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Spectrum regulation and frequency allocation in the context of a smart city – using the regulatory approach in Finland as an example

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ABSTRACT
Smart cities rely on data, wireless technology, and connectivity; therefore, the radio spectrum is essential for their future development. This article provides an overview of the regulatory framework and relevant actors related to spectrum use, thereby promoting foreseeability and thus investment in the smart city ecosystem. The focus is the EU-level, but due to the importance of national and local levels, Finland functions as an example. The article highlights the important role of network slicing, infrastructure and spectrum sharing, other forms of cooperation for smart city development, and various operational models and alternatives. The article concludes that smart city operations are both possible and also supported by current regulation and allocation. Despite international and EU-level frameworks, national approaches remain relatively critical. Future real-life experiences will indicate the direction of spectrum regulation, but clearly smart cities require dynamic, local and flexible (use of) networks.

KEYWORDS
Frequency allocation; network slicing; smart city; spectrum regulation; wireless communication

1. Introduction and research task

1.1. Urbanisation and smart cities

More than half the world's population lives in cities, and also the number and size of cities has increased.[1] Smart cities are becoming a central part of connected and sustainable societies around the world, including in European Union (EU) countries. The European Commission defines a smart city as 'a place where traditional networks and services are made more efficient with the use of digital solutions for the benefit of its inhabitants and business'.[2] The concept of the smart city relies on data collection and the use of

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[1]T Kempin Reuter, 'Smart City Visions and Human Rights: Do They Go Together?' (2020) 006 Carr Center Discussion Paper Series, Understanding the Impact of Technology on Urban Life.

[2]Commission (EC), 'Smart cities' (European Commission, An Official Website of the European Union) <https://ec.europa.eu/info/eu-regional-and-urban-development/topics/cities-and-urban-development/city-initiatives/smart-cities_en> accessed 1 January 2022.

new technologies, which aim to provide citizens with smarter and more sustainable services, for example in the fields of city administration, education, healthcare, public safety, real estate, and traffic and public transportation.[3] Smart technologies provide tools for cities and businesses to better optimise their use of resources, design preventive maintenance services and promote security.[4] Smart cities with new kinds of services provide solutions to challenges related to urbanisation, aging populations, and climate change, while concrete examples of applications include monitoring air quality or the movements of residents in order to prevent contagious diseases from spreading.[5]

1.2. Frequency regulation related to wireless networks for smart cities

Smart city services are provided with the help of wireless technology, connected sensors, and user devices that store and process large amounts of data.[6] This requires data sharing infrastructure capable of processing large amounts of data with high bandwidth and low latency. High bandwidth, low-latency real-time communication is crucial for traffic management and the operation of autonomous vehicles, among others. The evolution and increased use of mobile networks and the deployment of next generation wireless technology, such as 5G, are enabling new services, which are gradually transforming society and industries by facilitating a more advanced Internet of Things (IoT), machine-to-machine (M2M) communications, faster connections and ultra-reliable connectivity. For its part, 5G technology provides reliability, high data speeds and short latencies, which are important features in virtual and augmented reality solutions, telemedicine and industry. Moreover, 5G enables the simultaneous connection of numerous IoT devices as well as sensors with batteries that last for up to 10 years.[7] However, some services, such as smart lighting or monitoring urban air pollution, which rely on sending data packages to cloud-based platforms a few times a day, do not require such high bandwidth.

Wireless technologies rely on the radio spectrum. Due to the increased use of commercial mobile communications services, the demand for this spectrum is also greater than before.[8] Consequently, new types of solutions are required, also in the context of 5G. When using wireless communications, issues related to telecommunication regulations, spectrum licensing, cybersecurity, and data protection must be considered. Thus, various legal issues must be addressed alongside the technology itself. On one hand, it

[3]D Washburn and others, 'Helping CIOs Understand "Smart City" Initiatives: Defining the Smart City, Its Drivers, and the Role of the CIO' (Forrester Research, Inc., 2010) <http://goo.gl/4XHk0F> accessed 7 November 2022.

[4]RE Hall and others, 'The Vision of a Smart City' (2nd International Life Extension Technology Workshop, Paris, France, 2000) <https://www.osti.gov/biblio/773961> accessed 7 November 2022.

[5]J Salmelin and others, 'Smart City Design Guideline' (2021) An unpublished project document edited by J Turunen and others.

[6]Regarding personal data protection in the smart city context, see P Korpisaari and others, 'Legal Aspects in Developing Smart City Services and Data Ecosystems' in P Korpisaari (ed), *Sanan vapauksia ja rajoja: Viestintäoikeuden vuosikirja 2020* (University of Helsinki Faculty of Law, Forum Iuris, 2021) 160–70; A Alén-Savikko and others, 'Personal Data Protection, Frequency Regulation and Competition Law in the Context of Smart City Infrastructure' in P Korpisaari (ed), *Oikeuksia, vapauksia ja rajoituksia: Viestintäoikeuden vuosikirja 2019* (University of Helsinki Faculty of Law, Forum Iuris, 2020) 161–73.

[7]Traficom, 'Information about 5G' (2021) <https://www.traficom.fi/en/communications/communications-networks/information-about-5g> accessed 7 November 2022; L Sastrawidjaja and M Suryanegara, 'Regulation challenges of 5G spectrum deployment at 3.5 GHz: The framework for Indonesia' (Electrical Power, Electronics, Communications and Informatics Seminar (EECCIS), Batu, Indonesia, 2018) 213–14.

[8]F Beltran, 'Accelerating the Introduction of Spectrum Sharing Using Market-based Mechanisms' (2017) 1 IEEE Commun Stand Maga 66.

is crucial for companies, communities, and others involved in smart city operations to be aware of the relevant regulatory framework or uncertainties therein. This makes it possible to design operations in the most effective way while remaining compliant and avoiding harmful interference.[9] Foreseeability is crucial from the perspective of the heavy investments required to create an ecosystem that can support the technical needs of smart cities.[10] On the other hand, the requirements imposed by authorities within the relevant regulatory framework must also be taken into account in the development of new smart city infrastructures and services.

1.3. Scope and aim of research

As a scarce resource, spectrum must be managed and allocated.[11] The aim of this article is to map and analyse current spectrum regulation and spectrum allocation decisions in the context of smart city operations. The article also touches upon interests around connectivity and the various smart city operations that rely on wireless connectivity and spectrum.

National legislation and local concepts are crucial in this area, and thus the article uses the example of Finland and Finnish regulation. Finland was chosen because of its peculiar role in the information technology and communications sectors.[12] First, it was already a pioneer in the mobile communications sector in the 1990s,[13] and it was also among the first countries to deploy 5G. In terms of legislation, Finland, as a digital forerunner, assigned affordable broadband access the status of a legal right.[14] In practice, and in terms of statistics, Finland is one of the most connected countries in the world, with nearly all households (96%) enjoying access to broadband internet.[15] Moreover, the frequencies identified in Europe as 5G pioneer frequency bands (700 MHz, 3400–3800 MHz and 26 GHz) have all been allocated to mobile networks in Finland. Consequently, Finland is considered an apt example of a technologically advanced EU country for the purposes of this article, while also providing an interesting case study globally. In addition, the article also provides an overview of relevant EU and global spectrum regulation.

The article begins by briefly mapping the applicable regulatory framework for spectrum use both at the EU level and in Finland. Then, the use of radio frequencies in Finland is considered in more detail in light of the fit between the current framework and the smart city concept. After that, an analysis of spectrum allocation decisions in the context of the smart city is conducted both for Finland and the EU. Finally, the article

[9]With regard to interference in the form of jamming and spoofing, see A Alén-Savikko, 'Satelliittipaikannuksen häirintä lainsäädännön kohinassa' (2019) 3–4 Lakimies 240.
[10]Korpisaari and others (n 6) 158; Sastrawidjaja and Suryanegara (n 7) 213.
[11]F Beltran, S Kumar Ray, and JA Gutiérrez, 'Understanding the Current Operation and Future Roles of Wireless Networks: Co-Existence, Competition and Co-Operation in the Unlicensed Spectrum Bands' (2016) 34 IEEE JSAC 2831, 2829.
[12]See also the arguments used in M Ala-Fossi and others, 'Operationalising Communication Rights: The Case of a "Digital Welfare State"' (2019) 8(1) Internet Policy Review <https://doi.org/10.14763/2019.1.1389>. For more on the so-called 'Finnish model', see M Castells and P Himanen, *The Information Society and the Welfare State: The Finnish Model* (Oxford University Press, 2002).
[13]Ala-Fossi and others (n 12).
[14]Ala-Fossi and others (n 12). See also more about the "broadband for all strategy" in H Nieminen, 'European Broadband Regulation: The "Broadband for All 2015" Strategy in Finland' in M Löblich and S Pfaff-Rüdiger (eds), *Communication and Media Policy in the Era of the Internet: Theories and Processes* (Nomos, 2013) 119–31.
[15]Statista, 'Internet Usage in Finland - Statistics & Fact' <https://www.statista.com/topics/7400/internet-usage-in-finland/> accessed 31.3.2023.

presents the outlook for some core issues in the field of spectrum regulation and spectrum allocation and discusses the impact of smart city development for future spectrum regulation. In addition, the need for future research in these areas is briefly discussed.

The focus of this article is thus present and future spectrum regulation in the operation of smart city services and applications, all of which are exemplified with Finnish legislation and recent spectrum allocation decisions. Requirements resulting from telecommunications regulations or other legislation may be applicable when operating smart city services, while competition law concerns may also arise.[16] However, these issues are not discussed in this article.

2. Current spectrum regulatory framework

2.1. From a global to an EU regulatory framework

The allocation and use of radio frequencies, as a scarce resource, are coordinated at an international level by means of both treaties and soft law instruments; in addition, various types of regulations exist on radio equipment as well as communication networks and services. For its part, the International Telecommunication Union (ITU) functions as a crucial organisation in terms of both frequencies and technical standards in the field of information and communication technology (ICT), including radio communication. At the European level, the central organisations include the European Conference of Postal and Telecommunications Administrations (CEPT) and its Electronic Communications Committee (ECC).[17] European spectrum management and harmonisation is fostered by the European Table of Frequency Allocations and Applications, adopted within the framework of the CEPT.[18] At the EU level, there are also various other instruments, including the Radio Spectrum Decision 676/2002/EC[19] and the Radio Spectrum Policy Programme Decision 243/2012/EU.[20]

The allocation of spectrum in different regions for electronic communication services is decided and updated both at an international level, especially within the ITU's World Radiocommunication Conference (WRC), and at the EU level. Currently, it is the European Electronic Communications Code (EECC)[21] and the decisions of the European Commission

[16]Other requirements may include or be based on, among others, notification requirements to the competent authority prior to commencing operations, cybersecurity rules, rules on joint use and joint construction of physical infrastructure in certain circumstances as well as competition law (incl. notification requirements to competition authorities in cases of cooperation or creation of joint ventures). When engaging in operational actions, all possible requirements must be considered independently by the operative party in contact with the competent authorities. Regarding competition law in a smart city, see Vesala and Brouwer's analysis in Korpisaari and others (n 6) 194–99; regarding public procurement law, see Vesala in Alén-Savikko and others (n 6) 189–92.

[17]See, e.g. G Ancans and others, 'Spectrum Considerations for 5G Mobile Communication Systems' (2017) 104 Procedia Computer Science 509 <https://doi.org/10.1016/j.procs.2017.01.166> accessed 7 November 2022; Alén-Savikko (n 8) 244–45; European conference of postal and telecommunications administrators, 'The CEPT Portal' <https://www.cept.org/> accessed 7 November 2022.

[18]Electronic Communications Committee (ECC), 'The European table of frequency allocations and applications in the frequency range 8.3 kHz to 3000 GHz (ECA TABLE)' (ERC Report 25, European Communications Office, October 2021) <https://docdb.cept.org/download/3543> accessed 7 November 2022.

[19]Decision No 676/2002/EC of the European Parliament and of the Council of 7 March 2002 on a regulatory framework for radio spectrum policy in the European Community [2002] OJ L108/1.

[20]Decision No 243/2012/EU of the European Parliament and of the Council of 14 March 2012 establishing a multiannual radio spectrum policy programme [2012] OJ L 81/7.

[21]Directive (EU) 2018/1972 of the European Parliament and of the Council of 11 December 2018 establishing the European Electronic Communications Code [2018] OJ L 321/36.

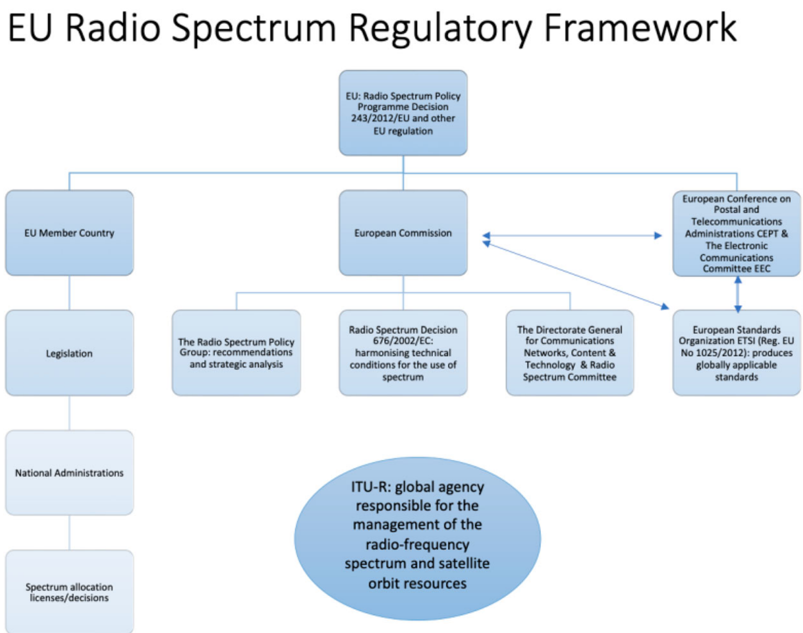

Figure 1. EU radio spectrum regulatory framework.

on the use of radio spectrum that set the main legal framework for national spectrum regulation in the Member States.

With regard to the conformity of various radio equipment, EU law includes the Radio Equipment Directive (RED),[22] alongside other directives closely linked thereto. The RED regulates, among others, the construction of this equipment and the obligations to which manufacturers and importers are subject. However, technical standards and conformity of radio equipment are not discussed in this article.[23]

Despite these global and regional frameworks, spectrum assignments and licence conditions are ultimately nationally determined (Figure 1). This means that in smart city operations country specific regulation must be taken into account case by case and in cooperation with competent national authorities, while local and regional circumstances are also important. For example, available frequency blocks and licence conditions may vary from one use case, country, and area to another. Next, this article explores the Finnish regulatory framework to provide a national-level example.

2.2. Regulatory framework in Finland

In Finland, the main applicable law on frequency administration and oversight is the Act on Electronic Communication Services (917/2014; later ECSA). The competent authority

[22]Directive 2014/53/EU of the European Parliament and of the Council of 16 April 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of radio equipment and repealing Directive 1999/5/EC [2014] OJ L 153/62.

[23]See, e.g. S Bu-Pasha, 'Vulnerabilities in Localization with Regard to GNSS and Harmful Radio Iinterference: International and EU Law Aspects' (2018) 6 IEEE Access 8332. <https://doi.org/10.1109/access.2018.2805282> accessed 7 November 2022; A Alén-Savikko (n 8) 247–49.

with regard to spectrum matters is the Finnish Transport and Communications Agency (Traficom) (see Sections 303–304 § ECSA).[24]

With regard to lower-level regulation, Section 95 ECSA states that 'the allocation and usage of the radio frequency bands is defined nationally by government decree'. Consequently, the Government Decree on Radio Spectrum Usage and the Frequency Allocation Plan by Traficom sets the scene in this regard. To this, should be added the regulations issued by Traficom, which, according to Section 96 ECSA, has 'competence to issue regulations on the use of radio frequencies for different purposes, with due consideration to the international regulations and recommendations on radio frequency use as well as the Government Decree'.

The right to use radio frequencies is subject to the permission of national authorities; that is, a licence is necessary unless Traficom grants an exemption, as specified below. Section 6 ECSA notes that a network licence is required to provide a network service that uses radio frequencies in a digital terrestrial mass communications network or in a mobile network practising public telecommunications, while the provisions also apply to a mobile network functioning as a public authority network operating in more than one municipality. However, there are derogations to this, namely with regard to the *de minimis* provision of network services, for example at a local level with dedicated frequencies: a network licence is not required for small-scale public telecommunications services in the case of local activities on a mobile network functioning in a geographically restricted area if the service is offered in a frequency band indicated for such use by government decree (Section 6(4) ECSA; see also Section 95(1) ECSA). Network licences are announced and granted by the Government (Sections 7–8 ECSA). According to Section 39 ECSA, the possession and use of a radio transmitter requires a radio licence. However, today, 95–99% of radio transmitters are licence-exempt. Thus, most radio equipment does not require a separate radio licence due to the so-called licence exemption.[25]

2.3. Ways to use wireless communication in smart cities under Finnish law

Conditions and requirements for each spectrum band differ. Finnish legislation contains both licence requirements and licence-exemptions, as mentioned above. Moreover, each licence stipulates the conditions for use. These conditions may include a specification of the services that can be provided with the licence, the geographic coverage of the licence, technical conditions for radio emissions and duration of the right to use the spectrum. Moreover, building connectivity with equipment that does not require a separate radio licence allows for a more flexible approach.

A network licence is required when operating a nationwide public network, such as a national mobile network.[26] Here, the user group is unrestricted. For their part, private networks can also be operated under a network licence. The Government grants national network licences by auction. There are currently three operators with network coverage

[24]See, e.g. Alén-Savikko (n 9) 252–53.
[25]ibid 254–56.
[26]A public mobile network means 'a communications network which is used to provide communications services for an unlimited group of users'. A mobile network means 'a network which is based on 3GPP technology and uses mobile terminal equipment'. About terminology, see: <https://www.traficom.fi/en/communications/communications-networks/applying-frequency-reservation-and-radio-licence> accessed 7 November 2022.

in mainland Finland, which means that one option would be to cooperate with such a network licence holder.

Another option is to operate local networks under a radio licence. Local and private networks are based on customer needs and are used, among others, in factories, power plants, ports, industry and university campuses. In such private networks, both the user group and the geographic coverage are restricted. Connectivity could also be required in a local restricted area, where the telecommunications services are public. Operating in such areas would also be covered by a radio licence pursuant to the above-mentioned Section 6(4) ECSA on small-scale public telecommunications services.[27] A radio licence can also be granted for short-term digital experiments, such as 5G/6G test network trials. Radio licences are issued by Traficom, which also collects the appropriate licence fees (Chapter 36 ECSA). The granting of radio licences for mobile networks is based on case-by-case consideration, and the procedure is less extensive than obtaining a network licence (Sections 40–41 ECSA). The licence may come with necessary conditions (Section 42 ECSA).

As mentioned earlier, the use of certain radio equipment does not require a separate radio licence. Examples of licence-exempt radio equipment are WLANs (wireless local area network), short-range devices (e.g. IoT), mobile terminal equipment, such as smart phones, telecommand equipment operating on collective frequencies, other low-power radio transmitters, as well as equipment for detecting movement and equipment for alert. Traficom regulates the conditions for licence-exempt radio transmitters.[28] However, similar protection against harmful interference is not guaranteed in spectrum bands shared between users on a licence-exempt basis.

It is not always necessary for a particular stakeholder or party to acquire a dedicated spectrum licence for smart city operations, as the right to use frequencies may also be leased from licence holders. Agreements concerning the lease of spectrum are principally commercially driven, while leasing is permitted in all auctioned network licences pursuant to Section 20(1) ECSA, which notes that 'a licence holder with a licence granted by auction may lease out the right to use the frequencies referred to in the licence to another company or organisation'. The Government is required to approve such leases unless there are strong reasons to suspect damage to national security or competition (Section 20(2) ECSA).[29] The licence holder in question remains responsible for obligations related to the network licence and a possible radio licence attached thereto (Section 20(1)

[27]To fall under the scope of Section 6(4), the provided service must be a *minor network service*, meaning 'operations that are minor in terms of the number of users, financial impact or significance in communications markets. Minor operations also cover operations that are minor based on the number of frequencies, other technical implementation or the service provided' and *local operation* meaning 'operation that is local, based on the number of customers/subscriptions, the geographic area of use or other purpose of use (e.g. factory)'. About terminology see: <https://www.traficom.fi/en/communications/communications-networks/applying-frequency-reservation-and-radio-licence> accessed 7 November 2022.

[28]See, e.g. Traficom, 'Regulation 15 on collective frequencies for licence-exempt radio transmitters and on their use' (Explanatory notes, 2021) <https://www.traficom.fi/sites/default/files/media/regulation/EN_M%C3%A4%C3%A4r%C3%A4yksen_15AR_perustelumuistio_%28englanti%29.pdf> accessed 7 November 2022.

[29]In the case of a joint venture, when leasing out the right to use the spectrum band, approval of the competition authorities might also be required. However, as noted above, competition law is not further discussed in this article. See, e.g. decision Dnro 438/14.00.00/2014 of the Finnish competition and consumer authority (2015), where a joint venture raised concerns about restriction of national network competition. Remedies were imposed by the competition authorities. <https://arkisto.kkv.fi/globalassets/kkv-suomi/ratkaisut-aloitteet-lausunnot/ratkaisut/kilpailuasiat/2015/kielto--sitoumus--ja-toimitusvelvoiteratkaisut/r-2014-00-0438_2018_dna.pdf> accessed 8 January 2022; For more on competition law, see J Vesala and D Brouwer in Korpisaari and others (n 6) 194–99.

ECSA). However, the licence conditions attached to the licence must also be followed by any possible leaseholder. With regard to radio licences, Section 48(1) ECSA notes that they may be transferred (if not prohibited in the licence), while Traficom must be notified thereof. However, pursuant to 48(3) ECSA, relinquishing a radio licence to a party who is leasing radio transmitter from the licence-holder or has been granted temporarily use of the licence-holder's radio transmitter is not considered transfer of a radio licence, and the licence-holder remains responsible for use in accordance with the licence conditions. In most such cases, the secondary user also requires a radio licence from Traficom.

As a rule, licence holders are entitled to lease out the right to use the spectrum; however, there may also be an obligation to lease. For example, in Finland, such an obligation exists with regard to the spectrum band 3410–3800 MHz (3.5 GHz) if the service is not provided by the mobile network operator (MNO) in a particular area.[30]

3. Allocation of spectrum bands in the context of the smart city

3.1 Spectrum allocation in the EU

Services in a smart city require connectivity, and different services have different needs for spectrum band depending on their nature. In the future, it will be possible to use 5G in any of the spectrum bands currently used for 2G, 3G, and 4G, and the development of 6G is also already under way. Frequency bands are assigned on a technology neutral basis.[31] Smart city operations may draw on various spectrum bands depending on the required features, technology, coverage, capacity, and network latency.

The frequency bands thus far harmonised for 5G in Europe are 700 MHz, 3.5 GHz and 26 GHz. Seven-hundred MHz is a so-called low-band spectrum offering large coverage but speed similar to 4G. In turn, 3.5 GHz is a mid-band described as ideal for 5G and suitable for rapid 5G in a city area, while 26 GHz is a high-band for services demanding ultra high speed and capacity. Since January 2022, commercial 5G has been available in all 27 EU – countries.[32]

The 5G pioneer frequency bands as well as the timeframe for the deployment of those bands are defined by the EECC. However, the assignment and use of radio frequency bands are determined nationally. Indeed, spectrum assignments and licence conditions for spectrum bands vary between EU-countries.[33] For example, in Finland, the lower part of the 26 GHz frequency band is reserved for local networks. The available

[30]Similar obligations for the secondary use of MNO's spectrum bands can be found, for example, in Denmark, see more: <https://www.gsma.com/spectrum/wp-content/uploads/2022/01/Spectrum-Leasing-5G-Era.pdf> accessed 7 November 2022.

[31]The principle of technological neutrality has been reinforced by the Framework Directive 2002/212, Recital 18 (Directive 2002/21 on a common regulatory framework for electronic communications networks and services (Framework Directive) [2002] OJ L108/33) and later by the European Electronic Communications Code, Recital 25: The principle sets a requirement for Member States 'to ensure that national regulatory authorities take the utmost account of the desirability of making regulation technologically neutral, that is to say that it neither imposes nor discriminates in favour of the use of a particular type of technology, does not preclude the taking of proportionate steps to promote certain specific services where this is justified, for example digital television as a means for increasing spectrum efficiency'.

[32]Commission (EC), '5G Observatory Quarterly Report 14 up to January 2022' (Quartely Report January 2022) <https://5gobservatory.eu/wp-content/uploads/2022/02/5G-Obs-PhaseII_Quarterly-report-14_FINAL-Clean-for-publication_16022022.pdf> accessed 7 November 2022.

[33]ibid 80–84.

bandwidths thus vary from country to country, as does the situation with regard to possible reservations in the spectrum band for local use.[34] This fragmentation in decision-making across the EU highlights the role of national regulators in spectrum allocation. Moreover, when moving to the 5G and 6G era, one crucial difference compared to prior generations is the wide variety of spectrum bands: low, mid, and high. The propagation characteristics of these bands differ such that, for example, network coverage can range from tens of metres to tens of kilometres. This is apt to lead to a greater variety of spectrum management approaches due to increased demand for spectrum bands. In addition, new ways to deal with existing spectrum users must also be found.

The term *spectrum management approaches* refers to regulatory decisions aimed at efficient use of spectrum. These approaches can be divided into three categories: administrative allocation, market-based mechanisms, and unlicensed commons. Further research is required to determine which type of approach is the most suitable for different frequency bands. However, dynamic spectrum use, spectrum sharing,[35] local licences, and unlicensed access to spectrum bands are likely to be of high importance in the context of 5G/6G.[36] In general, 5G and 6G are characterised by local spectrum use alongside traditional, exclusive, wide-area networks licensed via auctions.

3.2 Spectrum allocation in Finland

Currently, the allocated spectrum bands for mobile cellular networks in Finland are 450 MHz, 700 MHz, 800 MHz, 900 MHz, 1800MHz, 2 GHz, 2.3 GHz (local networks), 2.6 GHz, 3.5 GHz, 25 GHz (local networks), and 26 GHz. Three operators have nationwide network coverage in Finland.

For their part, the 5G pioneer bands, 700 MHz, 3.5 GHz and 26 GHz, have been assigned through auctions. Coverage for the licence holders is nationwide, with the exception of Åland. Following the 3.5 GHz auction in 2018, Finnish mobile network operators launched their commercial 5G networks in 2019. The most recent auction, for the spectrum band 26 GHz (25.1–27.5), was held in 2020.[37] The frequency bands 2300–2320 MHz and 24.25–25.1 GHz are available for local 4G/5G networks. These spectrum bands are the first dedicated 4G/5G spectrum bands for local use and, under certain circumstances, also for small-scale public networks and fixed wireless access. The benefit of local networks, among others, is that they can be tailored to the needs of an organisation.[38]

[34]M Matinmikko-Blue and others, 'Analysis of 5G Spectrum Awarding Decisions: How Do Different Countries Consider Emerging Local 5G Networks?' (2021) <https://www.econstor.eu/bitstream/10419/238039/1/Matinmikko-Blue-et-al.pdf> accessed 7 November 2022. The adoption of the 3.5GHz band is used as an example to indicate the fragmentation of 5G spectrum decisions at the EU and globally, 7–9.

[35]Report ITU-R M.2330-0, 'Cognitive Radio Systems in the Land Mobile Service' (11/2014), 9. <https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-M.2330-2014-PDF-E.pdf> accessed 7 November 2022. According to the ITU's definition, spectrum sharing refers to the situation where two or more radio systems operate in the same frequency band.

[36]See more about spectrum management approaches in M Matinmikko-Blue, S Yrjölä and P Ahokangas, 'Spectrum Management in the 6G Era: The Role of Regulation and Spectrum Sharing', 1. <http://jultika.oulu.fi/files/nbnfife2020050725614.pdf> accessed 7 November 2022. See also Beltran, Kumar Ray, and Gutiérrez (n 11).

[37]The 3.5 GHz frequency band was auctioned so as to award licences to DNA Oyj, Elisa Oyj and Telia Finland Oyj in 2018. The auction for the 26 GHz frequency band in 2020 also resulted in the same three MNOs obtaining licences for developing 5G networks.

[38]Traficom, 'Local 4G/5G Networks' <https://www.traficom.fi/en/communications/communications-networks/local-4g5g-networks> accessed 7 November 2022.

Local networks can be closed or connected to the public network. In the context of local networks, Finland has adopted a relatively new provision on cybersecurity for the protection of core network functions that complements existing regulation. According to this provision, the use of a telecommunications device is not permitted in critical parts of the public network if it can endanger national security and defence when used. This also applies to micro-operators and providers of private networks connected to certain universal communications networks (Section 244a ECSA). Currently, Traficom is drafting guidance on cybersecurity and risk management in local networks. This guidance will be completed during the autumn and published on Traficom's website.[39]

4. Future outlook for spectrum regulation

As mentioned earlier, global and EU-level tools exist in the area of spectrum regulation, but the national, regional, and local levels are crucial – indeed, with smart city concepts, the focus is rather specific. For its part, Finnish spectrum regulation and policy is well-developed and enjoys a good reputation worldwide; nonetheless, Finland has also pursued its own national goals in terms of spectrum policy.[40] In any case, certain issues must be taken into account concerning the type of network and radio licence conditions for local networks in the operation of smart city services, such as the extent, conditions, and manner of local network use. Moreover, there are overall policy targets to reach if Finland wishes to remain at the forefront of development.[41]

With regard to current and future smart city development, the need for mid-band spectrum for local networks has been recognised, and the European Commission has issued a mandate to the CEPT (European Conference of Postal and Telecommunications Administrations) on technical conditions regarding the shared use of the 3.8–4.2 GHz frequency band for terrestrial wireless broadband systems providing local-area network connectivity. In the EU, it is planned that at least part of the 3.8–4.2 GHz spectrum band will constitute the first harmonised spectrum band for local networks.[42]

Additional spectrum assignments are required for mobile telecommunications, including local (e.g. smart city) networks.[43] Such future spectrum bands possibly include the following: 1.5 GHz, 3.8–4.2 GHz, and 40 GHz.[44] Furthermore, the ITU-R is currently investigating the use of the upper part of the 6 GHz spectrum for mobile

[39]Traficom, '5G Momentum -ekosysteemi vie Suomea 5G-edelläkävijäksi' (5G Momentum Uutiskirje 4/2022) <https://uutiskirjeet.traficom.fi/a/s/185197098-6fca4af219d9140014d51b8d802b411b/5126584> accessed 7 November 2022.

[40]See, e.g. M Ala-Fossi, 'Finland: Surfing the Mobile Wave Against the Tide of EU Spectrum Policy Consensus' in G Taylor and C Middleton (eds), *Frequencies: International Spectrum Policy* (McGill-Queen's University Press, 2020) 46–67.

[41]Examples of the policy targets for smart city development can be found in the European Commission (EC) 2030 Policy Programme, 'Path to the Digital Decade programme' COM(2021) 574 final, 15 September 2021, arts 2 and 4 <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021PC0574> accessed 7 November 2022.

[42]Commission (EC), Ref.Ares (2021) 7794710 - 16/12/2021. Mandate to CEPT on technical conditions regarding the shared use of the 3.8–4.2 GHz frequency band for terrestrial wireless broadband systems providing local-area network connectivity in the Union.

[43]GSMA, '5G Spectrum: GSMA Public Policy Position March 2021' (June 2022) <https://www.gsma.com/spectrum/wp-content/uploads/2021/04/5G-Spectrum-Positions.pdf> accessed 7 November 2022. See also A Garcia-Rodriguez and others, 'Massive MIMO Unlicensed: A New Approach to Dynamic Spectrum Access' (2018) 56(6) IEEE Communications Magazine 186.

[44]European 5G Observatory, 'To Fulfil Its Potential 5G Needs Access to Much Higher Frequencies: 3.5 GHz and Above. This was not the Case with Earlier Mobile Generations' <https://5gobservatory.eu/5g-spectrum/> accessed 7 November 2022. 5G Spectrum: 'At the ITU World Radio Conference in 2023 (WRC-23) a further IMT identification could be approved for 3.3–3.4 GHz, 3.6–3.8 GHz, 6425–7125 GHz and 10.1–10.5 GHz, facilitating the use of these bands for 5G.'

telecommunications. According to agenda item 1.2 of the 2023 World Radio Conference, 6425–7025 MHz is being assessed for IMT (International Mobile Telecommunications) in Region 1 (Europe, the Middle-East and Africa) and 7025–7125 MHz globally. Finland supports the allocation of both these bands for IMT. The upper 6 GHz frequency is mid-band spectrum with great potential to provide improved 5G connectivity. For its part, 6G, yet another generation of mobile technology, is also on its way, as stated above, and it requires frequency bands above 95 GHz.[45] Preparations for the next WRC-23 meeting include new studies of IMT systems that, for Europe, involve considering the identification of new frequency bands, mainly 6425–7025 MHz (agenda item 1.2), and possible regulatory actions in the 470–694 MHz frequency bands (agenda item 1.5).[46]

For its part, the GSMA has published a report on estimated mid-band spectrum needs in 2025–2030: as regards additional mid-bands for improved 5G connectivity, they are considered important as selective tools for dense areas/'hot spots' in rural areas as well as for delivering network slices (for, e.g. train stations and railways), where nationwide coverage would not be feasible. Licensing of the additional mid-band spectrum should be service neutral and nationwide.[47] According to the report, a 'baseline spectrum' includes not only the spectrum currently used by mobile operators, but also near-future assignments situated between 725 and 1420 MHz.[48] Compared to fibre, mmWave 5G possesses great potential as an effective option for connectivity in dense urban areas using numerous antennas (e.g. via lamp posts), and the report deems it likely that operators will deploy mmWave spectrum outdoors/indoors.[49] Yet another GSMA report foresees the increased integration of mmWave with sub-6 GHz bands in order to achieve wide-area coverage alongside the additional capacity with mmWave bands.[50]

Moreover, the future introduction of 6G means that smart city networks should be developed such that they are also suitable for 6G technology. In 2018, a study by the Body of European Regulators for Electronic Communications (BEREC) deemed it likely that commercial uses would be primarily designed for 'a mixed connectivity environment' including 4G and 5G as well as other networks.[51]

For its part, the next generation of wireless technology enables so-called 'network slicing',[52] which allows tailored 5G-solutions to be offered at a national, regional or

[45]Millimeter Wave Products Inc., 'What is 6G?' <https://www.miwv.com/what-is-6g/> accessed 8 January 2022.

[46]ITU-R Preparatory Studies for WRC-23 <https://www.itu.int/en/ITU-R/study-groups/rcpm/Pages/wrc-23-studies.aspx> accessed 7 November 2022; See also 'White Paper on RF Enabling 6G – Opportunities and Challenges from Technology to Spectrum' (2021) 13 6G Research Visions 38 <http://jultika.oulu.fi/files/isbn9789526228419.pdf> accessed 7 November 2022.

[47]GSMA and Coleago Consulting Ltd., 'Estimating the Mid-Band Spectrum Needs in the 2025–2030 Time Frame: Global Outlook' (July 2021) 53 <https://www.gsma.com/spectrum/wp-content/uploads/2021/07/Estimating-Mid-Band-Spectrum-Needs.pdf> accessed 7 November 2022.

[48]ibid 2–3.

[49]GSMA, 'The WRC Series: Regional Spotlights: Impact of mmWave 5G' (2019) <https://www.gsma.com/spectrum/wp-content/uploads/2019/07/mmWave-5G-Regional-Spotlights.pdf> accessed 7 November 2022.

[50]ibid 21.

[51]BEREC, DotEcon Ltd and Axon Partners Group, 'Study on Implications of 5G Deployment on Future Business Models' (2018) BoR (18) 23, 100. <https://berec.europa.eu/eng/document_register/subject_matter/berec/reports/8008-study-on-implications-of-5g-deployment-on-future-business-models> accessed 7 November 2022.

[52]This refers to the provision of 'slices' that enable specific and separate uses of the network. See, e.g. ITU-T Rec, 'Series Y: Global Information Infrastructure, Internet Protocol Aspects, Next-Generation Networks, Internet of Things and Smart Cities' (Future networks. Y.3157 (02/2021)) <https://www.itu.int/rec/dologin_pub.asp?lang=s&id=T-REC-Y.3157-202102-I!!PDF-E&type=items> accessed 7 November 2022.

local level. Indeed, different smart city applications and services exhibit differing requirements and needs in terms of quality, prioritisation, latency and speed. This allows network management to be developed such that the physical network caters for multiple end-user and use-case specific virtual networks, with 'network slices' providing a variety of capabilities and characteristics.[53]

Network slicing has been recognised as one of the possible solutions to support tailored 5G connectivity in the smart city environment. However, spectrum for local networks, especially European harmonised approaches, is also required. These developments not only imply changes in operators' traditional business models but also create opportunities for local 5G network deployment.

The Radio Spectrum Policy Group has also initiated work on 6G development. The work programme for 2022 contains the item 'development of 6G and possible implications for spectrum needs and guidance on the rollout of future wireless broadband networks'.[54] Furthermore, the work programme also contains the item 'Mobile technology evolution – experiences and strategies', which investigates the phasing out of 2G/3G networks and the use of the released spectrum for 4G/5G/6G networks. Finland plays an active role in the sub-group responsible for both work items.[55] Finnish mobile operators have already announced the phasing out of 3G networks in 2023,[56] the year in which the GSM coverage obligation for 99% of the population will also be re-evaluated.[57]

Investing in smart city connectivity solutions requires a foreseeable future with regard to spectrum issues, as mentioned at the beginning of this article. For its part, sharing is seen as an important tool: indeed, regulation has encouraged infrastructure and spectrum sharing, which may increase in the future due to the cost efficiencies it offers to parties involved in telecommunication services. National authorities should also ensure effective spectrum use and support licence leasing by appropriate national licence procedures.[58]

Operation of smart city services can be accomplished in cooperation with parties in the smart city ecosystem, taking into account the relevant competition law framework (e.g. conditions imposed for the sharing agreement or joint venture to ensure market balance and benefits for end-users).[59] Both the forms of cooperation between

[53]See International Telecommunication Union (ITU) (n 46); BEREC, DotEcon Ltd and Axon Partners Group (n 45) 100–01. See also A Alén-Savikko, 'Network Neutrality in the Era of 5G: A Matter of Faith, Hope, and Design?' (2019) 28(2) Information & Communications Technology Law 115, 124–25 with references <https://doi.org/10.1080/13600834.2019.1587830> accessed 7 November 2022.

[54]Commission (EC), 'Radio Spectrum Policy Group, Work Programme for 2022 and Beyond' (2022) <https://rspg-spectrum.eu/wp-content/uploads/2022/02/RSPG22-006final-work_programme_2022_and_beyond.pdf> accessed 7 November 2022.

[55]Traficom, 'Finland Strongly Involved in European 6G Spectrum Work' (press release 21.3.2022) <https://www.traficom.fi/en/news/finland-strongly-involved-european-6g-spectrum-work> accessed 7 November 2022; One of the writers of this article, Heidi Himmanen, acts as a co-chair of the RSPG sub-group 'The Development of 6G and Possible Implications for Spectrum Needs, and Mobile Technology Evolution – Experiences and Strategies' <https://rspg-spectrum.eu/sub-groups/> accessed 7 November 2022.

[56]Ficom, 'Suomen 3G-verkot suljetaan vuoden 2023 aikana' (press release 27.9.2022) <https://ficom.fi/ajankohtaista/uutiset/suomen-3g-verkot-suljetaan-vuoden-2023-aikana/> accessed 7 November 2022.

[57]Liikenne- ja viestintäministeriö, 'DNA, Elisa ja Telia saivat uudet verkkotoimiluvat 900, 1800 ja 2100 megahertsin taajuusalueille' (press release 13.12.2018) <https://www.lvm.fi/-/dna-elisa-ja-telia-saivat-uudet-verkkotoimiluvat-900-1800-ja-2100-megahertsin-taajuusalueille-990437> accessed 7 November 2022.

[58]EECC, Recitals 119, 124, 132, 156, arts 45(1–2), 51(1–3).

[59]See GSMA and Coleago Consulting Ltd. (n 41) 7–8; see also BEREC, DotEcon Ltd and Axon Partners Group (n 45) 101, where it is also noted that '[c]harging models for shared infrastructure should ideally be capacity-based to ensure that there are no retail competitive effects'.

telecommunication actors and the actors themselves can vary widely; for example, the party in the sharing agreement, in addition to traditional telecom operators, might be a local company.[60] Principally, network and infrastructure sharing agreements are based on commercial considerations, and the contents of the agreements are not regulated.[61] The trend in legislation has been to allow telecommunications markets to be driven by market forces, and thus the remedies of competition law are also applied in the telecommunications industry. That means that obligations resulting from telecommunication regulation and the intervention of authorities are imposed only if market balance and the rights of end-users cannot otherwise be secured.[62]

Operational models based on spectrum licence leasing or network slicing are suitable options for operating in a smart city and may be more cost-efficient than owning a spectrum licence. Moreover, sharing the spectrum wisely and effectively between users and different radio services is one of the key future challenges, as it will be necessary to satisfy the spectrum needs of all users.[63]

5. Conclusions and further research

Thus far, city-level licensing has failed to receive any special attention in official documents or processes. However, as discussed above, the need for additional spectrum bands is recognised, even if smart city operations can be performed within the current regulatory framework and spectrum bands that have been allocated. Alternatives include owning a radio licence for private networks and local spectrum bands as well as cooperation with other licence holders and leasing the right to use the spectrum band. For their part, local networks can also be operated in cooperation with mobile telecommunication operators. Further, utilising unlicensed (licence-exempt) radio equipment is the fastest and most flexible way to introduce new services. It should be noted that unlicensed spectrum bands are shared between all users, and similar protection against harmful interference to that provided for licensed bands is not guaranteed.

When it comes to forms of cooperation in Finland, sharing and leasing are permitted in all auctioned network licences (700 MHz, 800 MHz, 2.6 GHz, 3.5 GHz, 26 GHz). In addition, the leasing of radio spectrum licences is allowed. Principally, the contents of leasing agreements are not regulated and can be agreed by the parties involved. Overall, the evolution of smart city networks and operations may be driven more by market forces than regulative actions, although competition law may play its part here, as mentioned above.

Recent spectrum allocation decisions also support the development of smart cities. In addition to the 5G pioneer bands, locally deployed networks are an essential part of the future operations of smart cities. Certain operations can be performed in the spectrum

[60]OECD, 'Wireless Market Structures and Network Sharing' (2015) OECD Digital Economy Papers, No. 243, OECD Publishing 2014, 5–7. <https://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=DSTI/ICCP/CISP(2014)2/FINAL&docLanguage=En> accessed 7 November 2022.

[61]M Bourreau, S Hoerning, and W Maxwell, 'Implementing Co-investments and Network Sharing' (2020) Centre on regulation in Europe (CERRE) Telecom Report, 14–15. <https://cerre.eu/wp-content/uploads/2020/07/cerre_implementing_co-investment_and_network_sharing-26.05.2020.pdf> accessed 7 November 2022. Shared use of passive infrastructure may be mandatory resulting from the telecommunication laws.

[62]EECC, Recital 29.

[63]See also Ala-Fossi (n 40) 62–63.

bands allocated for local networks; in Finland, for example 2300–2320 MHz and 24.25–25.1 GHz. In the EU, work is ongoing to harmonise the spectrum band 3.8–4.2 GHz for local networks. Local networks provide multiple operating possibilities alongside the operation of nationwide public mobile networks through auctions or administrative allocation.

Even if the regulative framework for spectrum regulation is provided at the EU and international level, a relatively strong role remains for country specific regulation by the relevant authorities. National licence conditions and frequency allocation must be taken into account case by case, as spectrum assignments and licence conditions for spectrum bands vary between EU countries. An open question is whether there is a need for deeper harmonisation within the EU in the field of spectrum regulation.[64] The strong role of national procedures and spectrum allocation may affect, for example, the entry of new players to European markets as well as market development. The future degree of regulation and harmonisation of spectrum management approaches also remains to be seen. Smart city operations are characterised by even wider shared use of spectrum bands, while spectrum management approaches remain fragmented. However, securing the provision of vital societal functions and the avoidance of harmful interference will always require country-specific spectrum regulation.

Currently, the impact of smart city development on future spectrum regulation is most evident in the context of local spectrum bands and with regard to the manifold ways to operate smart-city networks. This may contribute to ever greater divergences between countries as local spectrum bands and operations are tailored to country-specific needs according to local circumstances. The concept of a smart city arguably involves a citywide rather than nationwide area of operation, with each smart city characterised by its own specific network coverage and functionality needs.

The use of networks in smart cities will be even more dynamic, local, and most of all flexible. Therefore, spectrum regulation must also enable network tailoring for different users, use-cases, and services. In this regard, the EU's current spectrum regulatory framework can be considered up-to-date in terms of its ability to cater for smart cities. The relatively recent and comprehensive European Electronic Communications Code (2018)[65] supports the deployment of 5G and the development of 6G networks.

When estimating future needs for spectrum regulation, case law on the implications of smart cities remains undeveloped. Real-life experiences from smart city use cases and services are required to determine where and how to develop spectrum regulation. Interesting topics include the possible need for more mid-band spectrum and licence models to operate networks as well as the potential for cooperation with current licence holders. The role of spectrum regulation, licences, and spectrum allocation in the fragmented smart city environment remains to be seen. Currently, it seems that spectrum regulation is in place to support the smart city era, while real-life experiences will show which way to develop spectrum regulation in the future.

[64]Decision No 676/2002/EC of the European Parliament and of the Council of 7 March 2002 on a regulatory framework for radio spectrum policy in the European Community [2002] OJ L108/1. The 2002 Radio Spectrum Decision allows the Commission to adopt implementing decisions to harmonise technical conditions with regard to the availability and efficient use of spectrum for the proper functioning of the single market, arts 1(1–2).

[65]EECC.

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