Network slicing vs. network neutrality – is consent possible? (draft)

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Abstract

Network Slicing (NS) is the inherent concept of the 5G network and beyond, ensuring dynamic and flexible use of resources, considered also a fundamental enabler of the "Industry 4.0" vision. However, its widespread implementation today encounters barriers, among which the paradigm of "network neutrality" is of key importance. This paper discusses the various factors affecting the wide implementation of NS: legal and political – including the European Union regulation on network neutrality, trends in the telecommunications market, technical conditions of NS in 5G networks and beyond, especially physical barriers, and the fundamental conflicts of interest between various business actors in the telecommunications market as well as consequences of a dominant position of content providers over mobile operators enabled by the mentioned regulation. Based on the analysis of the above factors, it is concluded that NS has become a hostage of contradictory paradigms and visions that, if not revised, prevent sustainable development based on communication services implemented with the use of NS.

Index Terms

5G, 6G, network slicing, network neutrality, net neutrality, regulation, eMBB, URLLC, MIoT, QoS, QoE, Internet access, mobile service, specialised service, Industry 4.0, energy, efficiency, sustainability, spectrum, capacity, physical limit, digital transformation, market position imbalance, MNO, hyperscaler, OTT

ACRONYMS

The following acronyms are used in this manuscript:

3GPP	3rd Generation Partnership Project
5GS	5G System
5QI	5G QoS Identifier
6GS	6G System
AI	Artificial Intelligence
ARPU	Average Revenue Per User
BEREC	Body of European Regulators for Electronic Communications
BSA	BitStream Access
CP	Control Plane
E2E	End-to-End
EEA	European Economic Area
eMBB	Enhanced Mobile Broadband
ETSI	European Telecommunications Standards Institute
EU	the European Union
FWA	Fixed Wireless Access
GSMA	GSM Alliance
GWCN	GateWay Core Network
HCS	Human-Centric Services
HMTC	High-Performance Machine-Type Communications
IAS	Internet Access Service
IMS	IP-Multimedia Subsystem
IoT	Internet of Things
IP	Internet Protocol
ITU	International Telecommunication Union
LLU	Local Loop Unbundling
LTE	Long Term Evolution
M2M	Machine-to-Machine
MBRLLC	Mobile Broadband Reliable Low Latency
MIMO	Multiple Input, Multiple Output
MIoT	Massive Internet of Things
mMTC	Massive Machine Type Communications
MNO	Mobile Network Operator
MOCN	Multi-Operator Core Network
MORAN	Multi-Operator Radio Access Network
MPS	Multi-Purpose Services
mURLLC	Massive Ultra-Reliable Low Latency Communication
MVNO	Mobile Virtual Network Operator
NeN	Network Neutrality
NFV	Network Function Virtualisation
NGMN	Next Generation Mobile Networks
NRAs	National Regulatory Authorities
NS	Network Slicing
NSI	Network Slice Instance

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OIAR	Open Internet Access Regulation
OTT	Over-the-Top
PLMN	Public Land Mobile Network
QoE	Quality of Experience
QoS	Quality of Service
RAN	Radio Access Network
S-NSSAI	Single-Network Slice Selection Assistance Information
SA	Stand-Alone
SBA	Service-Based Architecture
SDR	Software-Defined Radio
SNR	Signal to Noise Ratio
SpS	specialised service
SST	Slice/Service Type
UE	User Equipment
UNESCO	United Nations Educational, Scientific and Cultural Organization
UP	User Plane
UPF	User Plane Function
URLLC	Ultra-Reliable Low-Latency Communication
V2X	Vehicle to Everything
VoD	Video on Demand
VoLTE	Voice over LTE
VPN	Virtual Private Network

I. Introduction

Network Slicing (NS) is the concept behind 5G System (5GS) [1] and beyond. A lot of effort has been invested into it, from research to industry standardisation. Today, however, NS has to face challenges in the area of the regulatory and business ecosystem. The goal of the paper is to discuss the aspects of Network Neutrality (NeN) regulations and their potential impact on the telecommunication network ecosystem implementing NS technology. The paper is structured as follows. In Section II, the motivation of the paper together with an outline of recent developments in the mobile network ecosystem is presented. Section III discusses the the European Union (EU) NeN regulation and other political factors impacting the NS implementation. In Section IV, the key global telecommunication market trends and forecasts are outlined. Section V provides the technological issues related to NS and relevant in the context of NeN principles implementation. Section VI presents the existing conflicts of interest in the business ecosystem. Section VII is devoted to the discussion on the key challenges, threats, obstacles, and open issues for NS, triggered or intensified due to the NeN regulations. Section VIII summarises and concludes the paper.

II. Motivation

The monetisation of telecom operators' resources has always been an issue of interest. Unused fixed network infrastructure has been offered in the form of leased lines (analogue or digital), copper links or dark fibers, Local Loop Unbundling (LLU) or BitStream Access (BSA) offers, collocation of third-party equipment in the operator's premises – voluntarily or under regulatory pressure. The widespread deployment of mobile networks has opened up new models of inter-operator collaboration and resource sharing: roaming (national/internatio-nal), Mobile Virtual Network Operator (MVNO) on top of Mobile Network Operator (MNO)'s resources, Multi-Operator Radio Access Network (MORAN) – shared radio access infrastructure, Multi-Operator Core Network (MOCN) – MORAN with spectrum sharing, or GateWay Core Network (GWCN) – spectrum and entire infrastructure sharing except for databases of subscribers.

Mobile networks up to 3G were in fact mobile telephony networks with value-added services, including access to the Internet Protocol (IP) network. Along with the 4G network, the "All IP" paradigm was implemented, i.e., the separation of access to the IP network from communication services built on top of generic access mechanisms. However, the 4G network is a universal, general-purpose network with a unified User Plane (UP) architecture for the entire spectrum of diverse services with often conflicting requirements, thus, it is unable to provide traffic handling to be satisfactory for all competing services. The application of the "All IP" rule was disruptive to the previous business model [2] and revealed a fundamental conflict of interests of business actors in the roles of service provider and access provider operating a general-purpose network. The experience of 4G networks has proven the need to diversify traffic processing according to the specific requirements of the service or application.

NS has emerged as a concept initially introduced with PlanetLab (a federation of overlay networks testbed resources distributed over the globe and offering the ability to slice the resources for services experimentation worldwide) [3], later reinvented by Next Generation Mobile Networks (NGMN) [1] as an inherent feature requested from (at that time) future 5GS to support fundamentally the vision of "Industry 4.0", and then adopted by 3rd Generation Partnership Project (3GPP). Starting in 2016, NS was a hot topic and attracted interest from numerous research projects, in particular those sponsored by EU under the Horizon 2020 calls. There is no unified vision of NS; they are located between the extremes of "separate complete single-purpose communication network, either isolated or interconnected with other complete networks" and "federation of multiple application-tailored communication networks on top on shared network control mechanisms". While the first one resembles the "Network Service" concept according to European Telecommunications Standards Institute (ETSI) Network Function Virtualisation (NFV) [4], i.e., an isolated communication solution implemented in a virtualisation platform with all

5GS Control Plane (CP) features deployed per slice, the latter one is followed by the 3GPP approach in which implemented are application-specific User Plane Functions (UPFs) and necessary control mechanisms as add-ons to generic 5GS CP [5]. However, it can be stated that NS is about adapting a service traffic processing chain architecture to the specific requirements of the service while optimising resources use, and with regard to spatial distribution and dynamics of traffic demand [6].

The ability to implement NS is directly conditioned by the deployment of a 5G network in the Stand-Alone (SA) architecture (rare, so far). The 3GPP standardisation of NS in 5GS is still under development (in the scope of currently ongoing Release 18), and there yet remain open issues [7]. Nevertheless, MNOs with clear conviction identify NS among the top benefits of the 5G technology (44% of indications) [8]. However, the expected benefits can be precluded by often-overlooked non-technical obstacles, which will be discussed in this paper.

III. Legal, regulatory and political conditions for network slicing in the European Union and associated states

The fundamental concept associated with NS is the principle of NeN, intuitively understood as the "transparency" of the network for the transmitted data, both technical (equal treatment of all Internet communications) and in terms of the fundamental freedom of speech (no discrimination or filtering out of any content). However, there is no single universally accepted definition of NeN [9]. Within the European Economic Area (EEA), i.e., EU and associated states – Liechtenstein, Iceland and Norway, under the banner of NeN, the Open Internet Access Regulation (OIAR) has been implemented [10]. Its basic principles include: (i) obligation for public Internet Access Services (IASs) providers to treat all traffic equally, without discrimination, restriction or interference, and irrespective of the sender and receiver, content, applications, services, or terminal equipment; (ii) reasonable traffic management measures: transparent, non-discriminatory, proportionate, commercial considerations-agnostic and based on objectively different technical Quality of Service (QoS) requirements of specific categories of traffic, without specific content monitor and maintained only for a necessary period of time; (iii) prohibition of traffic management measures going beyond the above, in particular, to block, slow down, alter, restrict, interfere with, degrade or discriminate between specific content, applications or services, or specific categories thereof. The only listed exceptions for the latter are, in the case and for the duration of necessity: (i) providing compliance with EU or national law; (ii) preservation of network integrity and security; (iii) prevention of impending network congestion and mitigation of existing exceptional or temporary one, with equal treatment of equivalent categories of traffic. Finally, providers of IASs to the public may offer or facilitate services optimised to QoS requirements for specific content, applications, or services, or a combination thereof, as long as the network capacity is sufficient to provide these services in addition to any IASs, not as a replacement for IASs and without the detriment of IASs availability or general quality for end users.

Pursuant to the provisions of OIAR, the Body of European Regulators for Electronic Communications (BEREC) has issued implementation guidelines regarding the obligations of National Regulatory Authorities (NRAs) resulting from OIAR [11]. In addition, detailed expanded interpretations of the general provisions of OIAR have been added. In particular, equalisation of end users and content/application providers in terms of their rights as consumers of IASs has been stated. Networks outside the scope of OIAR are explicitly defined: non-public or for predetermined/closed user groups, e.g., corporate, Internet access in restaurants, etc., private Machine-to-Machine (M2M) networks. Similarly, outside the scope of OIAR are access services for terminals, which by their nature are used to communicate with a limited number of endpoints, e.g., e-book readers, or M2M terminals. However, sub-Internet services, i.e., restricting access to some communications services or applications (e.g., video streaming) or enabling access to only a predefined part of the Internet (e.g., particular websites), are considered as being in scope of OIAR. In the area of traffic treatment equality, the IP interconnect is excluded from the scope. It is also explained that equal treatment does not imply the same network performance/QoS experience by all end users. In the area of reasonable traffic management, it is acceptable, for optimisation of the overall transmission quality and user experience, to use necessary, suitable, and appropriate traffic management measures that differentiate between objectively different and QoS requirements-justified categories of traffic, within thereof similar treatment has to be provided. It is also allowed to prioritise the traffic related to network management/control over the rest. In the area of beyond reasonable traffic management, it is acceptable to use lossless compression that is transparent to the end user, but it is forbidden to use network mechanisms to force the communication service provider to degrade its service quality, e.g., to lower the resolution of video transmission. When discussing the three admissibility conditions for the principles of reasonable traffic management violation, it was clearly stated that congestion management can be done on a general basis, independent of applications, and only for exceptional cases; the recurrent and more long-lasting network congestion cannot justify the OIAR-allowed exception. Congestion management should not be used as a substitute for network capacity expansion.

The group of services beyond IAS (i.e., NeN rule) is named specialised services (SpSs) by BEREC. Their offering is limited by the OIAR restrictions mentioned above, which are aimed at ensuring the continued availability and general QoS of IAS. They are subject to verification by NRAs (the detailed guidelines for such a process are described) whether the application could be provided over IAS at the specific and objectively necessary QoS level or they are defined to unacceptably circumvent the provisions regarding traffic management measures applicable to IAS, discussed above. In particular, a simple prioritisation of traffic over IAS or comparable traffic violates OIAR provisions. SpS and IAS traffic fractions can be logically separated when using the same network resources (with static/dynamic reservation or without it). However, any detriment of the general quality of IAS for end users due to SpSs is unacceptable. Therefore, NRAs will also validate the network capacity in terms of its ability to support QoS of SpSs without negative impact on QoS of IAS. In mobile networks, featuring more difficult to anticipate users and traffic volumes mobility, if the overall negative impact of SpSs is unavoidable, minimal, and limited to a short duration, it should not be considered as a detriment for IAS QoS. If persistent perceptible decreases in IAS performance are detected, e.g. there is a statistically significant difference between performance before and after SpS is introduced, NRAs' intervention is required. Voice over LTE (VoLTE) and IPTV services are listed as undisputed examples of SpS; Virtual Private Network (VPN) service potentially contradicts the SpSs definition because it can provide Internet access via a remote gateway.

In addition to the law and regulatory policy related to the field, the telecommunications sector in EU is also influenced by other policies or is subject to ones on the digital future for Europe, clean energy and energy union, climate change, and European Green Deal [12]. In addition, due to the energy intensity of the telecommunications industry, it is additionally affected by the crisis in the energy carriers market initiated in 2021 and then intensified by the geopolitical situation after Russia's attack on Ukraine in 2022 (war and mutual economic sanctions between the aggressor and EU).

IV. Key trends in the telecommunications market

According to the latest forecasts [13], in the coming years, there will be a dynamic superseding of older technologies by 5G, including the currently dominant Long Term Evolution (LTE) – 4G; at the same time, the sharp growth in traffic volume will continue with the increase in demand for mobile broadband services and migration to voice services based on IP/IP-Multimedia Subsystem (IMS) technology (cf. Tab. I). In parallel, the share of smartphones among the mobile terminals used will increase: from 6.2 billion (75%) in 2021 to 7.4 billion (84%) in 2025 [8], additionally stimulated by such initiatives as "Smartphones for All" under the auspices of the International Telecommunication Union (ITU)/United Nations Educational, Scientific and Cultural Organization (UNESCO) Broadband Commission for Sustainable Development, aimed at providing the ability to access the Internet services through a smartphone to another 3.4 billion people by 2030 [14]. It should also be mentioned that the structure of demand for services is systematically changing. In the case of video streaming (62%), music streaming (56%), live sports (36%), gaming (36%), cloud storage (55%), and digital security (57%), the indicators in brackets refer to the percentage of contract mobile subscribers who have added or are interested in adding the respective services to their subscriptions [8].

The above phenomena are supported by MNOs, not only by their network expansion. The continuous increase in traffic is associated with the common policy of Average Revenue Per User (ARPU) defence (to save the flat ARPU trend or at least mitigate its decline) in a very competitive market – by raising the monthly data volume allowances in post-paid plans, introducing unlimited plans, enhancing QoS – especially through elevated data speeds, which additionally stimulate consumption. The mobile data traffic growth is additionally sustained by premium features like carrying over unused data to the next month, group data allowance sharing, or plans with a subscription of Over-the-Top (OTT) services with zero-rating: entertainment – Video on Demand (VoD), gaming, streaming of live TV or music; connectivity – social media, messaging, audio or video calls; and other – e-books access or map and traffic applications [15].

TABLE I
Selected indicators characterising the forecasted global market of mobile networks (based on [13]).

Indicator	Unit	2022	2028
Mobile subscriptions (total)	billion	8.4	9.2
Mobile subscriptions (5G)	billion	1.0	5.0
Mobile subscriptions (LTE)	billion	5.2	3.6
Mobile data traffic per smartphone	GB per month	15	46
Global total mobile network data traffic	EB per month	115	453
Global 3G/4G/5G Fixed Wireless Access (FWA) data traffic	EB per month	25	128
Global mobile 5G data traffic	EB per month	15	225
Global mobile 2G/3G/4G data traffic	EB per month	75	100
Global video traffic (1)	EB per month	90	324
Broadband Internet of Things (IoT) and Critical IoT (4G/5G) connections	billion	1.4	3.3
Broadband IoT and Critical IoT (4G/5G) share in overall IoT	–	50%	60%
Global population coverage with 5G networks	–	30%	85%
VoLTE subscriptions	billion	4.8	7.7

(1) Both social media and VoD.

The described trends have a significant impact on the problem of powering mobile networks. In 2018, based on the clearly exponentially decreasing trend during the period 2010–2017, the energy efficiency indicator of transmitted mobile data in Finland was expected (least squares fit-based estimation model) to fall to 0.017 kWh/GB in 2022 [16]. However, based on the pilot data collection by Finnish Traficom [17], the average mobile data energy efficiency in 2022 was still at the level of 0.12 kWh/GB, i.e. 7× higher than foreseen. Nokia reports up to even 90% energy savings (i.e., 10× lower consumption) with 5GS compared to legacy networks [18]. Hence, assuming the 5G and non-5G traffic distribution and global monthly data volume according to Tab. I, it would mean an approximate global annual energy consumption level of 141 TWh in 2022 and 246 TWh in 2028, or average global power consumption by mobile networks of about 16 GW in 2022 and 28 GW in 2028.

These figures consider only the data transmitted over the mobile networks and do not include the energy consumed by the IT systems hosting the OTT service platforms. For comparison, the global electric energy consumption in 2022 was about 27,000 TWh, while the global generation capacity was about 8500 GW and has grown since 2012 by about 48% [19]. During the same period, the worldwide mobile data traffic has increased 133.5-fold [13], [20]! While the computational model used here is very simplified, even the orders of magnitude give an idea of the scale of the problem.

V. Technological considerations related to network slicing

NS is associated with multiple technical and technological aspects.

- 5GS in its SA architecture variant provides support for NS per se. The entire signalling between User Equipment (UE) and Public Land Mobile Network (PLMN) takes place in the context of an individual Network Slice Instance (NSI), identified by Single-Network Slice Selection Assistance Information (S-NSSAI), composed of 8-bit Slice/Service Type (SST) and additional 24-bit slice differentiator [5], [21], so the potential capacity of this numbering is almost 4.3 billion NSIs! SSTs can take a value of either 128 3GPP standardised classes or one of 128 "private" classes inside PLMN. Currently, only 5 classes have been standardised: 3 basic ITU classes – Enhanced Mobile Broadband (eMBB), Ultra-Reliable Low-Latency Communication (URLLC), and Massive Internet of Things (MIoT) – equal to Massive Machine Type Communications (mMTC) by ITU, extended with Vehicle to Everything (V2X), and High-Performance Machine-Type Communications (HMTC). UE can be attached to up to 8 different NSIs at the same time. The visions of the future 6G System (6GS) assume much denser and narrower SST differentiation, e.g., Human-Centric Services (HCS), Multi-Purpose Services (MPS), reliable eMBB, Mobile Broadband Reliable Low Latency (MBRLLC), Massive Ultra-Reliable Low Latency Communication (mURLLC) [22] or hybrids of basic ITU classes: URLLC-mMTC, mMTC-eMBB, and URLLC-eMBB [23].
- Adaptation of NSI template to the service requirements is performed through flexible shaping of the UP chain and CP ability to accommodate slice-specific control mechanisms (e.g., network data analytics or UE authentication) through its Service-Based Architecture (SBA) and exposure of CP functionality to higher-level systems (e.g., vertical industry environment) [5]. GSM Alliance (GSMA) works on standardisation of interoperable NS templates at the level of their QoS definitions [24]. 5GS supports QoS through End-to-End (E2E) QoS flows, characterised by, i.a., 5G QoS Identifier (5QI) mechanism. The standardised 5QI values include the flow priority, guaranteed/non-guaranteed bit rate attribute, required packet delay budget/error rate, and maximum data burst volume; for guaranteed bit rate flows, maximum/guaranteed rate values can be defined [5].
- For radio access, the capacity of spectrum resources is the fundamental issue. Radio spectrum is a scarce good, subject to national and international management coordination. It is agreed to open more bands for use by mobile networks as well as there emerge various modes of band sharing: dynamic spectrum sharing (between different systems, e.g., 4G and 5G, for smooth transition), licensed shared access (primary, incumbent users allow other users – other MNOs or vertical industries – to share their resources), and license-exempt access [25]. However, the traffic capacity of radio channels, i.e., the quest for more and more spectrally efficient modulations, under the pressure of ever-growing demand for data rate, is not physically unlimited. The maximum errorless channel capacity in the presence of noise is bounded by the Shannon-Hartley theorem [26]. Additionally, the expected future mobile networks frequency range stretches from GHz up to sub-THz and THz bands. While the lower bands can be quite efficiently used, the higher frequencies suffer from high penetration loss, poor propagation characteristics, and very high losses due to channel attenuation and scattering [27], which require compensation by much more expensive and energy-intensive amplifiers. Hence, real-life deployments in higher bands are a challenge due to the short operation range (typically up to 200 m). Furthermore, the scope of usable frequency bands for each network cell is also reduced by the standard network planning procedures aiming to reduce cross-cell interference. Moreover, operation in THz bands requires specifically crafted transceivers [28], further questioning their exploitability in large-scale commercial deployments.
- The future Radio Access Network (RAN) infrastructure is expected to rely heavily on Software-Defined Radio (SDR). To handle the increasing data rates, the techniques that enable the improvements of the spectral efficiency of the transmission and coverage have to be applied, including gradually more advanced coding schemes, higher order and more complex modulations, increasing order of Multiple Input, Multiple Output (MIMO) systems, beam management mechanisms, RAN slicing specific support (e.g., scheduler-level algorithms), etc. Implementation of these methods together with the increasing volume of processed data, however, will require significantly higher compute power on the SDR side. Other technology-specific factors will need to be improved, such as, e.g., Signal to Noise Ratio (SNR) for higher order modulation schemes [29]. The energy aspect is especially important in the context of the green networking paradigm, promoted by the EU, and resulting energy efficiency targets. The technological enhancements will require significant energy investments on both network and UE side (additionally constrained by the battery size in the majority of devices) to operate efficiently and provide the throughput gains to the end user, at the same time contradicting the energy saving trends.

VI. Conflicts of interests and contradictions

The adoption of NeN principles will raise multiple contradictory challenges for IAS providers, particularly MNOs, to tackle. Some major identified conflicts of interest and contradictory requirements are discussed below.

The digital world to which the mobile networks contribute claims to be "virtual" (so "dematerialised"), but it is responsible for the consumption of 10% of the electricity produced worldwide and 4% of CO_2 emissions (almost double the civilian air sector), while the streaming technology alone produces 1% of global CO_2 emission. A single Google search power consumption is equal to a light bulb left on for 35 minutes, while an e-mail with a big attachment is the equivalent of 24 hours of lighting [30]. The digital revolution has specific energy and environmental costs that have only been increasing so far. While the pressure to reduce emissions related to terrestrial and aerial transportation, energy losses in buildings, and inefficient heat and lighting sources is everyday now, no one questions the paradigm of the ongoing and developing digital revolution in which the amount of data produced, processed and stored is growing exponentially, generating an obvious energy cost. It should be emphasised that this is happening even before the massive implementation of Artificial Intelligence (AI), which is announced in the future, especially as an inherent component of 6GS [22], [23]. On the other hand, the content providers accelerate the development of new services and increase quality – thereby, data volume demand. As of today, the 6 players consume the majority of the global OTT traffic: Google (20.99%), Facebook (15.39%), Netflix (9.39%), Apple (4.18%), Amazon (3.68%), and Microsoft (3.32%) [31]. Additionally, the mechanisms of auto-playing of the next video or commercials drive OTT providers' revenues, stimulating passive network traffic consumption having to be supported by Internet Providers, i.a., MNOs, at their cost. While the entry into the use of quantum computers with computing performance 1000× greater than supercomputers, at the same power consumption, is predicted, this technology will be used in central server rooms due to the requirements of powering and sterility of working conditions. This will deepen the imbalance between OTT providers and operators of virtualised, distributed networks based on commodity hardware, serving the OTT traffic.

The NeN approach principles will impose on IAS providers, in the face of a steady increase in traffic, the obligation to constantly improve the network capacity to accommodate OTT's services, which requires progressive investments in the infrastructural assets. In the current business setting, however, the OTT providers are the primary beneficiaries of the service hyperscalers, while the IAS providers pay for the delivery of the OTT traffic to the end customers [31]. Therefore, new business models shall emerge to facilitate financial contributions from the major traffic generators to the IAS providers that will enable a fair split of costs and gains of the OTT services upscaling. To this end, the NS paradigm can be efficiently exploited as it would allow the adoption of different pricing policies per OTT service.

The NeN focal area is the provision of services without deterioration of QoS. It has to be noted, however, that from the end customer point of view, the parameter that portrays the quality for the service consumer is Quality of Experience (QoE). In general, performing the mapping between the QoE and QoS is service type dependent and requires thorough studies of factors related to human perception. Several successful biological constraints have been well studied and can be leveraged to optimise resource usage, e.g. image and audio compression algorithms. As principles of NeN do not consider QoE as a target, which can lead to severe resource overspending. An example of such a common case is a very high-quality video streaming (4K and higher resolution) consumed via a handheld device. With the limited resolution of the human eye, perception is dependent mostly on the viewing distance and to a lesser extent on the display size [32]. For the relative viewing distances higher typical for smartphones, the sensitivity to spatial losses is low, i.e., 480p video is seen almost as sharp as HD video [32], which questions the rationale for constant improvement of the resolution of the transferred video (4K, 8K) in some cases.

VII. Discussion

Based on the analysis of considerations in the previously described areas as well as the mutual influence between them, some general observations can be made.

- NS has been proposed and then included in the standardisation as a fundamental feature of 5GS, which is to be further developed in 6GS. Its mass implementation was assumed, and the basic mechanisms to support it are those of differentiated processing of individual traffic fractions, QoS management, and traffic prioritisation. While the wired part of PLMN can theoretically be expanded without any obstacles, the bottleneck that forces hard competition between individual traffic fractions is frequency resources – both those at the disposal of individual MNOs and general ones.
- NeN rules in EU mandate equal, non-discriminatory treatment of all fractions of the traffic. The use of QoS management mechanisms is theoretically possible, in a proportional manner, but the use of prioritisation of access to resources for a class of SpSs, seemingly not subject to the NeN rigour, in practice would inevitably lead to the impermissible degradation of IAS QoS. The available frequency resources are not unlimited, and MNOs, under their licenses, may only divide them between IAS traffic and SpSs traffic.
- Both the forecasts regarding traffic volumes and the number of smartphone users – terminals generating traffic dominated by the ever-growing fraction associated with streaming – predict continuous growth. As the NeN rules equalise the rights of end users and content providers (OTTs), they gain a privileged position over IAS providers. However, the position of MNOs among IAS providers becomes extremely difficult here: any expansion of network capacity can be immediately consumed by ever-increasing OTT traffic. Blocking radio resources for future SpSs would be a form of protection against

charges of QoS degradation of IAS services, but it would be economically absurd (freezing resources so that they do not bring benefits) and an abandonment of optimisation of the use of resources from their flexible allocation.

- In its current form, NeN prioritises maintenance of QoS for the consumers of the typical, overwhelming eMBB traffic (streaming, social media, gaming, etc.) over other types of services. The NS paradigm, largely extends the spectrum of the latter, enabling MNOs to offer SpSs such as, e.g., safety-critical services requiring very high NSI availability, reliability, and resilience. Considering the network resource limitations and potential rapid changes in their usage (due to users' mobility, time of day, and other special circumstances such as e.g., sports events, concerts, etc.), maintaining the required service level for the eMBB consumers can potentially affect the performance of services in which interruption has critical consequences (injury, death, environmental or property damage, etc.).
- NS-based SpSs were and still are envisioned as enablers of the "Industry 4.0" vision. The services tailored for drones, telemedicine, transportation, agriculture and forestry, public security, and many other applications, with guaranteed QoS, would be of great social and economic importance as well as a business opportunity for MNOs being currently under extremely high market pressure. However, under the conditions imposed by NeN, such services can practically only be provided by MNOs not offering IAS. Nevertheless, even then, effective spectrum management in the spectrum sharing model may be impossible if MNO offering the privileged IAS is the co-user of the shared band.
- Due to physical constraints of spectrum capacity and energy consumption, the ever-growing variety of OTT services, especially those related to entertainment, and their elevated QoS requirements, will be near-to-impossible for MNOs to handle in the long run. The raising pressure for networks' energy efficiency further aggravates this issue, as it requires MNOs to reduce power consumption, which will also impact the total system capacity.
- In the case of road traffic, there is general agreement that there must be privileged, emergency vehicles to which other participants must give way. The economic, social, ecological, and climatic consequences of unrestricted motorisation are commonly discussed. The sense of certain ways of using cars is questioned, and pros/cons of individual and collective transportation are also compared. In the case of digital virtual reality, which leaves a deep footprint in physical reality (e.g., related to energy or raw materials consumption), the paradigm of the unlimited digital revolution and unlimited production, transmission, and consumption of data applies, and the footprint is continuously growing. Therefore, the question must be asked whether the "digital revolution" has turned into "digital greed". It will be appropriate to consider the sustainable use of the Internet and whether all uses of digital reality (e.g., telemedicine and entertainment), which is also a set of limited resources, are of equal social value and importance, also whether unrestricted mobile access to entertainment services, cannibalising other applications due to being privileged, is socially and economically justified.

In summary, it can be stated that NS is an idea, which consumed a lot of effort and resources during its development – in the stages of conceptualisation, research, trials, industrial standardisation, and harmonisation of interoperability. Currently, it is faced with a combination of factors (paradigms, regulations, trends, business models, physical and technological barriers) creating multidimensional contradictions preventing its wide implementation. Among them, the regulation concerning NeN is of root and key importance. Therefore, it is necessary to undertake a broad discussion towards the revision of the adopted paradigms and visions in order to unlock the opportunities for economic development, dependent also on the implementation of NS-based communication services. Care should also be taken to balance the market position of the telecommunications business actors in the context of sustainable development and exploitation of the planet's resources, as is the case of other sectors of the economy and industry.

VIII. Conclusions

This paper discusses the issue of the regulatory and business environment for the possibility of providing communication services based on NS, perceived as an enabler for the "Industry 4.0" vision. The basic features of the EU regulation concerning NeN have been presented, as well as other political factors affecting NS. Trends in the telecommunications market have been analysed; in particular, the continued unstoppable increase in traffic, driven mainly by OTT providers, placed by the NeN regulation in a dominant position over IAS providers, including MNOs. Technical conditions of NS in PLMNs have been discussed, especially physical barriers blocking unlimited traffic growth. Attention has also been drawn to the fundamental conflicts of interest between various business actors in the telecommunications market.

Based on the above considerations, a general conclusion is formulated that in view of the fundamental contradiction of the NeN, digital revolution, sustainable and socially responsible growth, and business fairness paradigms, until they are revised, the widespread implementation of communication services based on NS, and thus the realisation of the "Industry 4.0" vision are currently impossible.

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