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Analysis of 5G spectrum awarding decisions: How do different countries consider emerging local 5G networks?

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Abstract

Local 5G networks have gained increasing attention in the recent years, allowing different stakeholders to establish local and often private networks within a specific facility, such as a factory. These local networks can serve a variety of user groups with versatile needs. The deployment of the local 5G networks is fully dependent on spectrum availability in the given location, which in turn depends on the underlying regulations and varies for the different stakeholders involved and between countries. The link between emerging new business opportunities and the spectrum availability considering different stakeholders is of great interest from strategic management viewpoint. This paper presents an analysis of recent 5G spectrum awarding decisions considering how they connect with emerging local 5G networks from different stakeholder viewpoints. The analysis reveals how different countries have prepared for the new business opportunity arising from local 5G networks in their spectrum awarding decisions. The analysis also quantifies the spectrum availability for establishing local 5G networks considering different stakeholder perspectives. The findings indicate that the variety of approaches taken by the regulators in their spectrum decisions keeps increasing and new local spectrum licenses are emerging especially in the latest spectrum awards. The identified diverging approaches in different countries impact the business opportunities within the country as well as for export of solutions, which in turn can influence the competitiveness of countries differently.

1. Introduction

Spectrum allocation and assignment decisions play a critical role in the deployment of 5G networks. The spectrum decisions determine, which spectrum bands can be used for mobile communication networks and other radiocommunication services, and which stakeholders can actually deploy the 5G networks in the specific spectrum bands. 5G spectrum decisions have taken place in many countries globally during the recent years. A first study on 5G spectrum awards decision making in 2019 presented in [Matinmikko-Blue et al. 2019] concluded that all three major mechanisms for spectrum assignments, namely market-based mechanisms, administrative allocation, and unlicensed commons, were present in 5G awards depending on the country in question. Furthermore, a high fragmentation between the countries was observed in terms of who gets the spectrum access rights: existing mobile network operators (MNOs) as before, or whether changes to the market structures are actively sought through 5G spectrum decisions that can open the market for new entry. The spectrum awarding mechanisms used by the national regulators are critical in shaping the markets and

lead to different market outcomes, see e.g. [Kuroda & Forero 2017]. At the same time, the MNOs with current strong market positions also face a new market situation with 5G forcing them to reconsider their operations, see [Lehr et al. 2021].

The emergence of local 5G networks originally discussed in [Matinmikko et al. 2017] for vertical specific service delivery keeps gaining increasing momentum. The deployment of these local networks is fully dependent on the spectrum assignment decisions made by the regulators. The use of 5G to serve different vertical sectors, such as manufacturing, has particularly attracted recent attention and regulators have already taken actions to promote this approach in several countries, such as Finland, Germany and Japan, and many are considering. How the spectrum allocation and assignment decisions promote or hinder the emerging local deployment and new operational models has a link to nations' competitiveness through the growing digitalization of all aspects of society and shapes many companies' business opportunities. Our original study [Matinmikko-Blue et al. 2019] showed that the MNO market dominance has continued in many countries with the early 5G spectrum decisions, and only a subset of countries at that time allowed market entry for local and often private 5G networks by introducing local spectrum licensing that was discussed in [Matinmikko et al. 2018]. Although there are many recent 5G spectrum awards decisions made and plenty of spectrum data available, see e.g., [5G Observatory 2021], the topic of spectrum awards decision making for the establishment of local 5G networks continues to be an under-examined topic in the research literature.

This paper revisits the status of 5G spectrum awards two years later in 2021 and presents an analysis of the most recent status of 5G spectrum allocation and assignment decisions with a viewpoint of how these decisions taken in different countries promote or hinder the emergence of local 5G networks. The paper aims to answer the following research question: How do 5G spectrum allocation and assignment decisions consider the emergence of local 5G networks in different countries? More specifically, the business opportunity from the local networks through spectrum availability is of interest. The research first reviews different spectrum awarding mechanisms including market-based, administrative allocation and unlicensed commons considering them in the context of local 5G networks. Special emphasis is on the viewpoint of establishing local 5G networks by different stakeholders including the MNOs and non-MNOs which have diverging market positions and spectrum holdings. The research presents an analysis of the recent 5G spectrum awarding decisions in different countries in Europe, USA, and Asia including a qualitative analysis of the spectrum decisions including an evaluation of the impact of countries' spectrum awards decisions on the possibility for local 5G networks to emerge. A quantitative comparison is made for one country, Finland, presenting the amounts of spectrum assigned to deploy country-wide cellular networks or local networks by MNOs and local non-MNO stakeholders to give an idea of the situation today for establishing local 5G networks.

The rest of this paper is organized as follows. Chapter 2 reviews the state of the art of business opportunities of local 5G networks and related spectrum opportunities. Chapter 3 presents the results of the analysis of 5G spectrum awarding decisions from the viewpoint of local networks and how they impact the emerging business opportunities around local 5G networks. Chapter 4 provides conclusions.

2. Spectrum management for local 5G networks' business opportunities

Spectrum management decisions made by the spectrum regulators in different countries play a key role in shaping future societies by defining, which radio services can be operated by which stakeholders in the different frequency bands and geographical areas. This complex decision-making process in general aims at

maximizing the value of spectrum [see Bazelon and McHenry 2013], its efficient utilization and benefits to the society [see Beltran 2017] and is of great importance from strategic management viewpoint. In particular, the practical interpretations of efficient utilization and benefits to society vary a great deal between countries and are influenced by the different stakeholders in the country with conflicting views. This further complicates the attempts to predicting the long-term impact the spectrum management decision on the potential future business opportunities and new emerging business models, such as the local 5G networks.

2.1 Emerging local 5G networks

Local 5G networks have become of increasing interest as a new deployment model that allows different stakeholders to deploy their own 5G networks within specific premises with/without direct MNO involvement. The concept of local 5G networks and local operators was originally presented in [Matinmikko et al. 2017] and called “micro operators”. These local networks can serve a variety of user groups including closed user groups, resulting in private or non-public networks, or open user groups, such as MNOs’ customers, or a mix of them. Local 5G networks target at exploiting new business opportunities that arise from using mobile connectivity especially to serve the various vertical sectors’ needs, which would allow agile local players extend from connectivity to the use of data with scalable business models [Matinmikko et al. 2017]. On the other hand, local 5G network can also be deployed by traditional MNOs, allowing new business opportunities also for them. These models fall under different regulatory regimes influencing their deployments. Especially private 5G networks for industrial service closed user groups have become one such new deployment model with a lot of estimated market potential [Enterpriseiotinsights.com, 2021].

As the deployment of the local networks fully depends on the spectrum availability in the given area, new local spectrum licensing models for the local 5G micro operators were proposed in [Matinmikko et al. 2018]. The motivation behind local licensing was to remove MNO dependence and allow different stakeholders to gain access to spectrum directly from the regulator without MNO involvement as discussed next.

2.2 Business opportunity of local 5G networks

To map the opportunity landscape of local 5G networks, several reports [Deloitte, 2021; Ericsson, 2020; Frost & Sullivan, 2020] call the ecosystem stakeholders to prepare for repositioning to monetize on 5G and posit remarkable growth in vertical industrial settings. An estimate by [Frost & Sullivan, 2021] expects a minimum of 6% global efficiency improvement in industry verticals by the introduction of 5G.

Understanding the business opportunity landscape for local 5G networks calls for identifying the ecosystems stakeholders, whether existing or new, and their needs in various verticals and the business models applied by them. The key stakeholders originally presented in [Matinmikko et al. 2017] cover MNOs and local (micro) operators, various facility owners and users, various (also) location-specific context content and service providers, device and equipment vendors and network infrastructure vendors. This list was extended by application providers, network infrastructure constructors, mobile service end users, (3rd party) end user equipment providers and internet connectivity providers by [Ahokangas et al. 2019]. The roles of these ecosystem stakeholders may become combined in different ways depending on vertical-specific needs, influencing thus the arrangements how spectrum is managed and the value of the spectrum for the stakeholders [Matinmikko et al. 2018]. For vertical business opportunities, the fundamental spectrum

considerations stem from the requirements for time to access, reliability, quality of service, coverage, and equipment density and types in the industrial settings.

Thus, the scalability, replicability across various use-cases and markets, and economic sustainability of the business models employed by the local players may vary. Three archetype business models for local 5G micro operators were presented by [Ahokangas et al. 2019] including vertically, horizontally or obliquely organized business models. Also, [Ahokangas et al. 2021] discussed four business model scenarios for local operators including the retail model, the wholesale model, the vertical context model, and the (multi-)context-service model. The vertical model rests on the idea of addressing the opportunity to provide tailored end-to-end services in restricted areas e.g., for industrial automation, local utilities, industry sites or campuses in a project-based mode. The oblique model is based on an opportunity to provide mass-tailored end-to-end services to various segments. The horizontal model addresses the opportunity to provide local hosted connectivity for MNOs as a neutral host. In some cases a local 5G deployment can face a bottleneck of cost, competition law, or visual esthetics. Neutral host model has been introduced as a possible means to reduce these bottlenecks by integrating the local physical 5G base station infrastructure and the spectrum ownership into a single actor, neutral host. A neutral host model may enable earlier and larger deployments of costly city-wide local 5G networks through cost sharing between MNOs. Neutral infrastructure may also enable service-based competition to satisfy requirements of competition law. However, the regulator needs to take the neutral host model into account already in the spectrum licensing process.

Stakeholder roles are changing also in practice, challenging industry legitimacy in these emerging ecosystems [Ahokangas et al. 2021] for the stakeholders. MNOs are spinning off tower companies that are entering data center hosting, webscale companies are extending their presence to edge clouds and are providing far edge services to host MNOs' services needing virtual network functionality (VNF). Independent fiber connectivity companies are entering from intercity services to provide access network service providers, and neutral host service providers are diversifying to different services. As a result of all these, private investors have started investing in this transitioning business, and first examples of alliances of webscales and neutral host service providers have emerged. The enabling technical drivers behind these changes include cloudification and the evolution and convergence of edge cloud and data center architectures for providing low-latency applications that enable e.g., open ecosystems and orchestration of services. At the economics front, site densification has become more costly due to scarcity of real estate where the infrastructure could be placed, pressures on the costs of technological infrastructure, and the differences in pay-back times of technologies and infrastructures. So far, the government responses to these changes have been few, but a visible trend for separating fiber companies, different operators, and service providers with regulatory decisions is emerging.

Although the importance of various industry verticals has been recognized in reports [Deloitte, 2021; Ericsson, 2020; Frost & Sullivan, 2020], there is no consensus what industries and use cases adopt the local operator concepts and with what business models. Similarly, the fragmentation of the various industries' needs means challenges for spectrum allocation, management, pricing, at the local level and scalability, replicability, and sustainability challenges at the market level for the various stakeholders. For regulators there is a choice how to balance promoting efficient spectrum use, fairness, competition, and innovation in spectrum allocation and licensing decisions. Currently, different countries have different goals for their spectrum policies, and employ different strategies for local networks.

2.3 Spectrum opportunity landscape

5G has brought a complex mix of spectrum bands with different propagation characteristics and available bandwidths into the table. The European pioneer bands for 5G including 700 MHz, 3.5 GHz and 26 GHz bands all have highly different characteristics, including e.g., different cell radius, bandwidth capacity and outdoor to indoor propagation feasibility, which in turn directly influence the feasible deployment models. At the same time, the spectrum awarding decisions taken by the regulators in the new 5G bands have varied between different countries significantly, see e.g. [Matinmikko-Blue et al. 2019; 5G Spectrum Observatory].

Three main spectrum management approaches including administrative allocation [Levin 1970], market-based mechanisms [Beltran 2017; Melody 1980; Valletti 2001] and the unlicensed commons approach [Bazon 2009] are all present in the 5G spectrum decisions, see [Matinmikko-Blue et al. 2019] for more details. There is divergence between the spectrum assignment methods chosen by the different countries even within the same region such as Europe. At the same time, there are countries that have chosen to use the same awarding mechanisms in all three different spectrum bands, despite of their distinct deployment characteristics. At the same time, countries have considered the role of obligations very differently, some introducing new obligations and others without such obligations on e.g., coverage requirements [Matinmikko-Blue et al. 2019; 5G Spectrum Observatory].

Spectrum opportunities for local 5G networks vary significantly between countries, see e.g. [Matinmikko-Blue et al. 2019; 5G Spectrum Observatory], and also by the stakeholders. The MNOs themselves can establish local networks in their own licensed bands and they could lease their licensed bands for other stakeholders for local networks. Non-MNO stakeholders are in a different position which yet varies between countries regarding their opportunities to access spectrum. There are countries, such as Finland, Germany and Japan, that have reserved parts of the bands for local use through administrative allocation, and these bands and available bandwidths vary from country to country. The high fragmentation observed in [Matinmikko-Blue et al. 2019; 5G Spectrum Observatory] between the different countries' spectrum awarding decisions highlight the role of countries in defining their markets and business opportunities. Figure 1 illustrates the spectrum management approaches and link to local 5G networks. More details on spectrum options for local vertical specific 5G networks can be found in in [Ojanen et al. 2020; Vuojala et al. 2019].

<p>Administrative allocation:</p> <p>Regulator decides which stakeholder can access the spectrum. Goal is to create rules and conditions to minimize harmful interference and to protect incumbent spectrum users.</p> <p>It is used in 5G for assigning local spectrum access rights in some countries.</p>	<p>Market-based mechanism:</p> <p>Regulator defines spectrum property rights that are awarded using some market mechanisms, such as auctions.</p> <p>Auctions are used in 5G extensively with different rules and obligations. Secondary markets typically allow MNOs to transfer rights to others for establishing local networks.</p>	<p>Unlicensed commons approach:</p> <p>Regulator allows spectrum access to many wireless systems under pre-defined rules and conditions that are based on sharing of the spectrum.</p> <p>It can be used to establish local networks, technologies depend on the conditions.</p>
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Figure 1. Spectrum management approaches and link to local 5G networks.

3. Analysis results

First, we analyze recent 5G spectrum decisions considering the role of local 5G networks in different countries. Special focus is on how the spectrum awarding decisions facilitate the emergence of local 5G networks by different stakeholders – MNOs and non-MNOs. We first provide a case example of the 3.5 GHz band, continuing from [Matinmikko-Blue et al. 2019] presenting different approaches taken by regulators for the given band, followed by an quantitative assessment of one country, Finland, about the availability of spectrum for MNO networks and local networks. This is followed by the assessment of the relation to business opportunities for the different stakeholders.

3.1 Spectrum preference for local networks

Table 3-1 summarizes the identified high-level spectrum preferences for a local 5G network. The use of harmonized bands provides scalability and replicability through the existing device ecosystem. The spectrum assignments should include wide enough bandwidths for parallel wideband applications. As many of the applications are related to critical infrastructure and business services, guaranteed spectrum availability and protection from harmful interference are required. Both indoor and outdoor coverage is typically required, as well as mobility for human and machine users. Transmit power levels allowing for outdoor coverage are needed, as well as flexibility of the uplink/downlink (UL/DL) ratio that enables capacity flexibility for various applications. Individual authorizations, i.e. licensing, are the preferred authorization method, and license application submission should be possible any time. The authorization duration should facilitate regulatory certainty and flexibility within the expected facility lifetime. The license fees should be known in advance and affordable industry or community grade pricing is preferred.

Table 3-1. Spectrum preferences for local networks.

Element	Local network preference
Spectrum band	Band preference depends on the deployment mode. Both the low to medium frequency bands are suitable for wide area coverage. High bands are suitable for local capacity.
Band availability	Harmonized spectrum bands are desirable due to widely available ecosystem including widely utilized mature standardization process (IEEE and or 3GPP) and radio authorization framework (EU/ETSI, FCC) for the scale and replicability.
Bandwidth	Sufficient bandwidth is needed for wideband applications and the number of users within the same location.
Availability	Guaranteed full time high availability of the spectrum band is preferred without disruptions or evacuations of the band.
Interference protection	Pre-defined interference protection is preferred, as defined by regulator through authorization conditions or technical solution. Exclusive, protected band is preferred for critical infrastructure use cases but sharing possible case-by-case.
Sharing conditions	Sharing conditions are preferred to be stable and pre-defined, resulting in low transaction friction and cost.
Co-existence mechanism	Should avoid complex technical or restrictive operational requirements. Local exclusive coverage is preferred.

Mobility	Novel use cases require support for human and machine mobility, and including airborne mobility for UAVs (Unmanned Aerial Vehicles).
Location and coverage area	Should be tailorable and defined by the applicant: Local or regional outdoor, or indoor coverage as required by the use case. Deployable for one or multiple areas. Regulation allowing offshore and airborne use.
Transmit power	Typically, medium/high output power needed for outdoor and rural deployments
UL/DL ratio	Flexible, e.g. wideband sensor applications are typically uplink orientated
Authorization method	Locally individual authorization is preferred with application possible any time as time-to-deployment critical.
Authorization duration	Flexible and renewable spectrum access rights are preferred to be in line with typically long facility life cycle and varying service contracts.
Cost/pricing	Known, stable and affordable license fee are preferred.
Regulatory certainty	Predictable framework and schedule and fast time to market are desired.

3.2 Spectrum awards decisions for local 5G networks

Next, we look into different countries' spectrum awards decisions from the view-point of local 5G networks. The following countries were selected for analysis: Finland, Germany, Japan, UK and USA to represent geographical diversity and different types of fore-runners. Table 3-2 presents the results of the comparison where the considered spectrum bands are around 3.5 GHz band which is a common band for 5G networks globally.

Table 3-2. Analysis of 5G spectrum decisions around the 3.5 GHz band.

Element	Finland	Germany	Japan	UK	USA
Considered spectrum band	Total of 390 MHz at 3410-3800 MHz divided to three 130 MHz lots.	a) Total of 300 MHz at 3400-3700 MHz. b) Total of 100 MHz at 3700-3800 MHz.	a) 3600-4100 & 4500-4600 MHz b) 4600 – 4800 MHz local indoors only and 4800 – 4900 MHz outdoors	a) 150 MHz at 3410-3480/ 3500-3580 MHz. b) 120 MHz at 3.6-3.8 GHz. c) 390 MHz at 3.8-4.2 GHz.	a) 150 MHz at 3550-3700 MHz. b) 280 MHz at 3.7–3.98 GHz.
Spectrum assignment method	Market-based mechanism using SMRA auction	a) Country-wide licenses auctioned in 2019. b) Local licenses are available through administrative allocation.	a) Awarded to four MNOs with administrative allocation. b) Local licenses are granted to the owners of the land or property covered in the application. Where the land or building is not owned by the applicant, the latter is limited to fixed wireless services.	a) Auctioned in 2018 to MNOs. b) Auctioned in 2021 to MNOs. c) Available for shared access licenses through administrative allocation.	a) CBRS - Managed shared spectrum with three access layers. Market based Priority Access License (PAL) awarding through auctions and license by the rule based General Authorized Access (GAA) through unlicensed commons model b) Auction of 5 684 licenses based on

			Existing MNOs are not allowed to apply for local 5G licenses.		Partial Economic Areas (PEAs).
Pricing and results	SMRA auction used to define prices. Total 77.6 M€ paid, close to reserve price.	a) Auction raised 6.55 billion € from four MNOs who obtained 90 MHz, 90MHz, 70 MHz and 50 MHz bandwidths. b) 3.7 GHz local license fee calculated from bandwidth, duration, and area.	a) Four MNOs received licenses through administrative allocation. b) The license fee for the base stations is 5900 yen/year, for mobile station 370 yen/year.	a) Auction raised 1.15 billion GBP from four MNOs getting 20 MHz, 40 MHz, 40 MHz and 50 MHz. b) Auction resulted in 820 million GBP. c) Annual license fee £80 per 10 MHz.	a) 228 PAL Bidders, \$4.6B, Vast majority of spend from CSPs, 92%, ~2% of licenses won by non-CSP bidders. Pricing determined by PAL spectrum secondary markets. GAA access requires SAS service fee per CBSD. b) 81 billion \$ collected from auctions where 21 bidders won all available 5 684 licenses.
Stakeholder perspective (MNOs, non-MNOs) and role of local 5G networks	All spectrum awarded to all three existing MNOs. Non-MNOs can only gain spectrum access through the MNO. No local licenses. MNOs can deploy local networks in the spectrum they obtained.	a) Four MNOs obtained licenses with varying bandwidths. b) 3.7 GHz for licensed local and regional private networks for industrial applications, not for public networks. Open for applications by owner of property, tenant, lessee, someone commissioned by owner. 123 licenses awarded by June 2021.	a) Previous market of three MNOs complemented with fourth player. b) n79 band available for local private 5G use in indoors from 12/2020. The license duration is 5 years, but can be renewed.	a) & b) MNOs received licenses. c) Spectrum is made available under a Shared Access license on a first come first-served licensing basis for low power licenses per area (r= 50m) and for medium power licenses per BS.	a) Licensed access to CBRS band as PAL User through secondary markets. PAL auction (Auction 105) was held in 3Q2020. No offshore or airborne use. PAL licenses issued by end of 2020, secondary market follows. 3550-3700 MHz is available for Unlicensed GAA Tier. b) 21 different entities won licenses including MNOs and other stakeholders.
Uniqueness of the case	If MNO does not offer tailored service locally, it needs to lease the band.	a) Licenses introduced coverage obligations to MNOs. b) First countries to award mid-band spectrum for local networks.	Administrative allocation still in use for MNO spectrum awards.	MNO bands are opened for new entry when unused. Local shared access licenses are made available in many bands.	a) Introduced a three-tier model with different levels of spectrum access rights awarded through different mechanisms with a spectrum access system for coordination.

The analysis in Table 3-2 clearly shows that there is a high divergence in the approaches that national regulators have adopted on 5G spectrum decisions regarding the 3.5 GHz band. While some countries have auctioned the bands to the MNOs with nation-wide license even without coverage obligations, other countries have chosen to promote the establishment of new 5G local networks also for non-MNO stakeholders by making local spectrum licenses available through administrative allocation around this band. Some spectrum decisions introduce a new stakeholder role of an intermediary for facilitating the use of spectrum by different stakeholders and instead of being the regulator itself, there can be brokers. There are unique features in the 5G spectrum decisions including different levels of spectrum sharing and awarding mechanisms used.

Next, we present numerical results on the amounts of spectrum made available or MNOs and other stakeholders in Finland based on [Traficom 2021a; Traficom 2021b]. Table 3-3 shows the current spectrum for country-wide mobile communication networks deployed by the MNOs as well as local spectrum available for different stakeholders.

Table 3-3. Mobile communication spectrum availability for MNOs and local networks in Finland.

	Country-wide for MNOs	Local for different stakeholders
Spectrum bands	452,4-456,9 MHz (non-MNO) 703-733 MHz + 758-788 MHz 832-862 MHz + 791-821 MHz 880-915 MHz + 925-960 MHz 1710-1785 MHz + 1805-1880 MHz 2500-2690 MHz 3410-3800 MHz 25.1-27.5 GHz	2300-2320 MHz 24.25-25.1 GHz
Available bandwidths	4.5 MHz 60 MHz 60 MHz 70 MHz 149 MHz 119 MHz 190 MHz 390 MHz 2 400 MHz	20 MHz 850 MHz
Total	3441 MHz	870 MHz

Table 3-4 summarizes the amounts and proportions of different types of spectrum (low, mid, high) for country-wide MNO networks and local networks. Total of 650 MHz, 390 MHz and 2400 MHz have been given to MNOs at low, mid and high spectrum bands, respectively. On the other hand, 20 MHz at 2.3 GHz band and 850 MHz at 25 GHz band are available for local networks through administrative allocation. From the total spectrum made available for mobile communications networks, the percentages at low and mid bands are very low while the availability of local spectrum increases at high bands.

Table 3-4. Amounts and proportions of different spectrum band types for country-wide and local networks in Finland.

Area\Band type	Low (>3 GHz)	Mid 3GHz – 6 GHz	High (>6 GHz)	Total
Nationwide	650 MHz for nationwide use (97% of low band total)	390 MHz for nationwide use (100% of mid-band total)	2400 MHz for nationwide use (74% of high band total)	3440 MHz (80% for nationwide use)
Local	20 MHz for local use (3% of low band total)	0 MHz for local use (0% of mid-band total)	850 MHz for local use (26 % of high band total)	870 MHz (20% for local use)
Total	670 MHz (16% for low band from of total)	390 MHz (9% for mid-band from total)	3250 MHz (75% for high band from total)	4310 MHz (100%)

3.3 Impact on business opportunities

Next, we analyze what the available spectrum means from the deployment perspective of emerging local 5G networks for the different stakeholders including MNOs and non-MNOs. Table 3-5 presents examples of different countries. Countries are selected to represent different spectrum availability, stakeholder preference, innovation policy, speed of actions, different goals, and administrative practice (legacy).

Table 3-5. Analysis of resulting business opportunities of local 5G networks in different countries from different stakeholder view-points.

Country \ Stakeholder	MNO view	Non-MNO view
Finland	MNOs can establish local networks for new business in their bands. There is business opportunity for MNO also from leasing of spectrum bands to other stakeholders.	Different stakeholders can obtain local licenses on first-come first-serve basis 2.3 GHz and 26 GHz bands for new business opportunities.
France	3.4-3.8 GHz band has been made available for MNOs resulting in a total of 2.8 billion € fees paid.	Local licenses are available at 2.6 GHz TDD band with minimum surface of 100km ² from 10 MHz to 40 MHz. Example fee for 20 MHz, 1 year, is $20 \text{ MHz} \times 8.7 \times 0.006 \times 2 \times 34000 = 70992\text{€}/\text{year}$.
Germany	Spectrum made available for MNOs through auction that resulted in high prices paid for the spectrum. 5G spectrum auctions in the 3.5 GHz band introduced coverage obligations to MNOs for other bands.	Industrial private use is made available in 3.7 GHz band for stakeholders relevant to the facility in question. Also 25 GHz band has been made available for local licenses through administrative allocation.
Japan	MNOs have received spectrum through administrative allocation in both mid (3.6-4.1 GHz, 4.5-4.6 GHz and high bands (27-29.5 GHz). Market has been opened for a fourth player in both bands. NTT Docomo,	2.6 GHz band is available for private LTE networks to support non-standalone 5G. Two types of licences: one for telecoms providers covering a municipality, the other for industry verticals where former takes

	<p>KDDI and SoftBank—along with the recent new entrant Rakuten. Rakuten challenge the status quo via their communications platform leveraging cloud-native, virtualized RAN (vRAN) and Open O-RAN technologies.</p> <p>Local licenses are only granted to the owners of the land or property covered in the application (this can include leaseholders). Where the land or building is not owned by the applicant then the latter is limited to fixed wireless services. Existing mobile operators are not allowed to apply for local 5G licenses.</p>	<p>priority over the latter.</p> <p>Local 5G licences in the 28.2-28.3 GHz band are granted to the owners of the land or property covered. Winners of local 5G licences also receive private LTE frequencies in the 2.6 GHz band to be used in conjunction with 28 GHz frequencies for non-standalone 5G, followed by transition to standalone version.</p>
South Korea	5G bands 3.5 GHz and 28 GHz auctioned to MNOs already in 2018 and more is made available.	Government has released the upper part (28.9-29.5 GHz) for 5G private/industry/local 5G use.
UK	<p>MNOs can deploy local networks in their licensed bands. They can also lease bands to others for local networks.</p> <p>On the other hand, MNOs are obliged to sharing through Local Access licence mechanism that enables shared use of MNOs' spectrum, in locations where a particular frequency is not being use.</p>	<p>Shared access licenses are introduced in several bands: 1800 MHz, 2300 MHz band, 3800-4200 MHz band and 24.25-26.5 GHz making spectrum available for non-MNOs on a first come first-served licensing basis per area.</p> <p>Additionally, local Access license allows access to spectrum which has already been licensed to MNOs in locations where they are not using their spectrum: 800 MHz, 900 MHz, 1400 MHz, 1800 MHz, 1900 MHz, 2100 MHz, 2300 MHz 2600 MHz and 3.4 GHz bands.</p>
USA	<p>In CBRS band, 228 Bidders, \$4.6B, 20,625 of 22,631 Licenses. Vast majority of spend from CSPs, 92%; ~2% of licenses won by non-CSP bidders. Top 5 bidders account for 86% of total spend.</p> <p>Spectrum has been auctioned to MNOs above the 3.5 band and will be auctioned in the band below.</p>	Non-MNOs can gain access to licensed shared CBRS band as PAL user through original auctions or secondary markets and through opportunistic GAA license by the rule.

The analysis of different countries' spectrum awards decisions shows that both administrative allocation and market-based mechanisms exist. When it comes to market-based mechanisms, the analysis reveals two main streams: countries where auctions are used as fund-raisers to collect money from MNOs to fund other operations, and countries where auctions are not used for collecting money, allowing investment in the networks.

Finally, Table 3-6 presents a summary of the role of different spectrum awarding mechanisms for the establishment of local high capacity networks from the viewpoint of different stakeholders: MNOs and non-MNOs. When local spectrum licenses are available either through administrative allocation or market-based mechanisms, there is the opportunity for non-MNOs to enter the market. At the same time the MNOs

themselves can establish local networks in their own licensed spectrum bands and or utilizing locally licensed spectrum directly or via their customer. When local spectrum availability through local licenses is low or non-existing, MNOs have the competitive advantage and can solely define the markets and control resulting business opportunities. In that case, the role of unlicensed spectrum becomes of great importance, being the only means to access spectrum. The real deployments for massive wireless service delivery require spectrum availability through different mechanisms in the high-demand locations where overlapping networks operating in different spectrum bands under different authorization models will be needed.

Table 3-6. Role of different spectrum awarding mechanisms for different stakeholders regarding local networks.

	Administrative allocation	Market-based mechanism	Unlicensed
MNOs	MNOs can deploy local networks in their licensed bands. If there is no local licensing, the market is in the hands of the MNOs.	MNOs can deploy local networks in bands that they have obtained from the regulator through market-based mechanisms (such as auction). Furthermore, MNOs can lease spectrum to other stakeholders to deploy local networks.	Unlicensed bands are available for MNOs for local networks that operate in unlicensed bands (different operational characteristics). New unlicensed bands such as 6 GHz make operations attractive due to large bandwidth availability.
Non-MNOs	Some countries have opened local spectrum licenses to non-MNOs through administrative allocation presenting a true business opportunity to establish local networks independent of MNOs.	Non-MNOs can lease spectrum from MNOs and others through market-based mechanisms. Some countries have made local licenses available through market-based mechanisms to non-MNOs.	Unlicensed bands are also available for non-MNOs for establishing local networks that operate in unlicensed bands (different operational characteristics).

The transitioning field of local and private networks raises the need to approach spectrum licensing and management from a wider perspective of legitimation, which is discussed e.g. in [Ahokangas et al. 2021], and national sovereignty [Moerel & Timmers 2021] that up to date have been considered separate questions. Furthermore, industry legitimacy is the consonance of an industry with its institutional environment [Kwak & Yoon, 2020], and it should be differentiated from legitimation given by a regulatory body. Also, the industry stakeholders' need also to gain legitimacy from each other which is a new situation with the advent of local networks deployed by different (non-MNO) stakeholders in addition to traditional MNO networks. At the same vein, discussions on national sovereignty for not only critical infrastructures but the whole ICT technologies have become a concern, raising needs for new kinds of governance and regulation.

4. Conclusions

This paper analyzes 5G spectrum awarding decisions and characterizes the connection to business opportunities around local 5G networks that depend on local spectrum availability. Our analysis results indicate that the spectrum bands, the quality of spectrum and the available bandwidths for local 5G networks especially for non-MNO stakeholders vary significantly between different countries, which creates a significant challenge for business opportunities. This is even more acute due to the highly distinct propagation characteristics between the 5G bands.

Overall, regulators have similar goals to ensure effective and efficient use of spectrum and promote innovation and competition. How this manifests into spectrum awards decisions differs and its analysis is of great interest. Emerging paradigms, such as the local networks and spectrum sharing, can disrupt the market depending on the decisions taken and currently the variety is big. Some countries have auctioned the band for country-wide networks by MNOs while others reserve parts to local use. Countries see differently the role of local networks: complementary to MNO networks or competitive.

This paper has continued the analysis of 5G spectrum awards decisions from the viewpoint of how different countries consider emerging local 5G networks for different stakeholders. Future work is needed to quantify the evolving spectrum availability for local 5G networks in different countries, which serve as inputs towards 6G networks in the 2030s. The way forward is to secure the availability of different types of spectrum – licensed for MNOs, locally licensed for different stakeholders, and unlicensed, to promote innovation and competition. Although the exact amounts of spectrum could vary, the basic principles define the market structures: if there is no locally licensed spectrum, the market is fully left for MNOs to define as well as unlicensed operations solely. If there are local spectrum licenses available for non-MNOs at reasonable cost, such as the facility owners themselves, the business opportunity exists for different stakeholders to establish these networks. There is also the business opportunity around other ICT solution and services around local networks which is also influenced by the local spectrum availability. The decision not to make local spectrum licenses available results in a restricted operational environment compared to countries with local licensing.

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