexibility to customize network parameters (e.g., uplink/downlink ratios) for specific industrial sites [1].

1.2. The Regulatory Paradigm Shift

Recognizing this limitation, regulators worldwide are shifting from "exclusive national licensing" to "localized industrial licensing." This change is more than just administrative; it is a strategic economic move to speed up digital transformation. By allowing non-telecom entities, such as car manufacturers, port authorities, and utility companies, to hold spectrum licenses for their specific geographic areas directly, governments aim to create a new ecosystem of industrial innovation [1].

The methods used to accomplish this differ greatly depending on national priorities, current protections, and geography:

- The United States has pioneered a dynamic, technology-driven sharing model (CBRS) that enhances spectral efficiency through automated coordination [1] [3].
- Europe (Germany, UK, France) has generally supported administrative assignments by reserving specific blocks of mid-band spectrum for local use at fixed, often low, costs to back industrial leaders [1].
- Asia-Pacific (Japan, South Korea) has adopted aggressive "Local 5G" strategies with dedicated spectrum and minimal fees to challenge MNO

oligopolies and maintain global manufacturing competitiveness [1] [4].

1.3. Scope of Analysis

This paper examines the regulatory landscape in these key regions, focusing on:

- Spectrum Bands: The specific frequencies allocated (Sub-6 GHz and mmWave) and their compliance with global 3GPP standards.
- Licensing Mechanisms: The process of obtaining spectrum (through auctions or applications) and its related costs.
- Market Dynamics: The adoption rates, major industry players, and the changing role of MNOs.

2. The Spectrum Ecosystem: Bands, Standards, and Fragmentation

Understanding the regulatory landscape requires familiarity with the frequency bands in use. The success of private 5G depends heavily on the availability of compatible devices (chipsets, modules, handhelds), which in turn depends on global band harmonization.

2.1. The Mid-Band "Sweet Spot" (3.3 – 4.9 GHz)

Mid-band spectrum is widely considered the best frequency for private networks, providing a good balance between coverage (ability to penetrate walls and span campuses) and capacity (large channels for high data rates) [5]. However, regulatory allocations are fragmented:

- Band n78 (3.3 – 3.8 GHz): This is the global roaming band and the most mature ecosystem. It is supported by the majority of commercial 5G devices [6].
- Band n77 (3.3 – 4.2 GHz): A broader band that covers n78. It is used in the US (C-Band) and in the UK's shared access band (3.8–4.2 GHz) [6].
- Band n79 (4.4 – 5.0 GHz): Primarily used in Japan (4.6–4.9 GHz), South Korea (4.7 GHz), and China. This band has a smaller device ecosystem compared to n78, which poses challenges for global companies trying to standardize equipment across regions [7].
- Band n48 (3.55 – 3.7 GHz): The specific US CBRS band. While technically within n78, it requires particular support for the US sharing protocols [3] [6].

As of February 2025, the Global mobile Suppliers Association (GSA) reported that Band n78 remains the most widely supported 5G band worldwide, emphasizing the advantage of regions aligned with this frequency [6].

2.2. The High-Band mmWave (24 – 29 GHz)

The millimeter-wave (mmWave) spectrum provides extensive bandwidth (hundreds of MHz) and ultra-low latency, but suffers from poor propagation. It necessitates line-of-sight and dense infrastructure.

- 26 GHz (n258): The standard for Europe (Germany, UK) [8] [9].
- 28 GHz (n257): The standard for Japan and South Korea [4] [7].

Table 1: Global Private Spectrum Allocations by Band [1] [6] [8] [9] [10] [5] [7]

Region	Country	Mid-Band Allocation	3GPP Band	mmWave Allocation	Licensing Model
Americas	USA	3.55 – 3.70 GHz (CBRS)	n48	MNO licensed only	Dynamic Tiered Sharing
Europe	Germany	3.7 – 3.8 GHz	n78	24.45 – 27.5 GHz	Admin. Application
	UK	3.8 – 4.2 GHz	n77	24.25 – 26.5 GHz (Indoor & low power outdoor)	Shared Access License
	France	3.8 – 4.2 GHz (Primary)	N77	26 GHz (Trials)	Admin. Application
APAC	Japan	4.6 – 4.9 GHz	n79	28.2 – 29.1 GHz	Local 5G Application
	S. Korea	4.72 – 4.82 GHz	n79	28.9 – 29.5 GHz	e-Um 5G Application

3. North America: The United States and the CBRS Experiment

The United States has adopted a unique, technology-driven approach to spectrum management called the Citizens Broadband Radio Service (CBRS). Instead of clearing the spectrum of incumbents or granting exclusive permanent licenses, the FCC created a dynamic three-tiered sharing system in the 3.5 GHz band.

3.1. The Three-Tiered Architecture

An automated, cloud-based system manages the CBRS band (3550–3700 MHz) called the Spectrum Access System (SAS). The SAS dynamically assigns channels to users to prevent interference and operates within a clear hierarchy [3].

3.1.1. Tier 1: Incumbent Access

This tier includes the United States Navy (radar systems) and commercial Fixed Satellite Service (FSS) earth stations. These users have absolute priority. When a naval vessel activates its radar in a coastal area, the SAS must immediately instruct lower-tier users to vacate the affected channels or reduce power [3].

3.1.2. Tier 2: Priority Access Licenses (PALs)

The PAL tier refers to the "licensed" part of the band.

- Allocation: PALs were allocated through Auction 105 in 2020 [3].
- Structure: Licenses are issued for renewable 10-year terms. They are assigned by county, allowing for granular geographic targeting [3].
- Rights: PAL holders are protected from interference by the third tier (GAA), but must accept interference from Incumbents. [3]

3.1.2.1. Auction Analysis:

While traditional MNOs like Verizon and Dish Network participated heavily to boost their 5G capacity, the auction was notable for the significant involvement of non-traditional entities, including cable operators and utility companies [3].

- Utilities: Companies like Southern California Edison (SCE) and San Diego Gas & Electric (SDG&E) obtained licenses to modernize their respective electrical grids. SCE spent about $118 million on 20 licenses, while SDG&E paid a premium ($0.5748 per MHz-pop) to secure critical connectivity [11].
- Enterprises: Chevron and John Deere also participated, indicating a shift toward industrial players directly acquiring spectrum assets [11].

3.1.3. Tier 3: General Authorized Access (GAA)

The GAA tier is the "innovation sandbox."

- Access: It is available to any user with FCC-certified radios (Citizens Broadband Radio Service Devices, or CBSDs) [12].
- Cost: There is no spectrum license fee. Users only pay for equipment and a small subscription fee to a SAS administrator [12].
- Rights: GAA users lack protection against interference. They can use any part of the 150 MHz band not currently occupied by Incumbents or PALs. This creates a low barrier to entry for Private 5G [12].

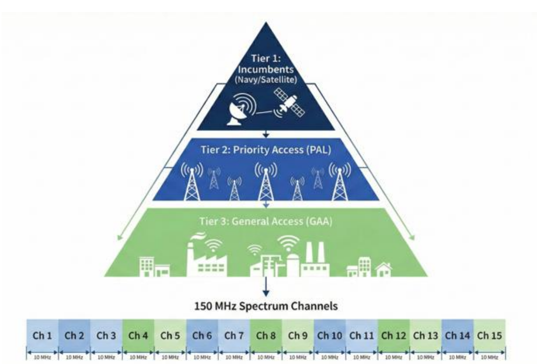

Fig 1: The CBRS Three-Tiered Hierarchy (USA Model)

The low barrier to entry for GAA has driven significant volume. According to recent reports, GAA users account for 71.4% of active CBRS base stations, indicating that the "free-to-use" model is the primary driver of private network adoption [13]. However, the model faces challenges. In late 2025, reports indicated that MNOs (e.g., T-Mobile) were withdrawing support for neutral-host CBRS models in favor of their own licensed spectrum, potentially isolating the CBRS ecosystem [14].

4. Europe: The "Campus Network" Model

Compared to the dynamic complexity of the US, European regulators have generally chosen "administrative assignment"—a model in which spectrum is allocated and assigned to companies upon application, for a specific fee.

4.1. Germany: The Industrial 4.0 Engine

Germany is widely regarded as the pioneer of the private 5G "Campus Network" model, fueled by the lobbying strength of its Mittelstand and industrial giants.

4.1.1. The 3.7 – 3.8 GHz Band (Lokale Breitband)

The Federal Network Agency (BNetzA) reserved the 100 MHz block from 3700 to 3800 MHz exclusively for local private networks [1] [15].

- Licensing Process: Enterprises submit an application specifying the geographic area (defined by polygon coordinates) they want to cover.
- Fee Structure: The fee is determined by a formula that balances affordability for the industry and discourages hoarding:
  $Fee = 1000 + B \times t \times 5 \times (6a_1 + a_2)$
- Where B is the bandwidth in MHz (10–100), t is the license duration in years, a_1 is the "settlement and transport" area in km^2, and a_2 is the "other" area in km^2 [15].
- Adoption: As of November 2024, BNetzA had issued 431 licenses for this band. The main users are in research and development, manufacturing (Metal/Electronics), and logistics [8].

4.1.2. The 26 GHz Band

Germany also opened the 24.25–27.5 GHz band for application-based assignment in 2021. This band is targeted at ultra-high-performance use cases, though adoption has been slower than mid-band due to propagation limitations [8].

4.2. The United Kingdom: The Shared Access Framework

Ofcom, the UK regulator, established the Shared Access License (SAL) framework, making the UK a flexible environment for private connectivity.

4.2.1. Spectrum Bands and Fee Updates (2025)

Ofcom made several bands available for sharing, including 1800 MHz, 2300 MHz, and 3.8 – 4.2 GHz [1] [9].

- Low-Cost Licensing: For "Low Power" licenses, fees are generally low. However, in late 2025, Ofcom revised its regulations. While rural fees remain low, the

cost for Medium Power licenses in urban areas increased from £80 to £160 per 10 MHz channel to account for higher demand and congestion risks [16].
- Enhancements: Ofcom also introduced new coordination mechanisms in 2025 to facilitate access to the 26 GHz band and offer improved antenna directionality options in the 3.8-4.2 GHz band [9].

4.3. France: The "Verticals" Strategy
France has adopted a centralized approach, starting with older bands before expanding into mid-band spectrum.

4.3.1. The Legacy of 2.6 GHz TDD
Arcep has designated the 2.6 GHz TDD band (2570–2620 MHz) for 'professional mobile radio' (PMR), a designation reaffirmed in its June 2024 consultation updates [17]. This band provides LTE maturity and is utilized for critical infrastructure, such as by Hub One for Paris airports and EDF for nuclear energy grids.

4.3.2. Transition to 3.8 – 4.2 GHz
Recognizing the capacity limits of the 2.6 GHz band, ARCEP launched a trial period for the 3.8–4.0 GHz band in 2022. Due to high demand from industrial sectors, ARCEP extended this trial into 2025 to include the entire 3.8–4.2 GHz band and began consultations to establish a commercial licensing framework for these frequencies by the end of 2025 [10].

5. Asia-Pacific: The "Local 5G" Offensive
In Asia, private spectrum policy is closely connected to national industrial strategies. Japan and South Korea see "Local 5G" as a macroeconomic tool to boost manufacturing.

5.1. Japan: Local 5G (L5G)
Japan's Ministry of Internal Affairs and Communications (MIC) announced "Local 5G" to enable industries to develop networks separate from national carriers.

5.1.1. Spectrum and Cost
Japan aggressively allocated both mid-band (4.6 – 4.9 GHz) and mmWave (28.2 – 29.1 GHz) spectrum [18]. To encourage adoption, MIC set spectrum user fees at a nominal level:
- Base Station Fee: Approximately ¥2,600 (approx. $17 USD) per annum [19].
- Terminal Fee: Approximately ¥370 (~$2.50 USD) per annum [18].

This pricing structure effectively removes OpEx barriers for spectrum, shifting the cost focus entirely to infrastructure CAPEX.

5.2. South Korea: e-Um 5G
South Korea launched "e-Um 5G" to promote competition in the B2B sector. The Ministry of Science and ICT (MSIT) allocated spectrum in the 4.7 GHz and 28 GHz bands [4].

Adoption: By 2024, frequencies had been assigned to 56 locations across 35 corporate entities, including non-telco companies like Naver Cloud and LG CNS, which are explicitly encouraged to become network operators for their own campuses [4].

6. Comparative Analysis
6.1. Licensing Economics
The differences in economic models are striking:
- Revenue Maximization (US Auctions): The US PAL auction generated billions in revenue, benefiting well-capitalized entities such as utilities and MNOs [11].
- Utility Maximization (Europe/Asia): Germany, the UK, Japan, and Korea view spectrum as public infrastructure. Fees are administrative, covering regulator costs rather than being market-driven. For example, Japan's ¥2,600 fee [18] and Germany's formula-based fee [15] are intended to reduce entry barriers for smaller industrial players.

6.2. The Ecosystem Fragmentation Problem
A significant challenge is device ecosystem fragmentation:
- n78/n77 Dominance: Private networks in Germany (3.7 GHz) and the UK (3.8-4.2 GHz) have strong support for Band n78 [6].
- The n79 Island: Japan and South Korea use the n79 band. Although popular in China, this band has historically received less support in global "prosumer" devices than n78, which could raise device costs for multinational companies operating in these regions [7].

7. Market Dynamics and Future Outlook
7.1. Growth Forecasts
The private 5G market is set for rapid growth. Projections suggest the market could reach $17.55 billion by 2030, with a CAGR of 35.4% [2]. As of early 2025, there were over 1,714 private network deployments worldwide, led by the United States, Germany, and the United Kingdom in adoption volume [19].

7.2. Future Outlook
As the industry advances toward 6G, lessons from 5G spectrum allocation are shaping policy. Organizations like the 5G-ACIA are advocating for increased cross-border harmonization to prevent the n78/n79 split in the next generation, aiming for a unified global industrial band to reduce device costs and simplify deployment for multinational companies [6] [20] [21].

8. Conclusion
The regulatory landscape for private wireless spectrum has shifted from a dominant MNO-centric model to a diverse array

of localized frameworks. The United States acts as a testing ground for dynamic sharing (CBRS), while Germany and Japan have set the "gold standard" for industrial policy with dedicated, affordable spectrum. The UK and France provide intermediate options, combining regulatory certainty with mechanisms for sharing. For multinational enterprises, this landscape presents a complex challenge: a private 5G strategy cannot be "one-size-fits-all" but must be tailored to the specific regulatory "flavor" of each region.

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