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Reimagining Electronic Communications Regulatory Environment with AI: Self-Regulation Embedded in 'Techno-Regulation'

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Abstract

In 2019, Roger Brownsword published a book in which he described the transformation of regulatory environments via technology and the reimagining of legal values and legal rules that must accompany this transformation. In *'techno-regulation'* the regulator expects a perfect control and elimination of non-compliance by employing a particular technology, whereas regulatees may have only a limited capacity to damage, disrupt and circumvent the technology put in place. This paper demonstrates how Brownsword's description of *'techno-regulation'* matches current trends in radio spectrum management and argues that radio spectrum management is the precursor of all technologically managed environments.

The paper identifies the normative and non-normative dimensions of technologically regulated radio spectrum and comments on the specificities of radio spectrum as a technologically managed environment. It assesses the driving forces behind the current trends in radio spectrum management, as well as the regulatory fitness of 'techno-regulatory' approaches to radio spectrum management. Finally, the paper describes how regulatees attempt to disrupt, hack or otherwise compromise the technology deployed by the regulator, and how radio spectrum management achieves control over compliance in the transformed environment.

Keywords: Radio Spectrum, Rule of Law, Techno-Regulation, Telecommunications, Regulation.

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1. Introduction

Theorising technological changes in jurisprudence may be compared to writing a science fiction novel. It requires a good amount of imagination and foresight, and it is an occupation that attracts those of a bookish bent. Many legal theorists try to paint a full picture of the future – some as an optimistically utopic vision, some as a dystopian critique. However, just as *'good science fiction must rest on good science,'*[3] it is also submitted that good legal theory must rest on good scientific and technological appraisals.

Many renowned science fiction writers possessed scientific training, which afforded them a certain advantage compared to legal theorists. Isaac Asimov had a doctorate in biochemistry, Arthur C. Clarke, a degree in mathematics and physics and H. G. Wells, a degree in biology.[4] One may suggest then, that legal theorists should also be encouraged to dip their toes in unfamiliar disciplines, to transcend the confines of legal studies, and to educate themselves in the current state-of-the-art scientific and technological knowledge and foundations of natural sciences, or pair up with experts in other fields who provide *'scientific advice'* or insight. As a matter of fact, a number of legal scholars have already done so, with brilliant results.[5]

Legal theories require confirmation of their credibility. In case of theories that concern technological changes and their effects on governance, regulation or law, evidence of their confirmation or falsification will continue to be generated in the future. A theory is always *'hungry'* for another new confirmation and practical examples of its applicability. However, one of the peculiar characteristics of legal theories is that they remain valid if they remain plausible.[6] After all, law is an argumentative discipline, and legal science does not require that States, regulators, practitioners, companies or other actors act according to a particular legal theory. A theory is also not resistant to hype and false positives. It may also easily fall into a trap when a few, repetitive examples informing a hypothesis are *'all there is'* and no new evidence is generated in support of its premises.[7]

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[3] Maria Popova (2014) 'Why Science-Fiction Writers Are So Good at Predicting the Future', Brainpickings, <https://www.brainpickings.org/2014/02/20/joe-hanson-scifi/> accessed 1 November 2020.

[4] *Ibid*.

[5] Roger Brownsword, a Professor at the King's College London, founded the Centre for Technology, Ethics, Law and Society. Mireille Hildebrandt conducts research on 'legal tech' as a Research Professor on 'Interfacing Law and Technology' at the Vrije Universiteit Brussels. Karen Young is the University of Birmingham's first interdisciplinary chair based at the Law School and the School of Computer Science. Lawrence Lessig, now a Professor at Harvard Law School, is a founder of the Center for Internet and Society at Stanford University. The work of all these scholars will be liberally cited in this article.

[6] See James Penner 'Basic Obligations' in Peter Birks (ed) The Classification of Obligations (Oxford: Oxford University Press 1997) 120-121.

[7][7] Palka Przemysław @PrzemekPalka, <https://twitter.com/PrzemekPalka/status/1218261722168868864/photo/1> accessed 1 November 2020.

It is true, that a theory may, in certain cases, describe only a small and discrete part of the world, and the examples provided with reference thereto may really be *'all there is'*. However, a theory that describes sweeping technological disruptions such as AI, *'algocracy'*[8] or the effects of computational decision-making on the rule of law, must possess a greater *'leeway for everything concrete that is supposed to be [the] subject'*[9] of its description. For Brownsword's theory of *'techno-regulation'* which is based on *'anticipating pervasive reliance on technological infrastructure'*, *'nothing will be left untouched.'*[10] For such theories, broader evidence is sought, garnered from various areas of practice.

This paper centres around the theory proposed by Brownsword in his 2019 book, which had been developed on the basis of the Law and Technology literature of the last 20 years, and in which he described the transformation of regulatory environments via technology and the reimagining of legal values and legal rules that must accompany this transformation. We provide a review of the Brownsword's theoretical account and relate it to the current state-of-the-art regulatory approaches in spectrum management.

We submit that the theory of *'techno-regulation'* can be successfully employed to describe the current trends in radio spectrum management. The authors subscribe to Karen Yeung's narrower definition of regulation that conscribes it to intentional endeavours that steer behaviour of others towards a desired outcome.[11] The paper also argues that radio spectrum management is not only one of many examples illuminating the theory, but the precursor of all technologically managed environments. It identifies the normative and non-normative dimensions of the technologically regulated radio spectrum and comments on the specificities of radio spectrum as a technologically managed environment.

The paper assesses the driving forces behind the current trends in radio spectrum management, as well as the regulatory fitness of the *'techno-regulatory'* approaches to radio spectrum management. Finally, the paper describes how regulatees attempt to disrupt, hack or otherwise compromise the technology deployed by the regulator, and how radio spectrum management achieves control over compliance in the transformed environment. The purpose of the paper is to critically generate evidence in support of the theory.

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[8] A Annesh 'Global Labor: Algocratic Modes of Organization', (2009) 27(4) Sociological Theory 347-370.

[9] Hans Blumenberg *Theorie der Unbegrifflichkeit* (Suhrkamp Verlag 2007) as cited in Roberto Simanowski *Waste: A New Media Primer (Untimely Meditations)* (MIT Press, Kindle Edition 2018).

[10] Roger Brownsword *Law, Technology and Society: Re-imagining the Regulatory Environment* (Abingdon: Routledge 2019) 4 citing Will Hutton *How Good We Can Be* (Little, Brown 2015) 17.

[11] Karen Yeung 'Are Design-Based Regulatory Instruments Legitimate?' King's College London Dickson Poon School of Law Research Paper Series: Paper No 2015–27, 12.

2. Techno-regulation and telecommunications

Brownsword takes the reader of his latest book Law, Technology and *Society* on a trip to the year 2061 – a year not chosen by chance, but rather because it will mark the 100th anniversary of HLA Hart's The Concept of Law. Following this, our description of regulatory approaches to radio spectrum management will also be positioned within the range of 40 years from now and will require area-specific regulatory foresight.

Brownsword's world of 2061 is a world where risks are managed by means of *'technological management'* instead of coercive rules. Such means will ensure that legal subjects cannot break rules, either because they will not participate in the regulated activities, or because it will be impossible for them, in the virtual or real world, to perform certain actions. In 2061, *'technological infrastructures... structure social order.'*[12] Important buildings and facilities will be geofenced, so that they will be immune from targeting by malicious or negligent individuals. Robots will take over dangerous jobs and places. Smart devices will perform measurements and control with greater accuracy and efficiency than humans.

In other words, in *'techno-regulation'*, the regulator expects perfect control and the elimination of non-compliance by employing a particular technology, whereas those who are regulated may have only a limited capacity to damage, disrupt and circumvent the technology put in place.[13] However, smart devices, robots and other technologies cannot function in a discreet fashion; in order to be truly able to replace coercive rules, they must be part of a larger technological infrastructure.

Speaking of infrastructure, one usually imagines fixed installations and physical facilities that secure the functioning of a system.[14] The term *'infrastructure'* evolved during the Second World War, and the system then referred to wartime logistics.[15] Today, we talk about infrastructure predominantly in connection with transport systems, healthcare systems, water supply networks, energy production and distribution and so on. We differentiate between hard/soft infrastructure, physical infrastructure, institutional infrastructure and other forms of infrastructure. Regulators in radio spectrum management often like this term, as they imagine controlled-access motorways[16] while talking about radio frequencies. Each radio frequency band operates as a traffic lane.

The more traffic lanes available in one direction of traffic, the higher traffic volume a motorway may contain. Moreover, motorways are only designed and built for certain classes of motor vehicles, and therefore, not all types of traffic can be seen on motorways. In a similar fashion, the radio spectrum can be used only in certain ways, and its width can satisfy only a limited demand, while it can absorb only a certain amount of traffic. Unlike passengers or cargo, radio frequencies are used to carry information: digital signals, voice,

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[12] Brownsword (n 8) 6.
[13] Ibid 28.
[14] Raisuddin Ahmed and Cynthia Donovan *Issues of Infrastructural Development: A Synthesis of the Literature* (International Food Policy Research Institute 1992).
[15] See Vladimir Prebilič (2006) 'Theoretical Aspects of Military Logistics', (2006) 22(2) Defense & Security Analysis 159-177.
[16] Article 1(h) of the Vienna Convention on Road Signs and Signals.

video, and other data. The broader the range of radio frequencies used, the more data can be carried.

In other words, much like the number of lanes on a motorway, the *'bandwidth'* is a measure of information-carrying capacity. Bandwidth, just like a motorway, can be used only at a limited speed: the devices (vehicles) that use radio frequencies can carry only a limited amount of information per unit of time. In professional jargon, this is called spectral efficiency and is measured in bit/s/Hz.[17] A similar analogy also works for orbital positions, which form an important part of the radio spectrum technological environment.

Radio spectrum is a national natural resource that is fully renewable. However, its capacity to fully renew itself is technologically dependent once radio spectrum is regarded as a resource of certain utility (as an infrastructure). Information that is carried on radio waves cannot be effectively transmitted if random signals (noise) cancel it out. To carry information in the presence of noise interference, a *'loudspeaker'* must be used, i.e. a device of a higher power that will broadcast the information over the noise. A second limitation of radio spectrum as a renewable resource is that a radio wave loses its intensity over the travelled distance. If a wave does not reach a receiver within a certain distance, the information carried will perish if it is not amplified.

However, this *'loss'* creates also space for another frequency use – a free radio wave that can carry new information. These inherent (physical) characteristics also significantly affect how radio spectrum will be technologically managed in the future. When designing infrastructure, one must always think about the properties of what is regulated or utilised: air, water, or sound. The regulation of sound via hygienic limits, a maximum volume for advertisements, the opening hours of pubs, and technical norms for earphones all take into account that acoustic waves propagate through a transmission medium that is a gas, liquid or solid material and that their intensity also decreases with the distance from the sound source. Air may appear to us as an unlimited and inexhaustible resource; however, given the demand for it in terms of its quality, it is a finite and precious resource that must be used discriminately and efficiently, averting its depreciation.[18]

These are all analogous examples to the radio spectrum. When designing out harmful or inefficient options or designing in protective measures against harmful or inefficient actions, one cannot be blind to the physical laws and properties of regulatory environments and regulated objects. They are what influences the inherent mechanism of regulatory steering in telecommunications, or indeed other, sectors as the range of normative (as well as non-normative) signals that a regulator may consider cannot sweep

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[17] Marnix Heskamp, Roel Schiphorst and Kees Slump 'Public Safety and Congitive Radio', in Alexander M. Wyglinsk, Maziar Nekovee and Y. Thomas Hou (eds.) *Cognitive Radio Communications and Networks. Principles and Practice* (Academic Press 2010), 467-487.

[18] Victoria H. Imperiale 'Characterizing Air as An Exhaustible Natural Resource', in Edith Brown Weiss, John H. Jackson, and Nathalie Bernasconi-Osterwalder *Reconciling Environment and Trade* (Brill | Nijhoff 2008) 247–264.

away these laws and properties.[19] In other words, these are the underlying normative views that need to be translated into a practical regulatory design.

In telecommunications, the physical properties of radio spectrum enable its broad employment, provided society uses it effectively and efficiently, and avoids harmful interference.[20] However, not all radio spectrum bands have the same potential utility. Between 300 MHz and 3000 MHz, one may find the so-called *'ultra-high frequency band',* which has been the most interesting from the perspective of potential technological applications, because it has provided for sufficient information-carrying capacity and its wavelength enables the carrying of information over a sufficiently long distance.[21]

These properties made it ideal for television broadcasting and other terrestrial radiocommunication services.[22] However, in order to make the technology successful, global regulatory efforts had to be exerted because radio propagation does not stop at national borders. The Radio Regulations of the International Telecommunications Union, regularly updated since their adoption in 1906, have provided for certain principles and tools concerning how to manage radio spectrum as a globally used regulatory environment, the most important of which are the harmonisation of radio spectrum bands and their standardisation and the assignment and authorisation of the radio spectrum use, which falls within the competence of national authorities.[23]

With the Iron Curtain definitively gone, international cooperation prepared ground for the 3G-technology (3rd generation) network. After 15 years of research and development at the International Telecommunication Union (ITU), 3G had been ready to launch, however, it needed to find the right space. Lower ultra-high frequency bands (under 1 GHz) were already crowded with television technologies; therefore only higher frequency bands (1.9 GHz and 2.1 GHz)[24] could have been used provided more base transmitters stations would be deployed in those bands.[25] Later, only international cooperation paved the way for the introduction of the LTE (Long-Term Evolution) and related 4G (4th Generation) standards, the widely-used mobile phone technologies of improved speed and capacity, *inter alia*, by

[19] Brownsword (n 8) 46.
[20] Directive (EU) 2018/1972 of the European Parliament and of the Council of 11 December 2018 establishing the European Electronic Communications Code (Recast).
[21] British Broadcasting Corporation (2006) 'The Spectrum and Its Uses - A simple guide to the radio spectrum', <https://pdfs.semanticscholar.org/5b77/5e7aa5d934711eae70f15182e54bdb97f8b5.pdf> accessed 1 November 2020.
[22] And there have been many more efficiency gains through international cooperation: for example, new television standards meant more television channels in one frequency.
[23] See David M. Leive 'Regulating the Use of the Radio Spectrum', (1970) 5 Stanford Journal of International Studies 21-52.
[24] The candidate bands were identified at the World Administrative Radio Conference (WARC-92) in 1992.
[25] Second part of the 3G story was the absence of the 'killer application' during the late 90's, when 3G standard matured. It appeared later, in 2007, with the introduction of iPhone using a touchscreen. The event launched successful 4G period.

vacating the 700 MHz and 800 MHz bands.[26] This meant that broadband, i.e. wide bandwidth data transmission – the flagship of which is high-speed Internet – could be developed by impressive international coordination efforts.[27]

The ultra-high frequency band maximises the utility that can be derived from radio spectrum characteristics: wide motorways can be built that will lead directly to everyone's home, everyone's office and everyone's equipment and that can overcome any hill, any dense urban area, any corner or desert-like valley. In this dense infrastructure, the band also makes sure that no information gets lost. All of this makes the ultra-high frequency band the top development priority for the European Commission and many national governments globally, notably by computing appropriate standards and compatibility parameters for band harmonisation.[28] It follows that extensive cooperation – across borders, industries or the public-private divide – is an important characteristic of the regulatory space in which techno-regulation takes place.[29] Particularly in telecommunications, such cooperation has always been relatively speedy since it has been largely code-based, founded on mathematical computations and algorithm drafting.[30]

3. Regulatory compound, values and accountability

From the television standards of analog television broadcasting of the 1950s to the first standards of analog wireless cellular technology in the 1980s, and to the current 5G (5th Generation) network plans, telecommunication regulation has been particularly influential on product design.[31] The purpose of this design influencing has been twofold. First, precisely as Brownsword presupposes, shaping product design is a good risk management tool: it can ensure peaceful coexistence of technologies by defining how they operate and

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[26] See RSPG Opinion 'A long-term strategy on the future use of the UHF band (470-790 MHz) in the European Union' (document RSPG14-585(rev1)).

[27] In the future, also via satellite constellations. See International Telecommunication Union (2012), Regulation of Global Broadband Satellite Communications, <http://www.itu.int/ITU-D/treg/broadband/ITU-BB-Reports_RegulationBroadbandSatellite.pdf> accessed 1 November 2020.

[28] See European Commission, 'European Commission to harmonise the last pioneer frequency band needed for 5G deployment', <https://ec.europa.eu/digital-single-market/en/news/european-commission-harmonise-last-pioneer-frequency-band-needed-5g-deployment> accessed 1 November 2020.

[29] Brownsword (n 8) 81.

[30] Karen Yeung 'Regulation by Blockchain: The Emerging Battle for Supremacy between the Code of Law and Code as Law', (2019) 82(2) Modern Law Review 207-239.

[31] See Hank Intven and McCarthy Tetrault 'Telecommunications Regulation Handbook Module 1 Overview of Telecommunications Regulation' (The World Bank 2000).

interwork.[32] What has been needed is ever greater global compatibility, a consolidation of national spectrum environments into a single global seamless network.[33]

In telecommunications, incompatibility is synonymous with risk that is worth regulating, from the perspective of the regulator as well as regulatee. [34] As a result, there are so far over 4000 ITU recommendations on standards for all fundamental components of information and communication technologies that have been vastly implemented at the national level.[35] Secondly, it is possible to regard influencing of the product design as a tool used to enhance the so-called quality of experience (QoE) or quality of service (QoS), and correspondingly as a tool that can mitigate risks thwarting these qualities.

It is important to note the latter two measures as one of the ultimate goals of the telecommunication regulator is to improve delight and eliminate annoyance of a user's experience with a service or an application, and to improve the overall performance of any service delivered via electronic communications.[36] Essentially, in telecommunications, risk management is associated with the maintenance of pleasure, enjoyment, and happiness. These are *'the desired social outcomes which the regulator intentionally seeks to bring about.'*[37] However, the specific measures employed in telecommunication regulation are largely underexplored in the Law and Technology literature. According to Julia Black, this is a hallmark of regulatory efforts – to focus on outcomes rather than on technical compliance.[38]

Alternatively, risk management in telecommunications is also linked to the maintenance of reliability, availability, accuracy and speed.[39] Here, the regulator seeks to ensure the quality of services for the military, research, industry, educational institutions, the police, fire departments or other emergency services using professional mobile radio (PMR). One may

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[32] See International Telecommunication Union and the World Bank (2020) Digital Regulation Handbook, p. 122. See also Deloitte (2017) To be or not to be: The future of the telco business model. Issue 7, <https://www2.deloitte.com/content/dam/Deloitte/pl/Documents/Reports/pl_Deloitte_TMT_Telco_2030.pdf> accessed on 1 November 2020.

[33] International Telecommunication Union, The Evolution to 3G Mobile – Status Report, https://www.itu.int/itunews/issue/2003/06/thirdgeneration.html> accessed 1 November 2020.

[34] See Jonathan B Wiener 'The Regulation of Technology, and the Technology of Regulation', (2004) 26 Technology in Society 488.

[35] International Telecommunication Union. ITU-T Recommendation series structure, <https://www.itu.int/en/ITU-T/publications/Pages/structure.aspx> accessed 1 November 2020.

[36] Qualinet White Paper on Definitions of Quality of Experience (2012). European Network on Quality of Experience in Multimedia Systems and Services (COST Action IC 1003).

[37] Brownsword (n 8) 57; See also Yeung (n 9).

[38] Julia Black 'Regulatory styles and supervisory strategies' in Niamh Moloney, Eilís Ferran, and Jennifer Payne (eds) *The Oxford handbook of financial regulation* (Oxford University Press 2015) 245.

[39] Quality of service speed, accuracy, dependability, availability, reliability, simplicity, charging and billing, end-to-end quality, confidence interval and probability. See International Telecommunication Union (2008) Series E: Overall Network Operation, Telephone Service, Service Operation and Human Factors. Quality of telecommunication services: concepts, models, objectives and dependability planning – Terms and definitions related to the quality of telecommunication services. Definitions of terms related to quality of service.

think of designing technological tools that correspond to values emanating from a broader moral and normative reflection of the moral community.[40]

The upcoming decades will bring a whole range of new uses of radio spectrum, for example in the areas of autonomous transport, smart cities and homes, or the Internet of Things, which will place increased demands on *'quantity'* and *'quality'* of spectrum usage. In that regulatory environment, the goal of the regulator and regulatees is to achieve ultra-reliable and low-latency massive machine-type communication in enhanced mobile broadband.[41] Some examples mentioned throughout literature including profiling and biometric identification technologies or robot carers, will necessarily become part of this technologically managed environment.[42] All of them will require a portion of radio spectrum.

Each of these technologies (smart cities, biometric identification, *et cetera*) can be analysed and theorised at many different levels, and although the purpose of the regulation of each of them is to prevent risks they generate, the regulation employing technology poses certain risks in itself. Brownsword suggests to consider four possible dangers of techno-regulation: *'first, that the technology cannot be trusted, possibly leading to catastrophic consequences; secondly, that the technology will diminish our autonomy and liberty; thirdly, that the technology will have difficulty in reflecting ethical management and, indeed, might compromise the conditions for any kind of moral community; and, fourthly, that it is unclear how technological management will impact on the law and whether it will comport with its values'*.[43] Also, for Hildebrandt, the danger lies more generally in the competition of the rule of law with technology forces where so-called ethical technologies emerge and lack the checks and balances of the rule of law.[44]

Theorising such dangerous outcomes does not mean that they are equally likely to materialise in every form of techno-regulation or that they will materialise at all. Brownsword reassures us that the main concern lies with regulatory interventions *'directed at human interactions in viable communities'* that arise out of the secured existence of generic infrastructure.[45] Since without a generic infrastructure, no human (moral) community can exist, *'regulators may legitimately use a technological fix where their intention is to protect the generic infrastructure.'*[46] On the other hand, specific infrastructure is less demanding in terms of protection as compared to generic

[40] Ronald Leenes and Federica Lucivero 'Laws on Robots, Laws by Robots, Laws in Robots: Regulating Robot Behaviour by Design', (2014) 6(2) Law, Innovation and Technology 195.
[41] See Shao-Yu Lien et al. 'Efficient Ultra-Reliable and Low Latency Communications and Massive Machine-Type Communications in 5G New Radio', GLOBECOM 2017 - 2017 IEEE Global Communications Conference, 4-8 December 2017.
[42] Brownsword (n 8) 254.
[43] Ibid 9-10.
[44] See Mireille Hildebrandt, *Law for Computer Scientists and Other Folk* (Oxford University Press 2020) 284-315.
[45] Brownsword (n 8) 77.
[46] Ibid.

infrastructure. Apparently, what matters is the environment-technology interaction that affects the context-based expectation of the members of a moral community.[47]

Whether radio spectrum is to be classified as a generic or specific infrastructure is questionable. However, the case may be made that radio spectrum would better fit the specific infrastructure definition as long as its compromising would still not have the effect to thwart any kind of human activity. As Brownsword puts it *'without the generic infrastructure, the construction of more specific infrastructure (such as the infrastructure for railways or road transport) would not be possible'* simply because humans will not be able to exist as their biological needs and vulnerabilities will not be met.[48]

Yet, radio spectrum is becoming more quintessential up to the point that sooner or later it may be considered a generic infrastructure. Brownsword argues that the Internet might follow the same road. Hildebrandt similarly recognises that spectrum-dependant RFID-systems and sensor technologies prepare the ground for ubiquitous automatic computing, a type of intelligence that will govern many aspects of human life.[49] The transition phase is therefore of crucial importance. If an infrastructure is destined, as the current technological developments go, to become a generic infrastructure, should it not be protected as such *ex nunc*? The question is more pressing as the regulation of radio spectrum already faces challenges typically experienced in the regulation of generic infrastructures, such as the existence of different regulatory levels, including interactions and transactions that may result in many local variations.[50]

Besides *'infrastructure'*, Brownsword also distinguishes the notion of *'commons'* for which the regulators have the paramount responsibility to maintain and protect. *'Commons'*, per Brownsword, comprise i) essential conditions for human existence, ii) the generic conditions for the self-development of human agents and iii) the generic conditions for the development and practice of moral agency.[51] This closely resembles Elinor Ostrom's conceptualisation of commons that ignore a public-private divide, and emphasise environmental and human needs of communities within complex socio-ecological systems.[52]

Moreover, radio spectrum may also be characterised as commons. It represents a medium through which people may satisfy their biological need to communicate. It enables information exchange that can raise confidence and trust in other human agents as well as the possibility to plan and operate purposefully and interactively. This means that under our current *'crowded'* conditions, the use of radio spectrum is dependent on the human

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[47] See Helen Nissenbaum, *Privacy in Context: Technology, Policy, and the Integrity of Social Life* (Stanford Law Books 2010).
[48] Brownsword (n 8) 82.
[49] See Mireille Hildebrandt 'Legal and Technological Normativity: more (and less) than twin sisters', (2008) 12(3) Techne: Res. Phil. & Tech. 169.
[50] Consider the ubiquitous uses of radio spectrum, and different preferences given to the uses by the regulator such as satellites or the military,
[51] Brownsword (n 8) 91.
[52] See Elinor Ostrom *Governing the Commons: The Evolution of Institutions for Collective Action* (Cambridge University Press 2015).

ability to reach agreement – to harmonise their actions and prevent *'chaos in the ether'*.[53] It has been suggested elsewhere that radio spectrum is technology-dependent commons where *'regulatory power came from cooperation, from basic agreement on common rules..., and from a set of institutions and social networks that built commitment to the system, negotiated its further development, and handled monitoring, troubleshooting, and conflict resolution functions*.'[54]

Finally, human agents also display moral judgments in communication and information exchange that increasingly take place via radio waves. Radio spectrum is today almost as important for communication as air or other medium, without which sound cannot travel since there would be no particles to vibrate. As such, the protection of radio spectrum secures a community's ability to articulate its moral code.[55] So, although compromising of radio spectrum would likely not have the effect of thwarting any kind of human activity, it can have an important impact on other aspects of the community, including its values and a culture of trust.[56] The result is perhaps a blended view of radio spectrum – a *sui generis* case mingling the characteristics of generic and specific infrastructures with those of commons.

On the basis of this idea, three responsibilities for regulators take shape: First, maintaining the commons so that *'any form of human social existence'* may be sustained.[57] Second, balancing out the interests in the community. This is also reflected in the Hildebrandt's and Koops's proposal to form publics that include diverse groups of stakeholders that should get involved in creating *'an incentive structure for smart environments'* with appropriate checks and balances.[58] Third, in designing tools for technological management, regulators should respect the specific values of a community, such as empowerment and autonomy. Brownsword suggests, that a particular community may prefer rules over technological management not because of certain flexibility but also because rule-setting requires public participation – a value essential for that particular community.[59] This is reminiscent of Helen Nissenbaum's advocacy for inclusion of *'values in technical design'*.[60]

The question for radio spectrum regulators, is then whether techno-regulation is compatible with these responsibilities of the regulators. This is ultimately a question of accountability of telecommunication regulators that opens more acutely considering all aspects of social life and human activities influenced by radio spectrum uses in a particular

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[53] See Thomas W Hazlett 'The Rationality of U. S. Regulation of the Broadcast Spectrum', (1990) 33(10) The Journal of Law & Economics 133-175.
[54] Erling Berge and Eda Kranakis 'Technology-dependent commons: The radio spectrum' (2011) 5(1) International Journal of the Commons 86–91.
[55] Brownsword (n 8) 96.
[56] Ibid 82.
[57] Ibid 30.
[58] See Mireille Hildebrandt and Bert-Jaap Koops 'The Challenges of Ambient Law and Legal Protection in the Profiling Era', (2010) 73(3) The Modern Law Review 73(3), p. 429.
[59] Brownsword (n 8) 97.
[60] See Helen Nissenbaum 'Values in Technical Design' *Encyclopedia of Science Technology and Ethics* (MacMillan 2015) lxvi-lxx.

moral community.[61] Seemingly neutral policies, even in the abstract (wave-like) domain of radio spectrum, contain many implicit moral judgments. From the societal perspective, technological but also rule-based radio spectrum regulation could have potentially important unintended effects.[62] These could include negative health impacts, whereby pushing for and enabling an ever better quality of experience may lead to sleep deprivation, social isolation, poor concentration and internet addiction in youth and adolescents.[63] They can also have negative privacy impact, whereby in essence in a *'seamless global network'* more data will become available and gathered throughout electronic communication and radio networks as radio channels become wider and latency-free.[64]

In that scenario, there is a risk of chilling effects on moral community.[65] They can have negative impact on crime rate, as for example pirating vast amounts of copyright protected work will become faster and more accessible.[66] One may also include the debate concerning the application of the precautionary principle in telecommunications in the context of mobile phone and base station radiofrequency exposures to insects or other forms of life.[67]

Telecommunication regulators may also potentially trigger cybersecurity risks when releasing information about spectrum use that prepares ground for effective spectrum sharing. Thus, it can be said that techno-regulation may enhance such negative effects. Brownsword suggests that *'regulators need to answer for both intended and the unintended channelling effect of their actions as well as omission.'*[68] This way, it is necessary for regulators to be conscious of the characteristics of the regulatory environment with its social arrangements before employing any kind of technology for regulating it.[69]

Spectrum management is predominantly an instrumentalist political arena. The common good that it purportedly pursues is efficiency in spectrum use – that is use by as many users as possible and for as many applications as possible in the full width of radio spectrum,

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[61] See for example Matt Grimes, M and S Stevenson 'Radio as a Tool for Rehabilitation and Social Inclusion' in Matt Mollgaard (ed) *Radio and Society: New Thinking for an Old Medium* (Cambridge Scholars Publishing 2012) 179-196.
[62] See KarenYeung 'Towards an Understanding of Regulation by Design' in Roger Brownsword and Karen Yeung (eds) *Regulating Technologies* (Oxford: Hart Publishing 2008) 79-102.
[63] See for example, Manish Kumar and Anwesha Mondal 'A study on Internet addiction and its relation to psychopathology and self-esteem among college students', (2018) 27(1) Industrial Psychiatry Journal 61-66.
[64] See for example, Valentina Nejkovic et al. 'Big Data in 5G Distributed Applications' in Joanna Kołodziej and Horacio González-Vélez (eds) *High-Performance Modelling and Simulation for Big Data Applications* (Springer Open 2019) 138-162
[65] See Ciarán Burke and Alexandra Molitorisová 'What does it matter who is browsing? ISP liability and the right to anonymity', (2017) 8(3) JIPITEC 1-35.
[66] See Sarah Jacobsson Purewal 'Does Faster Internet Access Lure Piracy?', PC World, 4 May 2012.
[67] Arno Thielens et al. 'Exposure of Insects to Radio-Frequency Electromagnetic Fields from 2 to 120 GHz' (2018) 8 Scientific Reports 3924.
[68] Brownsword (n 8) 59.
[69] Cf Sally Falk Moore 'Law and Social Change: The Semi-Autonomous Social Field as an Appropriate Subject of Study' (1973) 7(719) Law and Society Review 723.

with zero risk. In other words, efficiency is about making sure that the demand for new frequencies is met. If this demand is to be met, efficient regulation should make sure that existing and new regulatees do not interfere with each other, corresponding to an efficient allocation of resources.[70]

Efficiency is also about not impeding any new technology coming to the market in the future. This is for example done by repurposing of frequency bands in the process called *'refarming'* or by excluding a certain portion for radio spectrum for market use. For example, machine-to-machine (M2M) communication that will enable the realisation of automation in Industry 4.0 led the German regulator to dedicate 100 MHz in the range 3.4-3.8 GHz for industrial applications.[71]

The other two values (quality of experience and quality of service) that the telecommunication regulator pursues in the public interest tend to be more controversial. They express holistic measurements, taking into consideration psychological, technological and other contextual factors.[72] The danger of instrumentalism occurs when these values are followed for their own sake, that is when the link between the value as a numerical technical category and the actual improvement of life of individuals is broken. Only in the latter case, the employment of value-embedded technology can be considered legitimate.[73]

Spectrum management generally strives to listen to the needs not only of spectrum users – those that deploy receivers, transmitters and other devices - but also customers of spectrum users and the voices of visionaries – those who thought about global connected cars or playing virtual 4D games on a global scale. [74] With 5G and the public health question, it is also about listening to the concerns of a wider public – those who believe that using higher frequencies cause more than thermal effects on humans. Spectrum regulation may also turn into a discourse on environmental questions.[75] Last but not least, some may argue it is also about taking on board human rights concerns, if one conceives access to the Internet as a human right.

[70] See William H Melody 'Radio Spectrum Allocation: Role of the Market' (1980) 70(2) The American Economic Review 393-397.
[71] The Federal Government – Federal Ministry of Transport and Digital Infrastructure (2017) 5G Strategy for Germany. A scheme to promote the development of Germany to become a lead market for 5G networks and applications.
[72] See Fernardo Kuipers et al. Techniques for Measuring Quality of Experience', in Evgeny Osipov et al. (eds) 8th International Conference, WWIC proceedings, Luleå, Sweden, 1-3 June 2010, 216-227.
[73] See Bert-Jaap Koops 'Criteria for Normative Technology: An Essay on the Acceptability of 'Code as Law' in light of Democratic and Constitutional Values' in Roger Brownsword and Karen Yeung (eds) *Regulating Technologies* (Hart Publishing, 2008) 157-171.
[74] Brownsword similarly argues that 'to claim that the conditions for the use of technological management are simply about effectiveness is manifestly absurd'. See Brownsword (n 8) 132.
[75] For example, Section 54 of the German *Telekomunikationsgesetz* provides for protection of trees planted on and around trafficways and for the allowance made for their growth where telecommunication lines are installed.

4. Future-proofing rule of law and telecommunications

Technological regulation of radio spectrum does not escape the rule of law requirements, more so if it is conceived as commons.[76] Per Brownsword, the rule of law requires that the use of measures of technological management is consistent with the aspirations of the moral community and with its constitutive principles.[77] For Hildebrandt and Koops, it is necessary that such management embeds fundamental values that function as a prevention to the rule of technology.[78] Yet, the unclear status of radio spectrum, either as a generic or a specific infrastructure, renders it rather difficult to determine the consequences of technological regulation, and the respective foresight necessary to be employed by the telecommunications regulator.

When calling for accountability for anything that goes wrong in a moral community as a consequence of techno-regulation, one of the most difficult questions will be to decide who should be held accountable.[79] This is especially the case where the regulatory levels overlap and influence each other, and where there is distinctive regulatory accountability for generic infrastructure and for specific infrastructure. Suppose that the regulator must both allocate the desired spectrum to the military and actively protect it against unlawful interference of WiFi providers, for example by automatically detecting the presence of WiFi transmitters and shutting it down remotely.

The regulator knows the technology that is used by the military (usually military radars); however, the regulator has zero control over its use: they can be potentially deployed in a situation of non-international armed conflict between the government and a non-State armed group. Under the strict-control scenario, the non-State armed group could find no means to circumvent the technological measure. Similarly, preceding the Digital Rights Ireland decision, when telecommunication data had been retained on the basis of the later repealed Data Retention Directive, *inter alia*, tracing and identifying sources and destinations of communication, it was not the telecommunication regulators – the enablers of wide motorways - who objected to this use of radio spectrum and communication networks, but rather the data protection watchdogs.[80] This is despite national legal provisions that impose on telecommunication regulators to contribute to high levels of personal data and privacy protection.[81]

However, some telecommunication regulators such as the UK Office for Communication (OFCOM) are required to secure certain negative effects of their primary regulation. By virtue of Section 3(2)(e) of the Communications Act 2003, the OFCOM is required to provide adequate protections to the public from the inclusion of offensive and harmful material in television and radio services. It is also specifically endowed with a regulatory

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[76] Brownsword (n 8) 128.
[77] Ibid 132.
[78] Hildebrandt and Koops (n 56) 429.
[79] Brownsword (n 8) 131.
[80] Joined Cases C-293/12 and C-594/12 *Digital Rights Ireland*, ECLI:EU:C:2014:238 (8 April 2014).
[81] For example, Section 5(3)(c) of Act 127/2005 Coll., on electronic communications (the Czech Republic).

role in ensuring protection against unwarranted infringements of privacy resulting from activities carried on for the purpose of television and radio services.[82]

Despite these examples, it can be argued that the position of telecommunication regulators is similar to regulators of electricity providers who power up servers on which data are retained or water providers who cool down nuclear power blocks that cannot be shut down and provide power to government's internment camps, for example. Perhaps this is going rather too far down the road of assuming accountability of infrastructure regulators. Nonetheless, Brownsword warns that when the rule of law is weak, *'to expect citizens to respect the use of technological management... is manifestly unreasonable'*.[83] According to Brownsword, any use of regulating technologies by public bodies must be done in accordance with their lawful powers and constitutive rules of States, such as those that mandate respect for human rights. This echoes with Hildebrandt's[84] cautioning that if *'legality that protects individual persons against arbitrary and unfair state interventions'* is not upheld, law or techno-regulation for that matter will become a mere tool to discipline people by measuring their behaviour, disempowering them and nudging them into compliance.[85]

Therefore, it becomes mandatory in Brownsword's view, to make the regulatory environment compatible with respect for human rights and human dignity. The question then is why responsibility for the protection of the rule of law should be limited to particular regulators. On the other hand, some may argue that radio spectrum represents a particular regulatory environment with minimum risk of corroding the moral community due to a tighter regulatory control, because moral signals, unlike prudential signals that function relative to the regulatees' prudential interests, are absent from the telecommunications regulator's repertoire.[86]

In that way, it would be correctly assumed that the concerns of technological management changes from one context to another. Telecommunication regulation represents a primary example of a regulatory environment where the moral signalling register is becoming invisible, whereas it operates with everything what is technologically feasible.[87] Therefore, the regulatory registers employed in telecommunications are increasingly reflecting regulatees' interests and the state of the technology – standards, protocols, configurations, coordination and other mechanisms – rather than signalling a hypothetical morally desirable conduct, for example a one that would set a limit to the spectral efficiency.[88]

Regulatees' interests and the state of technology have an important impact on the choice of instruments that telecommunication regulators employ from their regulatory toolbox.

[82] Section 3(2)(f)(ii) of the Communications Act 2003.
[83] Brownsword (n 8) 115.
[84] Ibid 112.
[85] Mireille Hildebrandt, *Smart Technologies and the End(s) of Law* (Edward Elgar 2015) 226.
[86] Roger Brownsword 'Lost in Translation: Legality, Regulatory Margins, and Technological Management' (2011) 26 Berkeley Technology Law Journal 1321, 1328-1329.
[87] Brownsword (n 8) 64.
[88] See Ronald Leenes 'Framing Techno-Regulation: An Exploration of State and Non-State Regulation by Technology' (2011) 5(2) Legisprudence167.

These are not simple factors but complex regulatory considerations that require an extended regulatory outlook - a meta-regulatory approach such as that envisaged by Colin Scott.[89] To grasp the bigger picture behind the official regulatory output, it is not only necessary to take into account the physical characteristics, but also the finite capacity of the electromagnetic spectrum to accommodate new technologies, new users and the amount of transmitted information. The width of the electromagnetic spectrum cannot be expanded forever. It follows from it that competition on the telecommunication market is an important mechanism and must be thoroughly observed[90] and becomes one of the regulatory modalities as suggested by Lawrence Lessig.[91]

Therefore, a telecommunication regulator is normally endowed with special regulatory powers in telecommunication competition regulation. The regulator must also observe a certain hierarchy of interests that radio spectrum must accommodate, depending on a particular community's preferences, as well as the fact whether regulatees are to be involved in self-regulation.[92] The preferences to be considered include the military sector (national security interests), the police and emergency services (public order and health interests), satellites (research community interests), access to information by citizens (democratic interests), or access to the internet by consumers and businesses (market interests). All these interests should be in principle satisfied in an efficient spectrum allocation and management.

The meta-regulatory approach is also indispensable for developing certain foresight. For example, by taking into account innovations, the limits of the spectrum use can be stretched, although it is still valid to say that possible extension are not infinite. The regulator observes the dynamics of innovation in the telecommunication sector and predicts disruptive innovations.[93] In the last 50 years, telecommunication professionals recurrently adopted the opinion that the limits of the spectrum use had been reached.

However, each time, a disruptive innovation rebutted this opinion: first, a digital modulation[94], then dynamic programming algorithms[95] that enabled smartphone processing signals in real time and with incredible power, to the latest 5G technologies that move computational capacities from real devices to the cloud. Yet, all of these innovations

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[89] See Colin Scott 'Regulating Everything' UCD Geary Institute Discussion Paper Series (Dublin, inaugural lecture, 26 February 2008).
[90] See Nikos Th Nikolinakos *EU Competition Law and Regulation in the Converging Telecommunications, Media and IT Sectors* (Kluwer Law International 2006) 41-56.
[91] See Lawrence Lessig *Code and Other Laws of Cyberspace* (Basic Books 1999) 85-99. See also Lawrence Lessig 'The Law of the Horse: What Cyberlaw Might Teach' (1999) 113 Harvard Law Review 507–514.
[92] See Bert-Jaap Koops et al. 'Should Self-regulation be the Starting Point?' in Bert-Jaap Koops et al. (eds) Starting *Points for ICT Regulation* (TMC Asser 2006) 109-149.
[93] See Joseph Schuessler and Delmer Nagy 'Defining and Predicting Disruptive Innovations' Annual Meeting of Decision Sciences Institute 2004, Tampa, Florida 1-7.
[94] See Walter Ciciora et al. 'Digital Modulation' in Walter Ciciora et al. (eds) *Modern Cable Television Technology: Video, Voice and Data Communications* (Morgan Kaufmann 2004) 137-181.
[95] See G White 'Dynamic programming, the Viterbi algorithm, and low cost speech recognition', ICASSP '78. IEEE International Conference on Acoustics, Speech, and Signal Processing.

in radio spectrum found their limits that were so beautifully captured by the Shannon-Hartley theorem of the maximum rate at which information can be transmitted over a communication channel.[96]

It is very likely that the telecommunications sector will see more disruptions in the future: collaborative devices may improve signal reception of devices nearby; techniques like beamforming that enable to focus signals towards a receiver and thereby increase the potential for frequency reuse or multiple-input and multiple-output antennas (MIMO) that multiply the capacity of a radio link (channel) using multiple transmissions and multipath propagation will be deployed, et cetera.

Of course, the capacities of the regulator for foresight are bounded by a certain point in time in the future and must be periodically recalibrated in the light of ongoing innovation.[97] In the future, the regulatory prediction concerning spectrum use limits will need to be adjusted again, as the humankind will slowly learn how to use bands above 100 GHz that hide unimaginable (spectrum) resources.[98] Some answers to the question *'how the future will look like'* are already being hinted at by present usage. In the 120 GHz band, the first attempts to coordinate and license usage have been made; however, the technologies involved are still very costly.[99] Crucial battles lie ahead at the World Radiocommunications Conference 2023.[100]

5. Spectrum regulation as technological regulation

In telecommunications, there is an odd closeness between the regulatory *'ought'* and the regulatory *'is'*.[101] Practical options to act or behave a certain way in the regulatory environment must first be technologically realized even in environments that exist notwithstanding the technological maturity of humankind. Before Heinrich Hertz's 1887 discovery of electromagnetic spectrum, was the prediction of that discovery by James Clerk Maxwell 20 years earlier; and before this, using radio waves was impossible.[102] It took 13

[96] See Olivier Rioul and José Carlos Magossi 'On Shannon's Formula and Hartley's Rule: Beyond the Mathematical Coincidence', (2014) 16 Entropy 4892-4910.
[97] See Hans Jonas *The imperative of responsibility: In search of an ethics for the technological age* (University of Chicago Press 1984).
[98] See OFCOM (2020) 'Supporting innovation in the 100-200 GHz range. Proposals to increase access to Extremely High Frequency (EHF) spectrum', <https://www.ofcom.org.uk/__data/assets/pdf_file/0034/189871/100-ghz-consultation.pdf> accessed 1 November 2020.
[99] See Doug Irwin 'FCC Is Making Plans to Use Spectrum at 95 GHz and Above', Radio World, 8 May 2018.
[100] See International Telecommunication Union, Resolution 810 (WRC-15), Preliminary agenda for the 2023 World Radiocommunication Conference.
[101] See Roger Brownsword 'In the year 2061: from law to technological management', (2015) 7(1) Law, Innovation and Technology 28.
[102] See National Aeronautics and Space Administration. Astronomer's Toolbox, Discovering the Electromagnetic Spectrum,

years from this discovery for the Canadian inventor Reginal A. Fessenden to send audio by means of radio spectrum.[103] Electricity shares a similar history: From Faraday and Ohm to Bell and Edison.[104]

If one accepts Brownsword's premise that regulators move from channelling and signalling of prohibitions, permissions and requirements reinforced by non-normative regulation to embedded non-normative regulatory technologies in the physical surroundings, one may conclude that the non-normative dimension, in the sense of Hildebrandt's *'constitutive'* dimension, has been always a part of the regulation of human use of radio spectrum.[105] This may be also valid for other environments that humans tap into technologically. One of the recurringly provided examples of technologically embedded regulatory solutions are sensors detecting a human presence in a room and switching on the lights as compared to solutions that attempt to change the pattern of regulatees' behaviour and influence it in a prudent way.[106] However, the way that regulatees can use electricity has always been contingent on technology.

In the early days, electric service was a part-time service, and people received warning of the evening's blackout when their lights blinked off briefly. This meant that they had around 10 minutes to go to bed or find candles.[107] This is of course nowhere near the proposed purpose or sophistication of remote sensing. Nonetheless, it illustrates that the regulation of certain technological environments has been always at least partially technologically dependent.[108] Humans have never lived in an environment free of technological impediments or enablers.

Reminiscent of sensors in households, radio spectrum management has moved towards employing spectrum sensing technologies in a *'crowded'* regulatory environment, full of competing devices, services and applications requiring permanent coordination and spectrum sharing.[109] Such sensors may be regarded as *'embedded non-normative regulatory technologies'* per the Hildebrandt's categorisation. Let us take for example the 26 GHz band, one of the promising bands for 5G – the enabling technology for the Internet of Things, smart cities, smart households and different verticals.

<https://imagine.gsfc.nasa.gov/science/toolbox/history_multiwavelength1.html> accessed 1 November 2020.

[103] See Andreas Antonious 'On the Roots of Wireless Communications', (2011) 11(1) IEEE Circuits and Systems Magazine 14-25.

[104] See L. J. Davis *Fleet Fire: Thomas Edison and the Pioneers of the Electric Revolution* (Arcade Publishing 2011). See also L Kryzhanovsky (1989) 'Mapping the history of electricity', (1989) 17 (1-2) Scientometrics 165-170.

[105] Brownsword (n 8) 58; See also Hildebrandt (n 47) 169.

[106] Hildebrandt (n 47) 169.

[107] See Terry Hammonds *Historic Victoria: An Illustrated History* (San Antonio: HPN Books 1999) 87.

[108] Cf Mireille Hildebrandt and Laura Tielemans, 'Data Protection by Design and Technology Neutral Law', (2013) 29 Computer Law & Security Review 509-521.

[109] See Gary Kim 'What is Spectrum Sharing, and Why Does it Matter?', (2015) Spectrum Futures, <https://spectrumfutures.org/what-is-spectrum-sharing-and-why-does-it-matter/> accessed 1 November 2020.

In 26 GHz, outdoor 5G applications such as base transmission stations and terminals (facilitating wireless communications between user equipment and network) can interfere with neighbouring spectrum bands which are used by satellites for Earth remote sensing[110] and scientific research. In this band, there is an acute realisation among regulators that centralized regulation, particularly with regard to new 5G technologies, has only limited effectiveness as it cannot cope with the number of regulatees, their geographical location, the need for constant reconfigurations of devices and the future development of the electronic communications market.

Sensors will play an important role as they help to minimise interference caused by radio systems sharing the same frequency channels by autonomously detecting the status and availability of frequency channels for transmissions. The vision, and already a partially realised solution, is to create the so-called dynamic spectrum access – a dynamic spectrum management approach that divorces from the *'command and control'* approach.[111] Dynamic spectrum access is the best example of a matured technology-based ecosystem with several signs of networks comprising thousands of transmitters and receivers. Dynamic spectrum access or similar approaches are inevitable evolution milestone in radio spectrum coordination.

In 2018, the Czech regulator launched an experimental network of autonomous remote spectrum sensors designed to watch sensitive places, mainly exclusion zones to protect certain users, within the 5 GHz band. The project was launched to facilitate the harmonisation of the 5.8 GHz band.[112] In the UK, OFCOM is preparing dynamic spectrum access in the 3800-4200 MHz band, in order to open the band for new fixed wireless networks and coordinate its shared use between incumbent receivers of signals from geostationary satellites, incumbent fixed microwave links and newcomers by remote sensing and on-time control of spectrum usage.[113]

When a sensor detects operation of high-priority naval radar, all devices within the affected geographical zone will be automatically switched off based on a system's instruction. In order to introduce reliable feedback control, all deployed devices are certified by a product authorisation/certification authority. Teams of spectrum engineers and policy makers seeking to find more efficient tools for better regulation are working in the same direction, on a global scale, keeping in mind other evolution alternatives, like Licenced Shared Access

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[110] Assisting, for example, in environmental monitoring.

[111] See Benoit Freyens, Mark Loney, and Michael Poole 'Wireless Regulations and Dynamic Spectrum Access in Australia', IEEE Symposium on New Frontiers in Dynamic Spectrum (DySPAN) 2010.

[112] CEPT. 8th meeting of CPG PTD, March 2019, Tallinn, Estonia, <https://www.anacom.pt/render.jsp?contentId=1475686> accessed 1 November 2020.

[113] See OFCOM 'Enabling wireless innovation through local licensing: Shared access to spectrum supporting mobile technology' (2019) <https://www.ofcom.org.uk/__data/assets/pdf_file/0033/157884/enabling-wireless-innovation-through-local-licensing.pdf> accessed 4 April 2021.

(LSA)[114], White Space Devices (WSD)[115] or Cognitive Radio Systems (CRS).[116] WSD, for example are devices that can detect unused spectrum frequencies in a geographical area and allocate it to someone who is in a need for it, for example, because of congestion, poor performance or poor range of signals.[117] All these systems result in increased overall spectrum efficiency.

However, spectrum sensing technologies have certain disadvantages, which includes false detection or decreases in spectrum sharing efficiency as those devices that sense spectrum cannot transmit at the same time. Therefore, additional supporting technologies may be used to minimise these downsides, such as geolocation databases that provide sensor devices with information which spectrum channel and power level is available for sharing.[118] The aforementioned antennas with adaptive beamforming can also significantly reduce the interference range and enhance spectrum sharing in terms of space.[119]

Next, cognitive, AI and machine learning techniques will be deployed to dynamically and efficiently assess available spectrum resources. It has also become evident that these new regulatory approaches can be built based on information gathered through standard regulatory tools such as administrative acts that are boosted by technological solutions.[120] However, in the current generation of regulation, economic reasons are still pressing to use basic hardware, to focus on software modifications of devices and to take advantage of remote (cloud-based) calculation engines that are fed with feedback data from users' devices. [121] The effect of AI in radio spectrum technology-based coordination tools is not based on difficult algorithms, but on real life big data collections. Regulators have already launched algorithm evaluations based on benchmarks on quality-of-service measurements.[122]

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[114] See Juha Kalliovaara et al. 'Licensed Shared Access Evolution to Provide Exclusive and Dynamic Shared Spectrum Access for Novel 5G Use Cases', in Shahriar Shrivani Moghaddam (ed), Cognitive Radio in 4G/5G Wireless Communication Systems (IntechOpen 2018) 55-72.

[115] Federal Communications Commission 'White Space', <https://www.fcc.gov/general/white-space> accessed 1 November 2020.

[116] See Shahriar Shrivani Moghaddam 'Introductory Chapter: Primary and Secondary Users in Cognitive Radio-Based Wireless Communication Systems', in Shahriar Shrivani Moghaddam (ed), Cognitive Radio in 4G/5G Wireless Communication Systems (IntechOpen 2018) 3-14.

[117] See Joe Butler (2011) 'TV White Space Devices ...and beyond!', <https://www.oecd.org/sti/broadband/49435354.pdf> accessed 1 November 2020.

[118] See Rogerio Dionísio et al. 'Combination of a geolocation database access with infrastructure sensing in TV bands', (2014) EURASIP Journal on Wireless Communications and Networking 210.

[119] See Ehab Ali 'Beamforming techniques for massive MIMO systems in 5G: overview, classification, and trends for future research' (2017) 18 Frontiers of Information Technology & Electronic Engineering 753–772.

[120] A smartphone application or a geolocation database that uses the data in a computing algorithm and specifies information, such as geographic information system (GIS) maps.

[121] That is, for example, why the global positioning system is not used for printer connectivity.

[122] For example, in the Czech Republic, the regulator's website <https://qos.ctu.cz> presents results of quality of 2G/3G/4G services is based on (i) coverage simulation, (ii) professional measurements and (iii) collection of real-life smartphone data of thousands of end users.

Thus far, technological measures employed by telecommunication regulators do not provide a tight control of practical options that are open to regulatees. In fact, if someone decides[123] to operate a RLAN / WiFi application in a given band, and he or she decides not to comply with the requirements imposed by the regulator, there are very few practical impediments that would stop such an application to be put into use. The only real impediment is the market and the physics: if a user detects an interference form a non-registered application, he or she may notify the regulator, who will normally inspect the situation and enforce the regulation. Therefore, supposing a certain non-compliance, the regulation is enforced only where there is a real (existing) need for such enforcement. This may be considered both efficient and inefficient enforcement: efficient because the enforcement takes place only where needed, and inefficient because the enforcement does not cover all violations of regulations.

A similarity to traffic regulation, an often-invoked example covered by the Law and Technology literature, arises again: one may expect a little enforcing on speed limits on a backroad, in an uninhabited area as compared to dense city areas with far greater risks associated with speeding. It is also necessary to add that *'retrospective'* enforcement of telecommunication regulations is quite unsuccessful. If a sensor (a speed camera) is not firmly installed, an *in-situ* inspection finds the source of interference only very rarely. From this perspective, it is possible to suggest that technological management aims to close the enforcement gap. The way technological management is employed for this task depends on how risks are socially construed and contemplated.[124] Yet, this evokes the ever-recurring concerns that a moral community might be negatively impacted by techno-regulation that is merely employed to increase compliance.[125]

It will become a standard approach for telecommunication regulators to combine soft and hard versions of regulatory technological control.[126] Such approaches are underway. In the pioneering dynamic spectrum access-like tool for the 57-66 GHz band that has been launched in January 2020,[127] the Czech regulator has combined automatic coordination of outdoor spectrum usage by two different technologies: fixed installations of WiGig technology[128] intended for direct internet connectivity of households, and fixed microwave links used for interconnection (backhaul). The regulator introduced a coordination calculator incorporating an automated computation engine for the coordination of all radio stations.

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[123] Brownsword (n 8) 41.

[124] See Ortwin Renn *Risk Governance: Coping with Uncertainty in a Complex World* (Routledge, 2017).

[125] Leenes (n 86) 169.

[126] See Pat O'Malley 'The Politics of Mass Preventive Justice' in Andrew Ashworth, Lucia Zedner, and Patrick Tomlin (eds), *Prevention and the Limits of the Criminal Law* (Oxford University Press, 2013) 273 and 280.

[127] Czech Telecommunications Office 'Portál k evidence stanic v pásmu 60 GHz', <https://60ghz.ctu.cz> accessed 1 November 2020.

[128] IEEE 802.11ad: Report ITU-R M.2227-2 (Use of multiple gigabit wireless systems in frequencies around 60 GHz), Recommendation ITU-R M.2003-2 (Multiple Gigabit Wireless Systems in frequencies around 60 GHz).

As of April 2021, more than 50.000 stations passed successfully the process of coordination. Similar to a warning that drivers receive when they exceed the speed limit in semi-autonomous cars,[129] users of the 57-66 GHz band that register their stations on a web portal, are notified of a possible harmful interference with another station that is computed by the coordination calculator. If a risk of interference is identified, users are nudged into three possible actions by nudge tools (default, design or transactional shortcut).[130]

First, users may reconfigure their stations, i.e., they can take responsibility to program their own devices in a way that minimises associated risks. Second, they can contact other users and ask them whether they are willing to change their own parameters and minimise the risk of interference. Thirdly, they may submit a declaration of insulation in case that the interference is minimised by existing insulation barriers, or in case stations are separated by elevation or frequency separation. The latter comes about as the result of a simple law that stations that may be close in spatial proximity must rely on spectral separation and stations close in spectral proximity must rely on spatial separation.

The solution is similar to the one adopted by the US Federal Communications Commission in the 3550-3700 MHz band called Citizens Broadband Radio Service[131] that has aimed at protecting navy radars and can be used for 4G LTE as well 5G new radio to support large warehouse facilities, sports stadiums and remote mines.[132] In the band, four spectrum access systems, i.e. automated frequency coordinators that manage spectrum on a dynamic, as-needed basis, are deployed.[133] They manage the access of users with different priorities of access: (i) incumbent users such as the federal government; (ii) priority access license users who acquired spectrum rights via an auction; and (iii) general authorised access users who use devices on the basis of *'light'* general authorisations.[134]

General authorised access users cannot cause harmful interference into first two tier users, and are also not protected against harmful interference caused by others.[135] Around every deployed citizen broadband service device that registers with spectrum access systems, a default protection contour is determined based on a signal strength. Priority access licensees may opt to reduce the protection area, or they may enter into agreement on

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[129] See Ana M Pérez-Marín and Montserrat Guillen 'Semi-autonomous vehicles: Usage-based data evidences of what could be expected from eliminating speed limit violations' (2019) 123 Accident Analysis & Prevention 99-106.
[130] See Richard Thaler and Cass Sunstein, *Nudge* (Penguin Books 2009) 8.
[131] Federal Communications Commission '3.5 GHz Band Overview', <https://www.fcc.gov/wireless/bureau-divisions/mobility-division/35-ghz-band/35-ghz-band-overview> accessed 1 November 2020.
[132] Metaswitch 'What is the Citizens Broadband Radio Service (CBRS)?', <https://www.metaswitch.com/knowledge-center/reference/what-is-the-citizens-broadband-radio-service-cbrs> accessed 1 November 2020.
[133] Commscope 'Spectrum Access System (SAS) frequently asked questions' <https://www.commscope.com/solutions/5g-mobile/spectrum-management-solutions/spectrum-access-system-faqs/> accessed on 1 November 2020.
[134] Federal Communications Commission (n 129).
[135] Commscope (n 131).

spectrum leasing with users in their protection area.[136] This is also based on information that the device supplies to the system: its geolocation, height, whether it is deployed indoors or outdoors, and the unique call sign.[137] The US regulator approaches spectrum sharing as a problem that can be resolved by multi-objective programming, game theory and theory of mutual beneficial relationships.[138] In other words, the regulators *'seeks to direct, shape, or structure some aspects of their regulatees' conduct.'*[139]

Brownsword, following Hildebrandt's distinction of different levels of regulatees' decision-making,[140] proposes that *'where environments are technologically managed...the regulatory signal is no longer normative'* if the technologies deployed are preventing, disabling or compelling certain actions.[141] In a futuristic foresight in the telecommunications sector, new technologies will enable to differentiate between RLAN / WiFi applications that are used indoor and that are used outdoor. This is important in 5925-6425 MHz where outdoor RLAN / WiFi application may interference incumbent fixed microwave links.

If a device is deployed outdoors and there is a risk of interference, it will automatically reduce its power or turn it off. This will bring hard technological control to the telecommunication regulation. In this case, as Browsword would note, *'the regulatee is.. 'locked in' to the required action'*.[142] As the new technologies are being tested and deployed on the ground, technological management changes what is possible in regulation, mostly in terms how a certain kind of risk is managed, but also what is possible/permissible for regulatees.[143]

The above examples of techno-regulatory tools illustrate that in radio spectrum, as in other technologically managed regulatory contexts, law has increasingly become only one of the instruments among other signalling and steering tools.[144] Computation, remote sensing or map visualisation may look like basic technological tools; however, they employ sophisticated algorithms. All of them assist in the enforcement of a legal rule (or so-called general authorisation to operate devices in a given band) that was crafted to give effect to the technology-assisted enforcement requirements concerning data collection and data disclosure.

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[136] Wireless Innovation Forum (2020) 'Requirements for Commercial Operation in the U.S. 3550-3700 MHz Citizens Broadband Radio Service Band', <https://winnf.memberclicks.net/assets/CBRS/WINNF-TS-0112.pdf> accessed on 1 November 2020.
[137] Metaswitch (n 130).
[138] Eduard A. Jorswieck and M. Majid Butt 'Resource Allocation for Shared Spectrum Networks', in Constantinos B. Papadias, Tharmalingam Ratnarajah and Dirk T.M. Slock (eds) *Spectrum Sharing: The Next Frontier in Wireless Networks* (Wiley-IEEE Press 2020) 270.
[139] Brownsword (n 8) 56.
[140] Hildebrandt (n 47) 169.
[141] Brownsword (n 8) 56.
[142] Ibid 56.
[143] Ibid 121.
[144] See Bibi van den Berg 'Techno-Elicitation: Regulating Behaviour through the Design of Robots' in Bibi van den Berg and Laura Klaming (eds) T*echnologies on the Stand: Legal and Ethical Questions in Neuroscience and Robotics* (Wolf Legal Publishers 2011) 407–22.

Currently, one may say that telecommunication regulators manage radio spectrum in partially experimental way corresponding to the Brownsword's idea of the second-generation regulatory environment in which regulators *'rely on the design of products and places (architecture) as well as automation processes that result in humans being taken out of the loop'*.[145] Despite the necessity for techno-regulation, telecommunication regulators still base their actions, including other regulatory instruments on the valid legal framework that may include a relatively doctrinal interpretation of certain public law principles, such as the principle of legality. Such principles have usually constitutional power and treat as permissible only those regulatory signals, actions or measures that are undertaken on an explicit legal basis and can be later reflected in technology employed.[146]

6. Compliance

Enforcement in technological regulation is principally driven by the level of risk perception of the regulator, which is partly based on previous experience and partly on a stable source of competence and *'doing things as usual'*. One example of higher risk-sensitivity of regulators is a story that climaxed in 2019 when the World Radio Conference adopted Resolution 229, that opened the 5470-5725 MHz band for usage by outdoor WiFi radios and meteorological radars.[147] In order to avoid harmful interference of WiFi with radars, specific mitigation technology was imposed to WiFi products, the so-called Dynamic Frequency Selection. The Dynamic Frequency Selection is based on the Listen-Before-Talk algorithm and avoids co-channel usage by WiFi and radars.[148]

However, after installation of thousands of WiFi access point radios, cases of interference have increased across Europe. The reason is that WiFi users have sought to find available spectrum with a better quality of service; therefore, they switched-off the Dynamic Frequency Selection technology manually, circumventing the regulator.

Due to the general authorisation regimes for WiFi installations, radio spectrum regulators could not find a way to remedy the situation.[149] Only European authorities dealing with

[145] Brownsword (n 8) 61-62.
[146] Leenes and Lucivero (n 38).
[147] Resolution 229 (WRC-03, Rev. WRC-12) on the use of the bands 5150-5250 MHz, 5250-5350 MHz and 5470-5725 MHz by the mobile service for the implementation of wireless access systems including radio
local area networks.
[148] Vasilis Maglogiannis et al. 'An adaptive LTE listen-before-talk scheme towards a fair coexistence with Wi-Fi in unlicensed spectrum' (2018) 68 Telecommunication Systems 701-721.
[149] ECC Report 192 (2017) 'The Current Status of DFS (Dynamic Frequency Selection) In the 5 GHz frequency range'.

standardisation[150] and product regulation[151] adopted new measures.[152] However, for the present moment, the effect has been limited. The range of interference cases and the impossibility of administrations to remedy the situation (i.e. to find all sources of interference and impose penalties) is a painful regulatory lesson resulting in a higher level of risk perception on the part of regulators. Regulators' reluctancy to open new licence-free bands leads to extremely careful considerations in long preparatory processes (as for example happened with respect to 5G technology in the 26 GHz band). In the end, this story is evocative of Brownsword's warning that in certain regulatory areas, regulatees adopt their own codes and cultures that are at times rival with the official regulatory signalling.[153]

One observes, however, that in the telecommunication sector such rivalry between regulators and regulatees is less common, and perhaps even marginal, as it is both, impractical and at times technologically difficult not to follow the law. Acts of technical non-compliance by regulatees in telecommunications are very rare. One may observe primarily unintentional acts and individual acts of annoyance. In the telecommunication sector, it is in the regulatees' interest to comply with the signals provided by regulators. Nevertheless, Brownsword's advice, following other scholars' conceptualisations on legality, on how to improve enforcement comes in handy: it presupposes early warning, active participation of regulatees in designing techno-regulation that the regulator may facilitate in a number of ways,[154] and mutual cooperation between regulatees and the regulator when influencing the product design.[155]

Yet, for a long time, there has been a serious distrust as to the ability of regulatees to self-regulate in the telecommunication arena. It has been believed that only the regulator possessed the right tools (coordination) and information about the radio spectrum use that

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[150] European Telecommunications Standards Institute (ETSI).

[151] Group of Administrative Co-operation (AdCo) is an informal subgroup for market surveillance and conformity assessment. Telecommunication Conformity Assessment and Market Surveillance Committee (TCAM) was constituted by Article 13 Directive 1999/5/EC on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity to assist the European Commission.

[152] For example, the adoption of new product standard preventing manual switch-off of dynamic frequency selection.

[153] This is without considering cybersecurity issues. Brownsword (n 8) 52-53.

[154] Neil Gunningham, Peter N Grabosky and Darren Sinclair *Smart Regulation: Designing Environmental Policy* (Oxford University Press 1998) and Neil Gunningham 'Harnessing Third Parties as Surrogate Regulators: Achieving Environmental Outcomes by Alternative Means' (1999) 8(211) Business Strategy and the Environment 212-14.

[155] See Mark Thatcher 'Sale of the century: 3G mobile phone licensing in Europe' in Julia Black, Martin Lodge and Mark Thatcher (eds) *Regulatory Innovation: A Comparative Analysis* (Edward Elgar 2005) 96-97. In the Czech Republic, the operator of meteorological radars launched in cooperation with telecommunication regulator and the RLAN operators' association a system of WiFi signal sensors capable of detection of possible interferer up to 100 km distance. Moreover, the list of such interfering RLANs is published online[155] and several RLAN operators introduced watchdogs (linked to the meteorological operator's website) into the Access Points to check, whether the WiFi signal is not visible by meteorological radar.

could deliver efficiency. Under the new techno-regulatory models, regulatees are steered towards registration of their devices and proactive communication with other regulatees as well as the regulator. Facing a situation of information asymmetry, tools designed by the regulator aim to diminish the risk of potential harmful interference. It is a type of channelling of (unintentional) behaviour of regulatees. Design matters. For example, a single additional information (a MAC address) that must be manually filled in by regulatees without them understanding its purpose can represent a significant barrier to compliance and thwarts the regulator's efforts to steer regulatees towards self-regulation.

On the other hand, potential instances of tension in the early trials of techno-regulatory management may lead the regulator to carefully consider new technological tools. The Czech regulator ran extensive consultations with the public and the industry as regards the new techno-regulatory tool; it conducted a detailed personal data impact assessment; it cautiously assessed cybersecurity risks and impact on other legal interests (property rights, fair competition, consumer protection) so that the regulation does not amount to arbitrary use of power. It is possible that if the regulator continues to manage a regulatory environment more intensively in the future, its vigilance in terms of the rule of law safeguards and checking of compliance with its meta-precepts will decrease.

Nonetheless, one may contend that new means and methods of regulation are always encountered with greater scrutiny. As the new becomes habitual, the level of public and professional scrutiny can decline.[156] On the other hand, the early days of techno-regulation in telecommunications is also a period of systematic openness about the techno-regulatory tools employed. According to Brownsword, it would also represent good practice on the regulators' part to give a fair warning that new technological measures may be introduced.[157] How far this is transposable to the traditional public law fair warning doctrine requirements is unclear: questions remain whether algorithms that are not clear as to their functioning should be declared void or whether the unclear functioning of the algorithms should be interpreted in a manner that is favourable to regulatees.[158]

7. Concluding remarks

This paper has demonstrated that it is useful to proceed from the developing argument of the Law and Technology literature to re-imagine regulatory environment so that technological management is included in its purview. The paper has focused on certain dangers of techno-regulation and explained how to contemplate technological management in a broader scheme of political communities displaying certain moral codes. It has demonstrated how the newest regulatory approaches in spectrum regulation relate to this vision. It also demonstrated that for other regulatory environments to be

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[156] See Robin Craig 'The Regulatory Shifting Baseline Syndrome: Public Law as Cultural Memory', University of Utah College of Law Research Paper No. 426 (2021).
[157] Brownsword (n 8) 121-22.
[158] Cf Jeremy Waldron 'Vagueness and the Guidance of Action' in Andrei Marmor and Scott Soames (eds) *Philosophical Foundations of Language in the Law* (Oxford University Press 2011), p. 66.

technologically managed, the deployment of techno-regulation in radio spectrum is inevitable.

As Brownsword concludes: *'We need to be aware that technological management is happening; we need to try to understand why it is happening; and, above all, we need to debate (and respond to) the prudential and moral risks that it presents'*.[159] This is not only true in regulation of morally controversial or society-disruptive innovations but, as the case of spectrum management in this article showed, also of mundane infrastructures, as it were. It is, however, becoming an essential obligation of regulators of such infrastructures to be aware of potential dangers of new techno-regulatory tools in their hands in light of community values and the rule of law.

[159] Brownsword (n 8) 341.