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What are the major challenges in network neutrality regulation and commercial deployment of 5G networks?

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Abstract:

The following project aims to analyze the impacts of net neutrality regulations on commercial deployment of the 5G standards. The main scope is put on the cloud-based solutions which are considered as one of the essential components of the 5G network and narrowly researched in the context of net neutrality, as this part is perceived to be influenced by the regulations. In order to perform the analysis, a broad literature study was performed together with a session of six interviews with the stakeholders. The main chapter of the work debates whether net neutrality poses a threat for fully profitable operability of the 5G standard. The debate contrasts the claims founded in the literature and stated during the interviews and seeks in which areas are harmonious and non-harmonious. The research involves aspect like use case provision, the meaning of innovations, quality of service and network investment.

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Group: ICTE4 BUS 4.11
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Preface

These two years changed me completely and the way I perceive the world. I would never be the person I am today without all these people below.

My mother and my sister. I do not know what I did to deserve your kindness and constant support.

My professors - Annie and Reza. Thank you for your patience while explaining many complex telecommunication terms. I could not imagine better and wiser teachers.

For the trust and willingness to cooperate with me - Thank you Christian Kloch and TDC.

Finally: Arnab, Aron, David, Dragos, Juan, Kardo, Mouloud, Nicolai and Piotr.
For being the best brothers I could have ever have.

Thank you all.

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Acronym list

2G : Second Generation of Telecommunication Standard

3G : Third Generation of Telecommunication Standard

3GPP : 3rd Generation Partnership Project

4G : Fourth Generation of Telecommunication Standard

5G : Fifth Generation of Telecommunication Standard

5GC : 5G Core

AMF : Access and Mobility Management Function

API : Application Programming Interface

AR : Augmented Reality

Arcep : Autorite de Regulation des Communications Electroniques

AUSF : Authentication Server Function

BEREC : Body of European Regulators for Electronic Communications

BRAS : Broadband Remote Access Server

BSS : Business Support System

CAPEX : Capital Expenditures

CDNaaS : Content Delivery Network as a Service

cmW : Centimeter Waves

COTS : Commercial off-the-shelf

CP : Control Plane

DEA : Danish Energy Agency

DN : Data Network

DSL : Digital Subscriber Line

DSM : Digital Single Market

eMBB : Extreme Mobile Broadband

EPC : Evolved Packet Core

ETSI : European Telecommunications Standards Institute

EU : European Union

FCC : Federal Communications Commission

GSM : Global Positioning System

HetNet : Heterogenous network

IaaS : Infrastructure as an Service

IAS : Internet Access Service

ISG : Industry Specification Group

ISP : Internet Service Providers

ITU : International Telecommunication Union

ITU-R : ITU-Radiocommunication Sector

KPI : Key Performance Indicator

LBS : Location Based Services

LTE : Long Term Evolution

MEC : Mobile Edge Computing

MIMO : Multiple Input Multiple Output

mMTC : Massive Machine-Type Communications

mmW : Millimeter Waves

MNO : Mobile Network Operator

MTCaaS : Machine Type Communications as a Service

NBI : Northbound Interface

NF : Network Functions

NFV MANO : NFV Management and Orchestration

NFV : Network Function Virtualization

NFVI : NFV Infrastructure

NGMN : Next Generation Mobile Network Alliance

NR : New Radio

NRA : National Regulatory Authorities

NSA : Non-standalone

OPEX : operating expenditures

OSS : Operations Support System

OTT : Over-The-Top

PCF : Policy Control Function

PDU : Packet Data Unit

PDU : Packet Data Unit

PTS : Post- och telestyrelsen

QFI : QoS Flow Identifier

QoS : Quality of Service

RAN : Radio Access Network

RAT : Radio Access Technologies

RGW : Residential Gateway

RNIS : Radio Network Information Services

SA : Standalone

SBI : Southbound Interface

SDN : Software Defined Network

SMF : Session Management Function

SOA : Service-oriented Architecture

SpS : Specialised Service

TI : Teleindustrien

TNO : Netherlands Organisation for Applied Scientific Research

TOF : Traffic Offload Function

TOFaaS : Traffic Offload as a Service

TT-N : TT-Network

UDM : Unified Data Management

UE : User Equipment

uMTC : Ultra-reliable Machine-Type Communications

UP : User Plane

UPF : User Plane Function

VIM : Virtualized Infrastructure Manager

VM : Virtual Machine

VNFs : Virtualized Network Function

VNI : Virtualized Network Infrastructure

VR : Virtual Reality

Chapter 1

Introduction

The telecommunication world is currently coming through disruptive advancements as the access to data have become an essential part of the majority of the society. The analysis and predictions state that the volume of mobile data traffic will increase sevenfold between 2017 and 2022. Moreover, as the [14] continues to list, traffic from wireless and mobile devices will account for 71% of total IP traffic, while the wired-based devices will account for 29% by 2022. This rapid demand for ubiquitous and constant IP access was perceived as a chance for the Mobile Network Operators (MNO) and the equipment providers as a profitable business and consequently, to fulfil the customer's needs, the new standard, beyond 4G - Long Term Evolution (LTE) was proposed. The fifth generation of the mobile cellular standard (5G) is currently in the development phase, yet as [15] states the goals are to increase the data rate x10-x100, capacity x1000 or decrease the latency below 5 ms. All these advancements are possible by new, disruptive enablers like Cloud-Based Networking especially Network Function Virtualization (NFV), Software Defined Networking (SDN), Mobile Edge Computing (MEC), Heterogenous network (HetRAN), Massive Multiple Input Multiple Output (MIMO) or Millimeter (mmW) and Centimetres (cmW) Wave [16]. However, the standard suffers from multiple complex and multi-layered issues. [17] explains that among the bottlenecks for achieving full profitability of the technology is the fact that there are still many unknowns variables on which the standard depends. In the [17]'s view, the engineering parameters like capacity in the number of simultaneous users, indoor connectivity, spectrum sharing or the adjustment of the business models to the services might pose a challenge. Moreover, researches perceive 5G as one of the most complex wireless technologies over the past decade and outline the standards and regulations as an eventual blocking element for keeping the deadline roadmaps and tailoring the patterns for the business models. Even though many standard bodies have been involved, still they have conflicting objectives, which

are causing the negotiation issues like in case of spectrum sharing and its management. Moreover, there are also conflicts in the regulatory areas which are limiting the possible architecture models. One of the most perplexing issues is the convergence between net neutrality rules and one of the main enablers of 5G - Network Slicing [18]. No throttling or packets discrimination policy applied in the European Union (EU) [10] might jeopardize the profitability of 5G network and consequently prominently decrease the return of the investment (ROI). Accordingly to the [19], relased by Danish Energy Agency (DEA), clarity about the regulatory framework in regard to net neutrality and network slicing is one of the key concerns which need to be taken under the consideration while discussing full commercial roll-out of new infrastructure. This view is shared also by the industrial side of telecommunication. According to the Ericsson's CEO [20], there is a dispute in the field of the net neutrality as the company perceive tight regulations as a blocking factor for creating dedicated network for the specific purposes (slices) with the particular quality of service (QoS) parameters. The same belief is shared by the MNO side - Telenor's CEO [21], claims that EU legislation on net neutrality might threaten the business cases for 5G and the full utility of cloud-based NFV and network slicing deployment. As a result, the following circumstances open possibility for conducting an analysis of this multidimensional problem.

The mobile ecosystem is intertwined with the world of regulations which are shaping the business models, engineering capacities of and many other elements. With a high diversity of use cases proposed by the 5G, proper and clear guidelines are essential for the industry to launch a profitable endeavour. Therefore, a research in the form of a master thesis with the net neutrality and 5G scope was conducted to clarified the disputed issue.

1.1 Objective

The objective of the following master thesis is to research the confluence between 5G / net neutrality and assess in which scenarios these two models can operate in harmony and in which special adjustments must be implied for the upcoming 5G standard to work together with the net neutrality regulations.

The focus of the following work is put on the convergence between net neutrality regulations and 5G with its enablers, especially cloud-based network slicing component. In order to deliver comprehensive research, the broad literature study together with six interviews with involved stakeholders from industrial, academical and regulatory areas have been performed. As such, the examined domains are engineering capacities of 5G and the network data prioritizing. With reference to the upcoming mobile standard, the emphasis was placed on cloud-based enablers as they are the ones which might cause deployment issues [20].

1.2 Problem definition

The project aims at answering all the stated problem formulations, which include one main question and four subquestions, related to the different aspects of the study.

What are the major challenges in network neutrality regulation and commercial deployment of 5G networks?

- *What are the main quality of services parameters, needed to be considered while discussing net neutrality in regard to 5G?*
- *Which use cases will be influenced by net neutrality regulations?*
- *How can the 5G use cases be matched with net neutrality regulations?*
- *How can telecom industry adjust their architecture models to be in line with regulatory laws?*

1.3 Delimitations

This thesis touches one of the most complicated radio technology released in the recent times [17], due to this fact not all the aspects can be touched and described. The list in the following part outlines the limitations, which has not been considered for the project.

Delimitations list:

- To facilitate the wireless transformation, industry and academia presented various concepts 5G-related, which are quintessential for proper standard performance. However, this project focuses on cloud-based components of 5G, because these are the ones, which poses a challenge for net neutrality. As a result concepts like mmW, cmW, HetRAN or Massive MIMO are not analyzed.
- The conducted study focuses on 5G only, and delimits other wireless and wired technologies like fibre, cable, Digital Subscriber Line (DSL), 2G, 3G and LTE.
- Because of the level of the relatedness concepts similar to net neutrality like device neutrality and platform neutrality have been delimited.
- Along with net neutrality discussion, zero-rating and other commercial practices of sponsored data access have increasingly drawn more attention from policy-makers, industry and scholars. However, as net neutrality/5G debate has higher literature attention, zero-rating has been delimited.

- Because of its significance and the impact of net neutrality on how the internet is perceived, the debate in this regard poses an important element of the internet economy together with terms like peering, transit or interconnection. However, this work research more technical aspects of net neutrality (5G standard) rather than economic due to this fact these aspects have been delimited.

1.4 Project structure

The work was structured as follows. After the first opening chapter, the chapter 2 *Methodology* covers which methodology model applied for the matter of this project. It also explains how the data gathering process was managed. Following this, chapter 3 *State of the art* explains the elements of 5G and the net neutrality regulations. However, the chapter 3 investigates the particular concepts separately, the next chapter 4 *Literature review* scrutinizes the work done by scholars in regard to crossover. Consequently, the reader obtains two chapters build upon the current available literature, which serves a purpose of providing knowledge base for further divagations. *Literature review* is followed by chapter 5 *Introduction to the analytical model*, where the analytical model is presented. In order to understand further part, the reader cannot go into the data acquired from the interviews without the proper framing, which is the purpose of the analytical model incorporation. In chapter 6 *Field study* the data gathered from interviews and state of the art is studied. The core of is the chapter 7 *Net neutrality & 5G analysis*, where the discussion in regard to 5G/net neutrality is conducted. It must be highlighted that, till the final analysis, all chapters are neutral while the debate from the author's view is the seventh chapter - *Net neutrality & 5G analysis*. Lastly, the chapters 8 *Discussion* and 9 *Conclusion* provide the closing remarks and outline the results.

Chapter 2

Methodology

The following part outlines the aspects related to methodology model, which is employed for handling, collection and processing the data in order to obtain the desired results in the form of answers for the problem statement. This involves selecting the particular research methods and its proper utilization. With the purpose of presenting a clear structure for the reader, this chapter guides throughout the specific methodological aspects.

Firstly, the reader is acquainted with the graphical representation of the adopted methodology. The diagram depicts the consecutive steps, which represents the applied activities in the area of information collection. The next subchapters equip the reader with the particular blocks of the previously introduced diagram, thereby the holistic perspective is achieved. The implementation of the methodology diagram helps to shape and interpret the chosen methodology as the research methods can vary, consequently, the choice of the selected one must be augmented and discussed. In the case of the following work, in order to obtain the final output, literature review and interviews have been conducted. All the data aggregated from diverse sources paved the way to compose the core part of this project, which is the net neutrality and 5G (especially cloud-based network slicing enabler) coexistence and convergence.

2.1 Methodology diagram

As discussed, the Methodology diagram figure is a hierarchical model, which depicts the following steps on how the project was managed and what was the generally applied strategy to solve the problem formulation questions. The conductive steps depicted in the diagram are the counterparts of the utilized research methodologies.

In the holistic view, the first activity was to appropriately tailor the problem formu-

lation questions in the research area. Considering the fact, 5G use cases diversity and many nationwide net neutrality rules are, one main and four sub-questions have been produced. The next second step was to acquire the state of the art knowledge from multiple distinct sources. As a result, broad research has been conducted. This activity yielded the *State of the art* chapter production, which equips the reader with both - engineering and regulatory data essential to understanding the further deliberation regarding the perplexing 5G/net neutrality issue. The next part *Literature review* introduces the reader to previous works done by other researches within the discussed framework. Following this the analytical model, where the most important pillars influencing the net neutrality/ 5G interrelation are identified based on the theoretical understanding from chapter 3 and chapter 4. Following chapter frames the identified pillars in regard to interviews and research to which extent these parameters are important in the overall discussion. The kernel of work is *Net neutrality & 5G analysis*, where the distinguished cases are investigated and examined whether the net neutrality poses a threat for 5G commercial deployment. The final section of research concludes all the findings and draw concrete results. The graphical guide is included in the figure below.

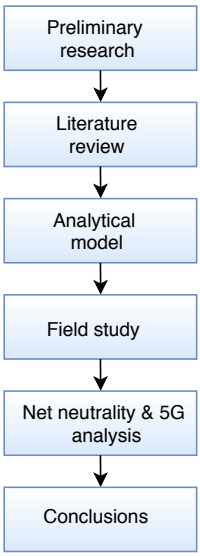

Figure 2.1: Methodology diagram (own picture).

In the following subchapters, the individual parts of the methodology diagram are described in details.

2.1.1 Literature review

For the purpose of solving the problem formulation questions, research analysis methods need to be utilized. A fundamental source of relevant materials is a literature review method. This activity requires the investigation of multiple, diverse papers delivered by entities associated with the new radio standard development and net neutrality regulations. As a result, the literary research affected the engineering side with scientific papers, technical documentation and reports, and regulatory side with the revision of the standards, specifications and regulatory guidelines and rules. This activity allowed to obtain deep and prominent insight into the researched matter. With the intention of acquiring the appropriate papers describing the state of the art, the set of the most relevant keywords was identified. In order to obtain valid and trustworthy information in the areas, platforms such as Google Scholar, Google, IEEE Xplore and Aalborg University library have been employed as search engines. The following keywords set was provided into the search engines:

∗5G AND Net Neutrality OR Zero Rating OR Network Slicing OR Network Function Virtualization OR Data prioritization

As a final output of this activity, chapter 3 and chapter 4 were created and significantly contributed to building the theoretical knowledge base, essential for the further deliberations. The further step of the study was tailoring an analytical model in the chapter 5.

2.1.2 Analytical model

For the purpose of providing an appropriate understanding of the gathered data and sharpen the studies, the analytical model is introduced and incorporated. The argumentation behind why the dedicated model must be included is the fact that the proper filter is needed before going to the field and testing the assumption. In other words, to fully frame the data gathering and answers from the interviews, the reader must be equipped with the analytical model beforehand.

Consequently, as a result, chapter 5 is incorporated to provide the bridge between the theoretical knowledge from chapter 3 and 4 to chapter 6 and finally the core of the research - chapter 7. The chapter outlines the most related areas, acquired from the theoretical knowledge base - chapter 3. These pillars were afterwards tested and framed with the interviews, which provided a solid ground for non-neutral debate in the chapter 7.

2.1.3 Field study

This part of the methodology is responsible for framing the identified areas from the previous chapter 5 in regards to the obtained answers from the interviews. Here, the data is appropriately framed and correlated with the answers from the interviews. Not only does the chapter seek the answer to which extent the identified pillars are relevant in the overall debate, but also equate the theoretical knowledge acquired from chapter 3 and chapter 4 with the interviewed specialists. It is important to highlight that this part, together with the previous (*Introduction to the analytical model*) are both impartial and analysing the crossover on the neutral ground. The main part of this work - debate whether net neutrality can jeopardize the development of 5G is incorporated as the chapter 7, where the main discussion is conducted with all the elements, analysed beforehand.

2.1.4 Net neutrality & 5G analysis

The main part of the work debate where the author discusses the crossover between perplexing net neutrality in the framework of 5G. The dispute is incorporated in the form of chapter 7 and in comparison to the previous parts is operating at the non-neutral ground. In other words, this part is not about showing and discussing the numbers/data/knowledge but expressing the author's opinion in the framework of the 5G/net neutrality crossover. In order to fully understand the chapter, the reader must firstly adapt the essential, basic knowledge in regard to both of the concepts (chapter 3 and chapter 4), understanding the importance of the analytical model (chapter 5), and the distinguished aspects validation framework (chapter 6). Lastly, after the debate, the reader obtains the answers for the stated problem formulation questions in the last *Discussion* and *Conclusion* chapters.

Chapter 3

State of the art

This section discusses extensively the areas connected with the research questions and provides a deeper understanding for the reader. The knowledge outlined here is essential for further elaborations and debates. As discussed, the study relates to the upcoming telecommunication standard in the framework of the net neutrality concept. Consequently, before diving into the tailored analytical model and impact analysis, concepts, technologies, use case classification, regulation and the crossover between net neutrality and cloud-based enablers must be introduced. However, as mentioned in the section 1.3 *Delimitations*, not all 5G elements are incorporated and elaborated in the following research. In respect to the level of relatedness to the main subject, only cloud-based concepts are presented below.

The structure of the chapter has been accordingly adjusted to the knowledge adaptation process. Consequently, primarily the general concepts have been introduced and gradually diving into a more complex and detailed aspect of the discussion. As a final output, the reader obtains a structured pack of all necessary elements needed for upcoming chapters.

5G standard opens the engineering part of the chapter, with the main assumptions, internal classifications and the relevant enablers. Then the more regulatory part is established - net neutrality debate with the presentation of pros and cons and legislative status in the EU and the United States (US). The argumentation behind why these two particular units have been selected is because both of the represent diverse approach towards equal data treatment. The reader obtains both sides of the debate - pro and anti net neutrality. Before the concluding remarks (subsection 3.4), the subchapter 3.3 equips reader in explanatory section why particularly network slicing is perceived as an enabler not aligned with the EU net neutrality rules. The literature merge between 5G and net neutrality is done in the next chapter 4 *Literature review*, where the related

academic works are presented.

3.1 5G standard

As [22] explains, the demand for the capacity in the mobile broadband communication increases dramatically each year, wireless equipment and infrastructure must be ready to support up to a thousand-fold boost in the total mobile traffic by 2020. This urgent need for higher data availability forced academical and industrial sides to cooperate and tailor new roadmaps for improvement of current - LTE standard. As a result, the fifth generation of radio communication is one of the most anticipated and disruptive technology in recent years [23]. Ubiquitous and ultra-fast connectivity, high-degree of the network reliability are few of the engineering traits of standard [24]. Among many standardization entities, the one responsible for features, parameters, architecture models and many other relevant ingredients is the 3rd Generation Partnership Project (3GPP). The organization released Release-14 in 2017 with new study item 5G "New Radio", which has been further developed in next Release-15 in 2018 with deeper and more elaborated guidelines in the field of 5G: 4G/5G cooperability, Massive MIMO, new beamforming technique or enhanced mobile broadband at the sub-40 GHz frequency [25]. Both of these releases might be considered as a starting point of new standard moulding. However, it must be highlighted that the overall telecom ecosystem is highly complex, multi-dimensional and complicated in both business and engineering perspectives. The upgrade from 4G to 5G influences multiple branches of industry like healthcare, automotive, media, manufacturing engineering, energy [26], with it all high data transfer capabilities and minimum latency features. [22] outlines that the main distinction between 4G and 5G will be a vast change in the proposed services portfolio, which will be beneficiary of such features like longer battery life, higher bit rates, lower infrastructure costs and higher aggregation capacity to serve multiple users simultaneously.

The forecasted standard will cover a vast array of business products and fulfil the data demands, consequently, 5G must be appropriately adjustable and manageable. The key to cover all the predicted use cases is the spectrum management [1] as the different slices of radio frequency have various parameters, which can be flexibly steered and accordingly adjusted to the MNO's needs. This subject will be further presented in the next section, which is outlining the match between the spectrum and use case categorisation. It is crucial for the reader to understand how diverse use cases are grouped because, in the holistic view, this knowledge is utilized for the analytical model and net neutrality and 5G crossover study. Afterwards, the reader is familiarized with the 5G network architecture and finally, the key elements of the 5G network called enablers. However, because of the scope of the following project - only cloud-based technologies are scrutinized and

introduced.

3.1.1 Use case pyramid

The landscape of 5G use cases is diverse and heterogeneous. Some of the services require stringent data rates and lower latency ratio, while others are operating at more loose conditions without the critical network reliability. The analysis of the needs and requirements led the standardization bodies to the common agreement upon the overall classification and use cases segmentation. Forums such as Next Generation Mobile Network Alliance (NGMN) [27] and International Telecommunication Union Radiocommunication Sector (ITU-R) [2] consider the following main 5G services segments:

- **Extreme Mobile Broadband (eMBB)** - characterized by high operational frequency (above 6 GHz, mmW and cmW segment of the spectrum). The services in this category require extremely high data rates (in the range of 10 - 20 Gbps in the peak rates) and loose latency parameters. The use cases are more static and consumed mostly within the indoor environment. It is perceived that this network set will redefine the media industry [28], [29], with applications like Virtual Reality (VR), Augmented Reality (AR). In addition, the [30] outlines dense urban information society, open-air festivals network coverage, shopping malls or stadium as the places for the possible deployment of the eMBB network.
- **Massive Machine-Type Communications (mMTC)** - the main traits of the following are the ability to serve up for tens of billions of network-related devices. Perfect for the internet of things (IoT), which requires wide indoor coverage. The operational spectrum is 2 - 6 GHz [1], used mostly for wide areas coverage applications. In comparison to the previous category, the supported data rates are in the range from 1 to 100 kbps [31].
- **Ultra-reliable Machine-Type Communications (uMTC)**- this segment covers the applications, which demand ultra-reliable and constantly available network access. Accordingly to [31], the devices must be in connection with the network 99,999% of the time with less than 1 ms air interface latency. In opposition to eMBB, mobility and tight latency are the crucial factors. The industries which might benefit from this network setup are manufacturing and process engineering, automated energy distribution within the framework of the smart grid, e-health with remote medical surgery use cases or automotive industry with remote car sensing and control [30].

Moreover, as [2] states, the future telecommunication systems must be designed in a flexible manner, in order to provide the connectivity under all circumstances and in

the different models and scenarios. Consequently, the high degree of the modularity is expected to be included in the overall creation process so that all the forecasted businesses can be served and managed. To provide the full picture and how the distinguished categories are interconnected the diagram below was introduced:

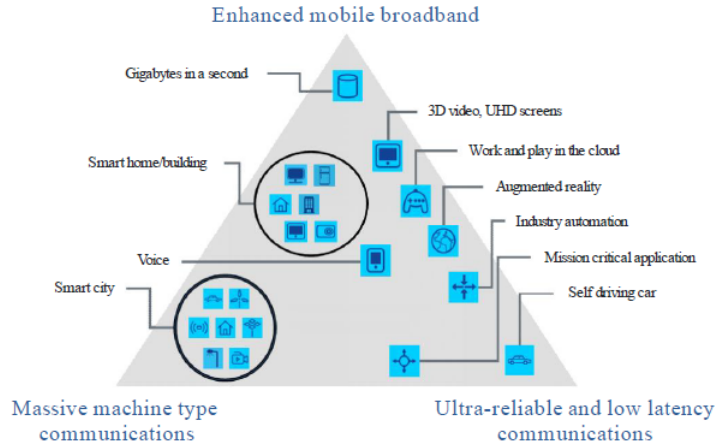

Figure 3.1: 5G use cases categorisation source: [2].

As it can be noticed, the three segments create one coherent model, where the use cases are interwoven and intercorrelated with each other. One of the parameters which are responsible for the layers distinctions in the radio spectrum. This essential element of the overall telecommunication ecosystem is used for the plethora of economic, developmental or scientific purposes with the vast amount of end-users. As [32] explains, the radio spectrum is the portion of the electromagnetic spectrum that carries radio waves. The range is defined by the utilized frequency of the transmitted signal and mostly considered from 9 kHz to 3000 GHz. The important traits are signal propagation features, which defines the purpose of the used spectrum. Predominantly, higher frequencies reach shorter distances but they have a higher information-carrying capacity. This dependence has been noticed by the standardization bodies and accordingly aligned with the 5G use cases. The study conducted by [1], explains that diversified requirements for usage scenarios call for high, medium and low frequencies utilization. By exploiting scientific characteristics of radio portions, the match with 5G use cases has been performed. A harmonized and structured listing was of frequencies, use case category and spectral features are appended in the form of the table below.

The following distinction must be understood by the reader because the further divagation in regard to net neutrality and 5G are based on three generic groups of use cases as it was explained in the previous chapters.

Table 3.1: Correlation between 5G usage scenarios and the operational frequencies. Based on [1].

Use case category	**Spectrum layer**	**Radio frequency**
eMBB	The high frequency allows addressing the extremely high data rates usage.	6 GHz
eMBB, uRLLC, mMTC (no deep coverage cases)	Medium frequencies, the compromise between wide-area coverage and proper capacity.	2 – 6 GHz
mMTC, eMBB, URLLC	Low frequencies, with good indoor coverage	Below 2 GHz

3.1.2 5G network architecture

One of the most essential elements while discussing telecommunication technologies is their architectural framework. The incorporation of the 5G scheme and its building blocks set the scene for the upcoming sections, which include the descriptions of the 5G enablers. In addition, [18] research indicates 5G architecture as a key component to understand the alignment between net neutrality rules and the upcoming standard. Consequently, the literature research in regard to the following concept was conducted. This section is mostly based on the 3GPP technical specifications where the standardization body outlines the principles that are applied to the 5G architecture.

Firstly, it is important to highlight that 3GPP, similarly to the previous generations of the wireless standards, defined two main architectural segments - a new 5G core (5GC) as well as a new radio access network (RAN) called 5G New Radio (NR) [3]. Both of these segments are needed for the subscriber to access the Data Network (DN) resources like operator services, Internet access or 3rd party services etc. Each of the parts consists of blocks interconnected with the standardised protocols. Secondly, the distinction between the User Plane (UP) and Control Plane (CP) must be introduced. [33] describes UP as the collection of the resources across all the network devices responsible for forwarding the traffic. While CP, as [33] continues to explain, is the collection of functions responsible for controlling network functions, such as providing the instructions to the devices, network elements in respect to processing data units (packets, frames, bits etc.). Furthermore, CP involves the set of instructions correlated with operations like fault management, performance management and configuration management. Accordingly to 5G Network

Architecture specification [3], the 5GC provides a separation of UP from the CP functions, to allow the independent scalability, evolution and more flexible network deployments, which is one of the main concepts behind the new scheme. At this stage of the project, the reader must acknowledge this basic distinction, the CP/DP will be further elaborated in chapter 3.1.3.3 where SDN concept is scrutinized and detailed.

The picture below depicts the designed scheme:

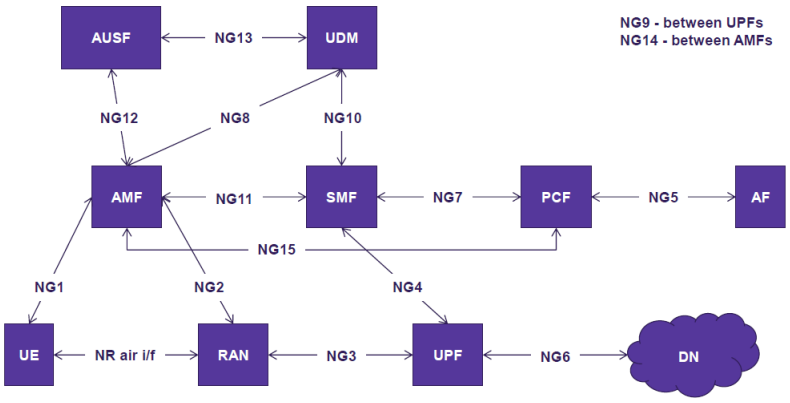

Figure 3.2: 3GPP 5G network architecture [3].

The following framework involves both of mentioned network parts - NR and 5GC. The user equipment (UE) symbolizes any terminal which can be plugged to the network and together with RAN represents NR part, while the rest of the blocks represents the 5GC network segment. The first aspect to describe is UP connectivity, called Protocol Data Unit (PDU) Session, which runs from the UE, through RAN and User Plane Function (UPF) to the Data Network (DN) (bottom line of the picture). Accordingly to the 3GPP's PDU Session User Plane Protocol specification [34], the PDU Session procedure includes a QoS (Quality of Service) Flow Identifier (QFI) field, which administers the transferred packets in regards to the different QoS profiles. In other words, in PDU Session there might be multiple different QFI channels and each of them carries the data with various QoS requirements. It is also important to highlight the importance of UPF element as it is directly involved in PDU Session operations. As [35] states, the UPF is an anchor point for the RAN so the UP connectivity will always be running from the antenna towers (RAN) to UPF in the core network. Additionally, as UPF is fixed at the UP channel, consequently it is an ideal point to enforce the QoS policy. Moving forward to the upper layer of the picture, blocks related to keeping the PDU Session active for the subscriber and ensuring the PDU Sessions follows them as the subscriber moves around the network. The first considered element of 5GC is the Access and Mobility Management

Function (AMF), which looks after the subscriber mobility administration functions like tracing area or potential cell attachment. In addition, as the 3GPP TS 33.512 describes, AMF plays a significant role in registration and security management, especially when it comes for authenticating process whether the subscriber has a right to utilize the network resources [36]. The next element in the 5GC segment is Session Management Function (SMF), which handles the establishment, modification and at the end the teardown of the PDU Sessions. Consequently, the SMF is directly involved in the policy control function to determine whether or not the distinguished data session can be executed. Following that, the Unified Data Management (UDM) block is a central repository of subscriber information, which is directly involved in the access authorization, because it holds the security keys and the subscriber profile. Moreover, UDM is responsible for registration and mobility management, as the element tracks where the user is attached. Next, Policy Control Function (PCF) is included to dynamically administer the policy control over the network. The dynamic conditions are based on the network environment at the given time. For example, in the scenario when the user wants to set a PDU Session, the SMF will check whether the network conditions will allow doing to connect the terminal to DN. The PCF analyses the data such as a subscriber geographical location and allows or forbid the PDU Session establishment. Lastly, The Authentication Server Function (AUSF) was specified by 3GPP to handle authentication requests for both, 3GPP access and non-3GPP access networks [37].

The main difference between the 4G and 5G architectures, is the fact that the previous standard was considered as an upgrade from the previous generation standards, while 5G is envisioned as more flexible standard. As a result, the new framework, designed by 3GPP must be able to support cloud-based technologies like SDN, NFV, MEC or Network Slicing [3]. This remark is shared by [38], as authors highlight the importance of more permanent and evolutionary change rather than a typical upgrade. 5G as a technology which offers a wide array of the various use cases must be flexible enough to accommodate their requirements. Following that notice, [3] lists other principles among which: mentioned earlier UP separation from the CP function, modularizing the function design to enable network slicing (this enabler will be described in chapter 3.1.3.1) or possibility to integrate elements from the different generations, namely Non-standalone (NSA) model. In other words, 5G allows uniting the multiple elements from various generation networks. In NSA, the NR cells work together with LTE radio cells and utilize dual connectivity operation (user's terminal consumes radio resources provided by at least two different network points like 5G's antennas or 4G's antennas), which transmits signal further either to 5GC or 4G's core - Evolved Packet Core (EPC). As a result, MNO might choose to utilize the NR radio cells in combination with LTE radio cells to provide radio access to the core part. The second possible integration model is a

Standalone (SA) scenario, where MNO uses only equipment of one particular technology (such as 5G).

The next sections outlines the particular technologies, which enables the operability of the following network scheme.

3.1.3 Cloud-based enablers

Even though 5G is still in under the development process, many businesses have already started to prepare for the 5G utilization [39]. As such, a broad variety of influenced industries have different expectations toward the network parameters. To fulfil these demands multiple bodies have been involved in the tailoring new concepts and ideas on how to redesign the future of telecommunication. As a result, multiple concepts have been created like HetRAN, beamforming, Massive MIMO, cloud computing etc. However, because of the level of relatedness and scope, only cloud-based enablers are analyzed in the following chapter as these are the ones perceived to be in conflict with data prioritizing rules [18]. All these technological enablers have been examined below and presented to the reader. Described four enablers are tightly intercorrelated and connected via one denominator - Cloud computing. As an additional part, appendix A describes how the enablers (Network Slicing with NFV & Network Slicing with SDN) are interconnected together. The reason why this part is included as the part of the project, is because the enablers are not working as a separate technologies, yet more in the complementary model. Still, it is an additional information for the reader rather than core part of the debate between net neutrality and 5G, consequently the interconnection is appended as a appendix A.

3.1.3.1 Network Slicing

In this subchapter, the Network Slicing concept is outlined and scrutinized. In the holistic view, this part has a higher significance in comparison to the other 5G cloud-based enablers because of its level of relatedness to the net neutrality and 5G crossover. The reason why network slicing has the highest priority among the mentioned enablers is the fact that this particular technology is perceived as not in the line with compulsory net neutrality regulations [18], due to this fact the solid knowledge foundation must be provided. In order to assure smooth knowledge transfer, firstly reader must be familiarized with slicing concept in details, secondly with net neutrality (in the upcoming section) and finally, the crossover between these two theories is done. This strategy provides the hassle-free onboarding process into further divagations.

A study by [40] recognizes network slicing as one the essential components of upcoming 5G standard, which is able to accommodate the wide range of diverse use cases

and business actors in the flexible, productive and resource efficient way. Accordingly to [39] a concept of network slicing is the ability to deploy distinguished services across the 5G network via particularly tailored layers of the system. To put it another way, next-generation radio systems will be able to operate at various logical network partitions (i.e. slices) with appropriate isolation and predefined parameters which serve a particular application purpose or service category. As the main characteristics of this network division, [41] outlines high–reliability (immediate fault detection), high-scalability (separating to 100 slides depending on the customer order), automatization of network operations, cross-domain by using open network configuration design model and cost-effective and prompt new service deployment process (convergence with virtualizing technologies like SDN, MEC and NFV). Furthermore, [42] highlights the economics capabilities and explains that deployment of slicing can bring the savings in both capital expenditures (CAPEX) and operating expenditures (OPEX) segments by achieving the higher efficiency through streamlined processes and improved service life-cycle management with automation.

[4] scrutinizes slicing enabler in regards to architectural implementation and feasibility. Accordingly to [4], a layer of the network is composed of the collection of 5G Network Functions (NF) and specific Radio Access Technologies (RAT) setting that combined together provides value for a specific business model. Furthermore, one of the main principles of slicing concept is the ability to provide only traffic management, which is essential for a distinct use case and all redundant functionalities must be avoided. The second principle is the adaptability feature, which allows third-parties entities to expand existing businesses and tailor new ones via pre-defined Application Programming Interfaces (APIs). The described connection of specific NF and RAT settings are illustrated at the architecture below:

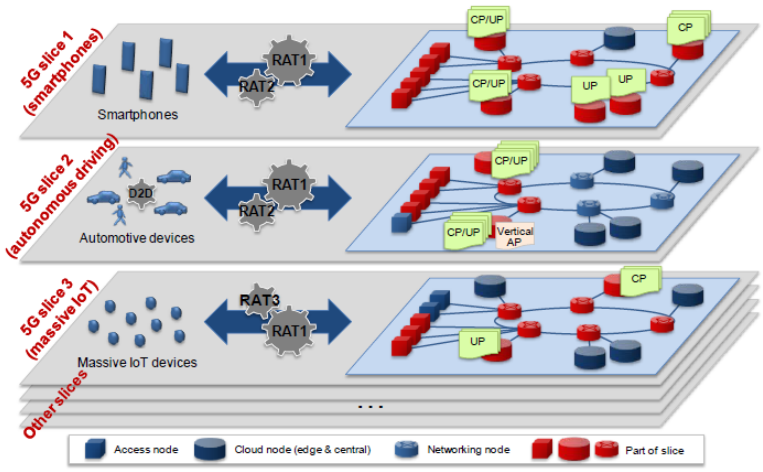

Figure 3.3: 5G network slicing implementation example [4].

As the picture depicts, the network has been cut into three distinct layers and each of these represents diverse use cases with different parameters needed to launch the service. 5G slice for traditional smartphone branch will utilize fully-fledged functions distributed across the network. In regard to autonomous driving, parameters like reliability, security and ultra-low latency will be deciding for 5G slice supporting this group of business. Lastly, massive IoT category will expect to work on slice which is non-mobility support and lose obligations in the framework of data rates or latency.

The discussion about network slicing was enriched by [43], where authors are identified RAN-specific conditions required to achieve the desired network slicing vision. This recognition is crucial for the overall understanding of the feature because slicing operates at the complex and multi-dimensional environment of telecommunication realm, consequently, the relations between RAN and slicing concept are crucial to acknowledge. The list below highlights the most important correlations:

- **Maximized utilization of RAN resources** - network slicing should be able to support various virtual networks on the same physical infrastructure level in order to reduce the costs or energy in comparison to the deployment of separate physical network for different business cases. [43] outlines radio resources segment (frequency, time, power), and hardware/software platform utilization.
- **Slice-aware RAN** - as mentioned, some services require data with high reliability (i.e. autonomous driving from URLLC category), consequently network must implement mechanism which is able to distinguish the possible scenarios and accordingly adjust the network traffic distribution system and provide more resources

automatically after detection of critical data use case. This rule will be further developed as it poses a disagreement with existing net neutrality rules.

- **Traffic differentiation** - similarly to the previous rule, prioritization mechanism should be supported by 5G RAN network in order to provide differentiation of slices.
- **Protection mechanisms** - RAN network must be able to cooperate with network slicing security mechanisms to provide slice isolation and eventually omit the congestion within one slice.
- **The management of the infrastructure support** - slice feature should dynamically and efficiently be able to allow quick set-up of new services or modification of previous ones. To achieve this goal, slice must efficiently utilize system topology (the software and hardware resources) available at different sites (processing, storage and networking).
- **RAN should support slice management** - it is forecasted that MNO should be allowed to control the slice of the network as if it was a separate dedicated network, rather a part of the existing one.

Before diving into the key characteristics of slices in regard to 5G use case category, network slicing architectural concept must be presented. A study by [5] states that diverse and sometimes extreme requirements will challenge a monolithic, currently utilize network and transport framework to accommodate a wide array of services. Due to this fact the slicing architectural concept has been standardized by NGMN [5] and included below:

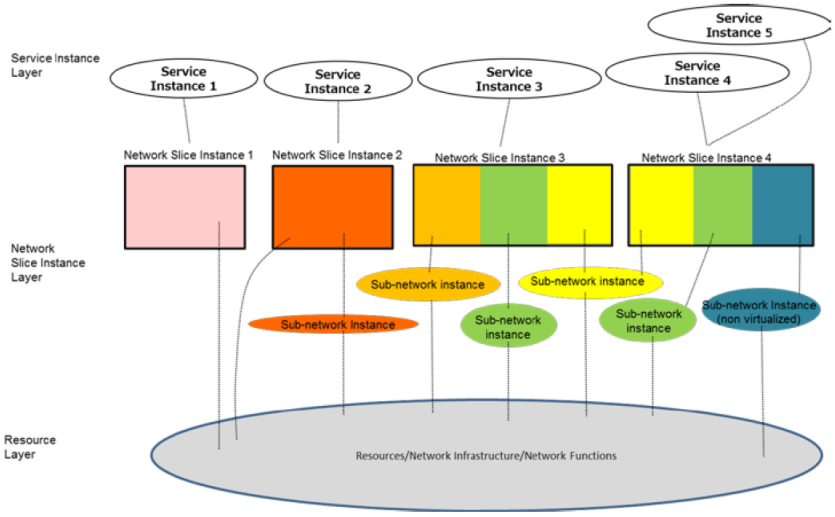

Figure 3.4: The conceptual model of network slicing [5].

The standardized conceptual model consists of three particular layers:

- **Resource layer** - comprises physical and virtual resources from the underlying network and made it possible to be utilized by the upper architectural network layers [44].
- **Network Slice Instance Layer** - the following part may be composed by none, one or more sub-networks instances, which can be shared by other network slicing instances.
- **Service Instance Layer** - this high-level represents all the services scheduled for end-users or business.

This architectural framework is crucially important as it is further matched with the NFV concept model. As mentioned 5G is characterized by the versatility of proposed products and business solutions. This products diversity is one of the key drivers of network slicing implementation because of a wide range of parameters [45].

This paragraph outlines the idea of personalized slices concept. The following association between 5G use cases array and slicing concept was based on [45], where source summarizes industries with their most promising use cases and their services requirements. For instance, media industry (considered as an eMBB 5G category) with VR/AR is highly data consuming driven with its auditory, visual and haptic use experience model is perceived as one of the industries, which will utilize network slicing. It must be highlighted that VR/AR is a setup with many applications derived from like VR gaming,

VR broadcasting, military [45], Due to this fact it is challenging to find an ultimate network slicing model for the whole industry. However, [45] explains that in order to obtain audio-visual interaction 5G slice should be able to provide a latency range of 7-15 ms while maintaining 250 Mbps user data rates. The audio model with an only speaking option can extend the latency parameter to 100 ms. Moving forward to the next segment of use cases - Automotive industry (URLLC use case segment) is also diverse and multi-dimensional ecosystem with the wide array of various subsections like infotainment, telematics, road safety, advanced driving services like platooning or cooperative driving, here similar to VR/AR segment it is challenging to distinguish an ultimate parameters for slicing model. [46] managed to standardized main Key Performance Indicators (KPIs) requirements for automotive industry use cases. Accordingly to [46] in most of the cases the network availability and reliability are quintessential for proper use case operation. The slices should provide 99,99% of reliability and availability of connectivity, yet the data rates requirements are looser in comparison to eMBB use cases. For instance, high definition local map acquisition only 960 to 1920 kbps are needed. In regard to third distinguished category - IoT - source [46] summarizes that slice must be able to deliver a small amount of data packages (low throughput), in high-latency tolerant model, however in respect to good coverage. Of course, all these parameters vary in regard to the particular use case.

Network slicing concept is crucially important for the following research, not only because of its significant attention from both the academia and industry but also since the concept is envisioned as one of the main key enablers for the 5G it plays a meaningful role in the analysis of confluence between 5G and net neutrality regulations.

3.1.3.2 Network Function Virtualization

One of the components of the 5G network, which is able to enhance functionality, architecture, operational agility and reduced costs is Network Function Virtualization (NFV) [47]. The following concept has been standardized and scrutinized by the European Telecommunications Standards Institute (ETSI) Industry Specification Group (ISG) [6]. In a strict sense, the virtualization process transforms a physical machine into the virtual one [48] with all the major advantages and benefits. The reason for this tectonic shift is the liberation from the hardware-based network with all its drawbacks and hurdles. [49] explains that hardware appliances quickly reach the end of the life and as the innovation processes are accelerating to fulfil the data demand constant investment in deploying new hardware prominently prolong the return of the investment. Due to this fact, NFV aims to address these problems by merging the IT concept of Cloud Computing and accordingly blend with the telecommunication world. Among the advantages of the shift,

[49] adds reduced CAPEX and OPEX by diminishing the need of equipment purchase, decreased payback period time from new services, enhanced flexibility to scaled up and down the network, opportunities to trial and deploy new innovations services at lower risk.

Virtualization concept allows Network Functions (NF), currently implemented on proprietary and closed platforms offered by network equipment providers to be implemented on Commercial off-the-shelf (COTS) servers, which is perceived as a revolution in the network design [50]. The paramount rule of the virtualization process is the ability to host the network functions on one or more virtual units, referred as Virtual Machines (VMs). Furthermore, Virtualized Network Functions (VNFs) are deployed on top of a virtualized infrastructure, which might be set in more than one physical location. As a result, network applications are not embedded tightly to dedicated hardware infrastructure but designed as the applications, which can be adjustable within the cloud framework [48]. This approach of functional decoupling yields a disparate development of hardware and software sides of the network, what finally results in faster growth of innovative services over already deployed physical infrastructure.

While discussing the NFV architectural framework cannot be omitted because of its level of relatedness and importance. The management of VNFs requires an effective and dynamic framework, which is able to portion the cloud resources into hardware and software convergence [48]. Accordingly to ETSI specification [6], the NFV architectural models is composed of three elements:

- **Virtualized Network Function** - the NF functional block within the network, that models a home network functionalities like Residential Gateway (RGW), Firewall, Radio/Fixed Access Network Nodes, Message Router, Broadband remote access server (BRAS) [48]. Additionally, as [48] notices, a single VNF can be composed of numerous internal components, an, therefore, it could be deployed over many VMs.

- **NFV Infrastructure (NFVI)** - the totality of all hardware and software components needed to create, manage, maintain and execute the VNFs. This layer contains the hardware resources, which are responsible for computing, storage and connectivity process to VNFs via the virtualization layer [48].

- **NFV Management and Orchestration (NFV MANO)** - this slice of the architectural framework provides the functionality required for provisioning of VNFs and related processes such as configuration and management of VNFs and the depending infrastructure (NFVI), which these functions run on [51]. In the holistic view, this segment covers the orchestration and the lifecycle management of NFVI and VNF.

To provide a better understanding for the reader all of the mentioned functionalities have been depicted as one figure below:

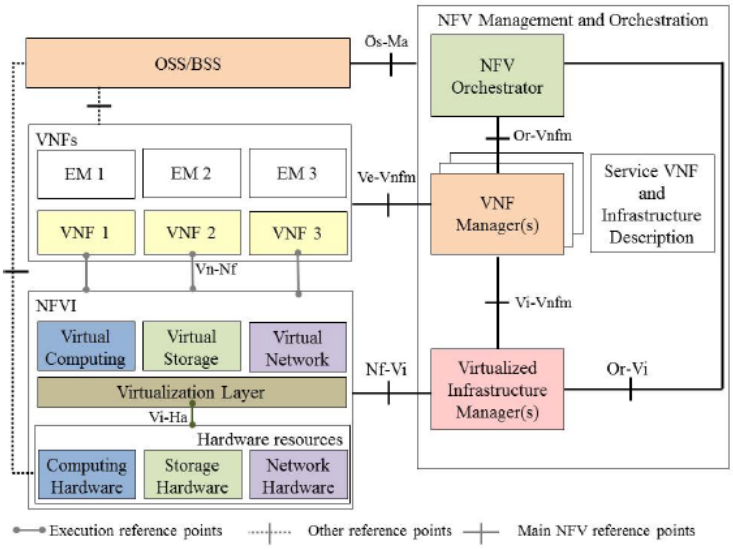

Figure 3.5: NFV architectural framework in regard to the functional block [6].

The VNFs are being separated from tight coupling with dedicated COTS hardware infrastructure via the virtualization layer. All essential resources like computing, storage and network are running on top of virtualization layer in the software-based platform [6]. This particular partitioning layer in the middle of NFVI besides the splitting also provides the mentioned network resources to dedicated VNF. As [6] continues to explain, the computing power is being provided in the form of mentioned earlier VMs, which are the hosts for VNF. What is more, the third MANO block manages and controls the overall process of network functions virtualization [47]. Three internal elements are tightly cooperating to bring the holistic cooperation process - NFV Orchestrator, VNF Manager and Virtualized Infrastructure Managers (VIM). In more details, the Virtualized Infrastructure Managers (VIM) manages the virtualized infrastructure and comprises the resources provisions to achieve the assumed benefits of NFV [47]. Next block, VFN Manager perform the installation, deployment and scaling of the distinguished VNFs in regard to their Element Management (EMs) [47]. Additionally, as [47] outlines, this particular element superintends the faults, performance, capacity planning and optimization. The effective implementation of the VNF Manager allows the MNOs to leverage the advantages of NFV enabler by reducing the CAPEX and OPEX costs in 5G by dynamic resource allocation and traffic load balancing [47]. The last segment - VIM

is responsible for resources management (inventory of software, computing, storage the network resources dedicated to NFV infrastructure), improve the energy administration, increase or decrease the demanded resources for particular VMs and allocation of the virtualisation enablers [6].

All these functional blocks are quintessential for proper NFV technology to operate. Starting with the given resources and functions to virtualize, then the virtualization process itself and finally the creation of VMs, which are hosting the VNFs is one of the keys to proper 5G functioning. As described, NFV provides scalability in regards to MNO's needs. Network operators can direct the overall process via a dedicated Operations Support System (OSS) and Business Support System (BSS) software platforms [6].

Before moving forward into the next enabler, [7] provides a merge between analyzed 5G Network Architecture and NFV concept. As the source explains, virtualization will play the role of setting the 5G architecture building blocks within the NFV framework. Rather than operating at the hardware level of equipment, MNO will have a possibility to operate at the softwarized version of elements like AMF, PCF, UPF, SMF or UDM (all introduced in chapter 3.1.2). This shift is one of the most important milestones among the current telecommunication trends - instead of utilizing hardware-based machines, NFV allows to put both CP and UP elements, billing and policy control (PCF) and subscriber management (UDM) as a software platform, which allows MNO to manage resources faster and cheaper in regards to the use-cases, network environment or available capacity. For example, if MNO needs more AMF resources, the physical deployment might least for a week, while NFV enables quick scaling -down/-up the network resources and as a result, significant time and cost saving can be achieved. The picture below encapsulates the idea of NFV employment in the framework of 5G architecture:

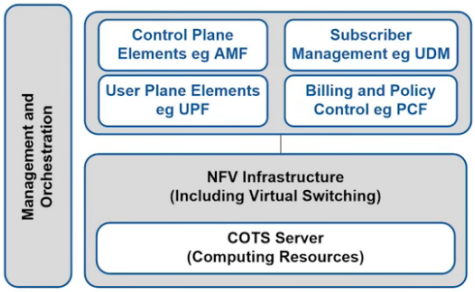

Figure 3.6: The 5GC elements within NFV framework [7].

As it can be noticed, as match between NFV (figure 3.5) and 5G architecture (figure 3.2) models has been done. An important remark is to mention the MANO module,

which facilitates, administers and organizes the network resources. in regard to the current network demands. This following softwarized version of 5GC is the targeted variant for 5G, where all the blocks are within the NFV framework [7].

To sum up, NFV is one of the puzzles in the overall telecommunication ecosystem. It is crucial for the reader to exhaustively apprehend, the recognition of the subject for the reason that virtualization is a key component to understand the network slicing and net neutrality discussion.

3.1.3.3 Software Defined Network

In order to tackle the seamless management of the physical and virtual resources, described in the previous section, besides the NFV, Software Defined Network (SDN) has been recognized as the third key component in the process of cloudification [52]. These two disruptive enablers are permeating and closely cooperate to deliver the end-to-end programmable and virtualized network environment. NFV has been created to administer functions related with agility, scalability and leverages the recent advancements in the field of cloud computing, while SDN is the complementary element of the overall system, which is responsible for making the connectivity process programmable [52]. As the [53] states the SDN is the physical disjunction of the network control and forwarding functions and as a result provides dynamic, manageable and cost-effective network architecture ideal for the high-bandwidth use cases. The key parts of the SDN concept are firstly, the idea of split between the network's control logic (referred also as a control plane) from the underlying routers and switches that govern the traffic transfer (the data plane) and secondly, with the detachment of both of the planes, the network switches becomes simple data forwarding devices and the top logic is deployed as a centralized controller [8]. In other words, the data plane resources (infrastructure of interconnected data forwarding devices [54] are being separated from the control plane (tables, protocols, algorithms and all logic-related elements [55]), and consequently, all control logic is being implemented as one unit called centralized controller [8]. All the decision-making processes are gathered in one network unit, rather than per forwarding devices. As a result, the network is more synchronized, easier to optimize and easier to steer. The controller directs the control over the state in the data-plane components via a well-defined API called OpenFlow [8]. [52] explains that OpenFlow is one of the most important elements of the overall SDN system. The reason behind why OpenFlow is crucial is because this protocol enables the communication between the infrastructure and controlling layer. Moreover, in [52]'s opinion, open interfaces like OpenFlow are indispensable for systems that are composed of the decoupled functional modules. This modular approach is advantageous for MNO, which can design their networks based on the various components

from any combination of a multitude of sources like commercial vendors and open-source groups. The next benefit of open, well-defined interfaces is the fact that they may vitalize the competitiveness between providers.

The overview of SDN concept, have been depicted below:

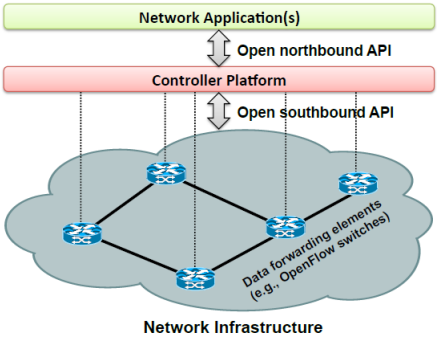

Figure 3.7: Simplified SDN architecture [8].

As the figure showcases, the equipment layer (network infrastructure with data forwarding elements interconnected via OpenFlow switches) is being separated from the logic layer (controller platform) via open southbound API and then via the open northbound API to network application. Accordingly to [8], southbound API is the part of the southbound interface (SBI), which is supervising the communication between the forwarding devices and logical unit or in other words between data- and control planes. Furthermore, as [54] states, the set of the forwarding devices is defined by southbound API. Then in the next, upper layer, open northbound API, which represents a northbound interface (NBI), bridges the network with the application developers.

SDN is one of the key parameters to enable the network transformation into agile, open and automated, cloud-based model [56]. By separating the forwarding and control planes, entire system can be centrally controlled, what significantly influence the improvement of resource allocation and the overall efficiency and performance. In addition, as [57] outlines, because of high level of complexity and use case diversity, ability to manage can be obtained via the network softwarization. The [57] states that one of the arguments behind the SDN utilization is the need for robust remote control over the network, which can be possible to obtain when system is programmable and able to be controlled from a distance through logical interfaces.

The [58] encapsulate the SDN concept in three principles:

- **Decoupling of traffic forwarding and processing from control** - this principle of independent deployment, life cycle and evolution of control and traffic

forwarding entities allows optimization of the network platform and provides the assumed adjustability [52].

- **Logically centralized control** - the detachment of both planes poses a precondition of the centralized logical control. The motivation behind logic centralization paradigm is the fact that resources are utilized more productive and efficient when analyzing from the holistic perspective. Moreover, as [52] explains that logically centralized.

- **Ability to program the network services** - accordingly to this rule, the client has the right to exchange information.

3.1.3.4 Mobile Edge Computing

As mentioned, cloud-based enablers like NFV or SDN, shift the quintessential telecommunication paradigms and providing the cost-saving opportunities for industry. However, the heterogeneity of devices, better affordability and further cost reduction require constant improvements in the overall network architecture. To fully leverage and understand the virtualization approach, Mobile Edge Computing (MEC) must be detailed in the 5G enablers section. Accordingly to ETSI specification [59], MEC provides the IT services and cloud-computing resources within the close proximity to the mobile subscribers - in the RAN segment. In other words, MEC platform is the next step in the evolution of radio receivers ecosystem and the convergence of IT and telecommunication engineering. The concept of putting the virtualized platform together with mobile radio base station was recognized by MEC research body as one of the drivers for emerging technologies for 5G [60]. The principle according to which Edge is enriching the overall performance of services is by providing computing, storage and bandwidth capacity that is shared by multiple virtual machines installed on top of them [61]. Consequently, the subscriber might expect significant enhancements in the QoS through lower latency, minimized data transit costs and reduced network congestion [61].

The specific characteristic of MEC are follow:

- **Proximity** - as the Edge Cloud is placed on the network edge, rather than in the further part of the architecture, it notably decreases the distance between the user and the computing power. As result, applications which are highly short latency-driven like AR or Video Analytics [62] can minimize round trip time and maximizes throughput for obtaining the highest possible QoS.

- **On-Premises** - as the Edge is placed at the radio access network, meaning that it can run in isolation from the other network segments while having access to the

local resources. This feature is peculiarly crucial for Machine-to-Machine security issues [62].

- **Location awareness** - as a part of RAN, Edge enables to leverage low-level signalling information to assess the position of each of the connected device. This feature is the foundation for the Location Based Services (LBS), which uses the global positioning system (GPS) to localize the users. One of the examples of MEC utilization in regard to LBS businesses are the shopping malls [63]. The MNO via the installed smalls cells in the facility is able to position the user and personalize the offer for the shopper [64].

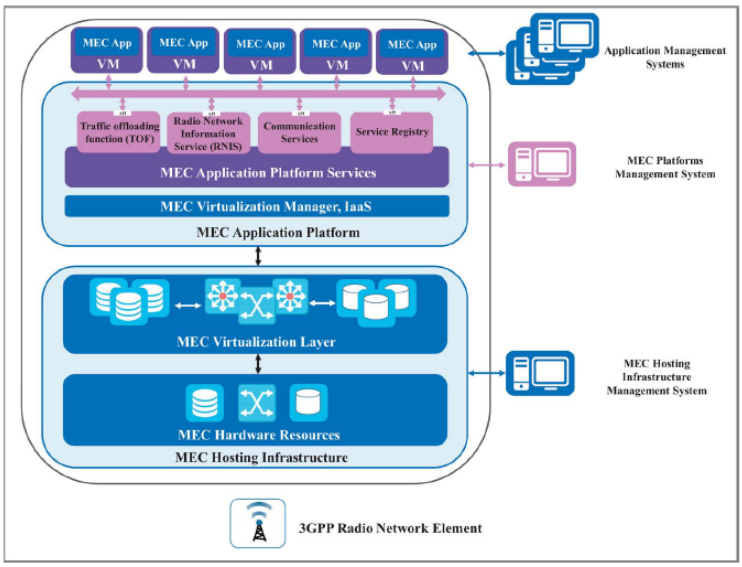

Figure 3.8: The defined reference framework for MEC servers [9].

The MEC architecture consists of three layers (presented at the above picture 3.8) :

- **MEC Hosting Infrastructure** - this layer includes two particular parts: hardware components (such as processing power, memory and network resources) and MEC Virtualization layer. To the main tasks of the MEC Hosting Infrastructure [9] involve setting the connectivity with the RAN network and abstracting hardware applications to the MEC application platform (throughout the MEC Virtualization layer).
- **MEC Application Platform** - the main task of the following structural slice is hosting the cloud-based applications. The layer consists of two main parts:

MEC Virtualization Manager conjointly with the Infrastructure as a Service (IaaS) controller and MEC Application Platform Services [62]. As [62] states, MEC Virtualization Manager underpins hosting domain by assuring IaaS resources, while the IaaS controller is responsible for security and resource allocation for application and MEC platform. Furthermore, ETSI standardized set of four middleware services to the application which are hosted on the MEC server: two infrastructure-oriented - Communication services, Service registry together with Radio Network Information Services (RNIS) and Traffic Offload Function (TOF). Infrastructure-oriented services (Communication services, Service registry) are responsible for the connectivity process between services and applications. The MEC platform has been designed accordingly to the rules of Service-oriented Architecture (SOA), consequently, the server communicates with applications via through well-defined APIs. The next service - RNIS provides the authorized application with low-level radio network data. In other words, RNIS supply MEC platform with all RAN network data like cell-ID, a location of the subscriber or cell load. The last middleware service hosted on the MEC server is TOF. Accordingly, to [65], TOF routes the individual packets to the relevant MEC applications.

- **Applications layer** - on top of the Application Platform, MEC applications are deployed and executed within VMs.

3.2 Net neutrality

This section is intended as an introduction to the debate on net neutrality as this concept is one of two main pillars of the following master thesis. In order to reader understand the further discussion, a solid and robust ration of knowledge must be provided in this field. However, before diving into the subject two issues must be emphasised. Firstly, the explanation why net neutrality and network slicing might be a non-complementary elements is described in the subsection 3.3. This way the reader will obtain structured and harmonized knowledge, which in the end allow to smoothly understand the deep picture on coexistence between 5G and net neutrality perplexing issue. Secondly, the debate about monetizing internet access and network utilization has many faces and battlegrounds like the economy, politics, technology etc. As a result, because of the scope, it is impossible to review all the aspects of the debate. The reader will obtain the most meaningful aspect of the discussion in order to understand further divagations. The section was divided into four sections:

First of all, the reader must obtain the knowledge in regard to the basic definitions, current situation and the significance of the subject, second and third are the consecutive

pro- and against- argument debate. Fourthly, the presentation of how two political scenes differently adopted the concept.

3.2.1 Introduction to the net neutrality discussion

The net neutrality is the fierce discussion between Internet Service Providers (ISP) and content providers, which has many dimensions, aspect and arguments to include. One of the possible scenarios of net neutrality rules utilization was described by [66]. Authors presents the situation where Comcast (the biggest ISP in the US) was asking giant, movie-streaming company Netflix to pay for a faster, more secure and stable connection to its subscribers. In the following situation, questions why Netflix should pay more than other services providers to deliver the end service or who will be the end payer of this transaction? Will Netflix cover the extra fee from their own budget or the monthly subscriptions will be higher? The following deal between Comcast and Netflix occurred in 2014 and it was perceived as a milestone in the history of the Internet, where content providers have not had to pay to assure the highest quality of the services [67]. This example of data prioritization of network administration is one of the pieces of the general debate called "net neutrality".

The definition "Network Neutrality" was coined by prof. Tim Wu in his widely recognizable and cited article [68]. Author debate whether an internet provider should treat IP data equally by discussing pro- and against- arguments for the open-access internet. However, as [69] explains to there is no generally accepted definition of net neutrality. For the purpose of this work the following strict definition was adopted:

> **Net neutrality** - Net neutrality prohibits Internet service providers from speeding up, slowing down or blocking Internet traffic based on its source, ownership or destination [66].

In other words, [68] purposed independent from additional fees internet, which is standing upon the impartial, unbiased and value-free grounds rather than the network, where operators can freely dictate their own conditions in regard to charging and monetizing the content.

From the engineering point of view, the discussion was enriched by [69] where referring to the main principles of the internet architectural design: Fragmenting of the messages into the data packages, which are routed to the network autonomously (end-to-end principle) and as fast as possible (best-effort principle). These rules yield that the involved network elements (routers, nodes, antennas) should not distinguish the packages based on their content, source, platform, user, application or mode of communication. Moreover, as [69] continues to explain, as routers are collaborating independently and

there is no router with end-to-end control over the data path, routers are transmitting packages to the one with the shortest distance to reach. It is possible that packages from the same message can be routed via the different paths as packets are stored in a router's queue if they arrive at a faster rate that router processing rate. As a result, data might be stuck at a queue then be delayed or deleted and dropped. Even though full routers are the main reason for congestion, no matter how important data is, routers must be always able to process the queue accordingly to the first-in-first-out principle. A complementary remark was being done by [70] where authors are describing the situation when Cisco released routers that enabled MNO to inspect data flows through their network and allowed to choose how to direct data packets for commercial or policy reasons. Authors are perceiving the fact that routers have the ability to steer the packages both ways - either de-prioritizing (throttling, discriminating) eventually blocking but on the other hand, the equipment is able to favourable and prioritize the packages for particular use cases.

After providing brief theoretical and engineering background over the issue, the debate in the form of two sub chapters (one presenting pro-net neutrality and the second against-net neutrality approach) is conducted. This way the reader will obtain a multi-dimensional perspective over the perplexing issue.

3.2.2 Pro-net neutrality argumentation

Valid arguments have been proposed by both sides. Pro-net neutrality beliefs researches refer to the following list of arguments:

- **Competitiveness and fair business practices** - one of the main stances of pro-net neutrality group is the crucial need for fair competition assurance [68]. As [70] refer to the example of 2005 Madison River Communication forced to pay a fine after being accused of deliberately blocking internet phone traffic VoIP or voice over Internet Protocol transmission and was forced to pay $15,000 fine to the government [71]. In this case, net neutrality was framed as a competition problem between telcos and over-the-top (OTT) players. The main concern raised by "neutralists": that ISP has a strong incentive to block OTT applications, such as mentioned VoIP service, which can jeopardize the telco's revenue. The thesis [70] state is that ISP may have an incentive to degrade the quality of OTT content, in order to decrease the market share of competition in favour of the ISP's own products. This argument is elaborated also by [68] where the author perceives the internet as a competition platform where multiple bodies can compete to deliver the highest quality of services. The diversion from net neutrality rules might pose a challenge for still moulding start-up companies, which are seeking for the appropriate business

model, and because of extra network fees, they cannot afford to validate and test their ideas.

- **Innovation protection** - the second argument is strictly correlated with fair business practices principles. Accordingly to [72], this argument yields the fact that since the neutral web design made it possible for small start-up companies to enter the market and become huge players, changing the neutral balance might threaten the stunning level of innovations observed so far. The distortion of net neutrality rules might raise the entry barriers for new-comers and consequently transform the internet into the ring-fenced property of the ISP [70]. The [70] enrich the discussion by stating that one of the most important internet assets is the ability to utilize the system as a playing field for the application and content developed, consequently [70] argues to maintain this vibrant ecosystem where small providers with the most promising innovations can challenge and effectively compete against vast monoliths. If small innovators will be unable to cover the extra ISP fee for prioritized access, the "creative destruction" which has shaped the internet known today for the last 10 years will be threatened.

- **Investment in network infrastructure** - in the era of constant data traffic growth [14] the investments in new telecommunication equipment is inevitable. Considering such disruptive technologies like 5G, which are forecasted to open new businesses, equipment segments must follow the trends. MNO argues that they should be granted to completely exploit their interests by charging a particular group of content providers for enhancing the end-user experience in order to deliver high-quality service to the end user. In order to do so, the network must be in the utmost condition to fulfil all the QoS parameters like latency or data rates[68]. Pro-neutralists argue that both end-users have for years been paying for the network improvements through subscription and bandwidth charges. What is more, content and service providers refuse to pay additional rates, determined by a third party based on the type of content the ISP wishes to transfer through their pipes. The second counter-argument is the fact that content/service providers claim that ISP forces them to share the revenues generated by their products, innovations and content [70].

- **Freedom of expression** - net neutrality concept is often referred in regard to free speech and human rights context [73]. The access to a reliable, unbiased source of information is the foundation of every democratic society and it is a basic human right. Accordingly, the internet as it is known today, without throttling, data prioritizing or discriminating is an unprecedented possibility for users to interact or exchange ideas and while at the same time, not restricted to the national borders

or data filters [73]. As [74] states, preserving net neutrality equals preserving the power of the individuals to select sources of information and fully utilize the potential of the global network. Moreover, the threat of net neutrality principle violations would have serious implications for the right to free expressions. A simple example might be a situation where ISP is blocking access to distinguished law-oriented blog because of its against-ISP concerns. Media pluralism and freedom of expressions have been also touched by [70] where authors relate the pluralism issue with the countries like Egypt, China, Turkey, Russia or Venezuela, where governments strongly violate neutrality by throttling social media platforms, anti-governmental news services or even private blogs. As a result, net neutrality is perceived as a pillar of free speech and the ultimate rule which prevents governments or ISP to degrade access to information and the possibility to interact with other users.

3.2.3 Against-net neutrality argumentation

In order to fully understand the net neutrality multifaceted debate, encompassment of several arguments against net neutrality must be included:

- **Enormous amounts of data are consumed without compensation** - The opponents of net neutrality argue that non-discriminatory model involves unfairness in regard to consumed data. In the era of continuous data traffic increase, streaming services like Netflix, youtube, LiveStream are consuming more data than mailing or real-time messaging. While the subscribers are paying the same amount of monthly subscription. In [75]'s opinion, there is a discrepancy between the bandwidth usage among internet applications. Consequently, it was proposed that some particular types of services should be charged more. The perfect example was the Google (service provider)/Telefonica (ISP) discussion when it was proposed that the search engines which are using mobile bandwidth for free should be charged extra because Telefonica provides network, sales, customer help, installation and maintenance for the end-user. On the other hand, Google argues why not Facebook, BBC, Spotify or The New York Times be required to pay more for network access? In addition, Google states that if MNO will slow down, throttle or discriminate access to the most popular searching engine, users will change the operator. In conclusion, data consumption discrepancy, because of its unfairness is one of the most important arguments against net neutrality.
- **Reduced income from internet uses limits infrastructure improvements** - this argument has been presented as a pro-net neutrality rule, however, broadband investment discussion has two sides of the coin - ISP and content provider.

Accordingly, to [70], ISP claims that they should have full access to administer and steer the network in the pipelines as they are owners of the infrastructure. Furthermore, ISP argues that because of constant improvement in the field of network elements industry, it is challenging to keep the pace in regard to latest applications and services, which are becoming more challenging for the network to process. [70] split the problem into two levels: micro and macro. At a micro level, ISP claim that to meet the subscribers quality demands and to repay the infrastructure costs, content providers should pay an extra fee, otherwise, it will be the end customers who cover the investment, while at a macro level additional network investment will accelerate the deployment of next generation of equipment.

- **Illegal activity monitoring** - by the rejection of net neutrality rules and non-data discrimination, illegal content might be viewed and easily accessed [74]. However, net neutrality proponents argue that net neutrality equals free speech (*Freedom of expression* argument from the previous section), however, the question is: to which extent ISP should allow for the uncensored and unlimited access to particular content? Data classification, sort and, if necessary, discrimination should be applied in the context of illegal and unlawful content at the outlined ranges.

3.2.4 Nationwide rules adaptation

In the view of various approaches to this multi-faceted topic, it is crucial to address the question of network neutrality through an international approach. The purpose of this subchapter, therefore, is to provide an explanatory arena aimed at presenting the net neutrality rules in different parts of the globe. Consequently, two regions have been selected, scrutinized and incorporated - EU and the US. The argumentation behind these following regions have been identified as a key one is because of both of them present diverse approaches towards net neutrality - open versus close internet policy. In addition, a broad literature study is frequently referring to the current policy situation in these particular regions.

3.2.4.1 Net neutrality rules in the European Union

The EU has adopted a fully supportive net neutrality position in the discussion ground, which means no throttling, blocking, bottlenecking, speeding or slowing down the data in the network traffic [10]. The idea of free, non-discriminated internet, allows content and services providers to deliver the data packages on equal terms via the high-quality open internet infrastructure. Furthermore, as [10] explains equal traffic mean that at the same time, even treatment allows reasonable daily traffic management in regard to

justified technical limitations. The EU's policy in the framework of net neutrality depicts the picture below:

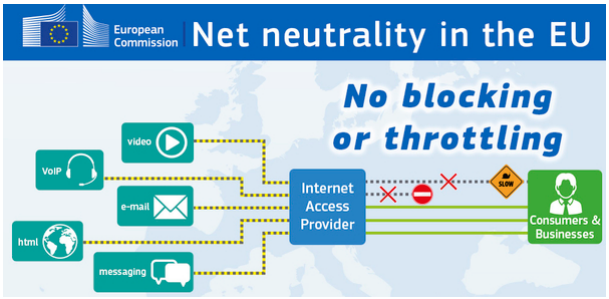

Figure 3.9: EU policy regard to net neutrality concept [10].

Net neutrality aspects are the part of the Digital Single Market (DSM) strategy, which aims to open up digital opportunities for EU citizens, businesses and enhance Europe's position as a global leader in the fields like digital marketing, e-commerce or telecommunication [76]. Accordingly to [10], the approved net neutrality regulations poses a major accomplishment in achieving more digitalized, modern and better ICT environment in Europe. EU's position in the framework of the DSM and net neutrality has followed the adoption of Regulation 2015/2120 on 25 November 2015 by the European Parliament and the Council. Accordingly to Article 3, paragraph 3 of the [77]:

"Providers of internet access services shall treat all traffic equally, when providing internet access services, without discrimination, restriction or interference, and irrespective of the sender and receiver, the content accessed or distributed, the applications or services used or provided, or the terminal equipment used [77]."

Article 3, paragraph 3 clearly prohibits any traffic differentiation, segmentation or filtering. The bodies which are responsible for monitoring and ensuring compliance with the provision of the open internet strategy are National Regulatory Authorities (NRAs). Accordingly, to the DSM strategy, each of the EU members has its own representative organization like Autorité de Régulation des Communications Electroniques (Arcep) in France or Post- och telestyrelsen (PTS) in Sweden [78] or (mentioned in the beginning) Danish Energy Agency (DEA). All these diverse institutions collaborate in the fields like traffic management, network measurements and finally net neutrality rules safeguarding. In order to bring the technical expertise and guide the NRA through the feasibility of the regulations, the EU has established the Body of European Regulators for Electronic Communications (BEREC). The European law, which established BEREC said that the

organization should provide advice to European institutions and NRAs in the field of electronic communication. Furthermore, Article 5(3) of the Regulation EU 2015/2120 explicitly obliges BEREC to issue guidelines for the implementation of the obligations of the national regulatory authorities [77]. As a result, BEREC has drafted the guidelines for NRAs to help with data differentiation monitoring and provision of internet access services on equal terms for all the end-users [79]. What the BEREC's guidelines introduce to the overall debate is the provision of interpretation on how specialised services (SpSs) shall be delivered. The term "specialised services" is one of the keys in the holistic picture of the discussion between net neutrality and network slicing, however, in order to maintain smooth transfer of knowledge, firstly the Internet Access Service (IAS) should be defined. Accordingly to the Article 2 of the [77] Regulation:

"Internet access service means a publicly available electronic communications service that provides access to the internet, and thereby connectivity to virtually all endpoints of the internet, irrespective of the network technology and terminal equipment used [77]."

Paragraph 10 of the BEREC Guidelines [79] provides the interpretation of the expression "publicly available". Services that are given not only to a predetermined group of users but to any client who wants to pay for the service are considered to be publicly available. If a service is offered only to a predetermined group of end users, then it is recognised as not publicly available. Following that, crucial insights must in regard to the importance of the SpS. Accordingly to Article 3(5) of the BEREC Guidelines [79]:

"Providers of electronic communications to the public, including providers of internet access services, and providers of content, applications and services shall be free to offer services other than internet access services which are optimised for specific content, applications or services, or a combination thereof, where the optimisation is necessary in order to meet requirements of the content, applications or services for a specific level of quality [79]."

This description is further developed by paragraph 101 in the Guidelines by the characterizations of SpSs:

"101. These providers are free to offer services referred to in Article 3(5), which BEREC refers to as specialised services[26]*, only when various requirements are met. Article 3(5) provides the safeguards for the provisioning of specialised services which are characterised by the following features in Article 3 (5) the first subparagraph:*

- *they are services other than IAS services;*

- *they are optimised for specific content, applications or services, or a combination thereof;*
- *the optimisation is objectively necessary in order to meet requirements for a specific level of quality [79].”*

At the bottom of the page, it can be read that under the 26 prefix means: *26 Network-slicing in 5G networks may be used to deliver specialised services.* Consequently, it can be assumed that 5G network slicing is considered as an SpSs. Following that, paragraph 110 provides a limitation within the SpSs by stating:

“110. If assurance of a specific level of quality is objectively necessary, this cannot be provided by simply granting general priority over comparable content. Specialised services do not provide connectivity to the internet and they can be offered, for example, through a connection that is logically separated from the traffic of the IAS in order to assure these levels of quality [79].”

As a result, the guidelines indicate a binary split between IAS and SpSs, without identifying any third category. An important overview of the convergence between IAS and SpSs describes Article 3(5) second subparagraph by stating:

“Providers of electronic communications to the public, including providers of internet access services, may offer or facilitate such services only if the network capacity is sufficient to provide them in addition to any internet access services provided. Such services shall not be usable or offered as a replacement for internet access services, and shall not be to the detriment of the availability or general quality of internet access services for end-users [77].”

Based on the following statement, three conclusions can be drawn:

- The SpSs cannot be utilized for any kind of the replacement for IAS.
- The SpSs cannot provide harm or damage to the availability or general quality of IAS for the end-users.
- The network must be specially adjusted in regard to the resources capacities to bring the SpSs in addition to any provided IAS.

3.2.4.2 Net neutrality rules in US

The regulatory status of internet services in the US has been a subject for a public debate for decades. Many parts of the discussion were to find an appropriate balance between the

main regulatory body Federal Communications Commission (FCC) and the sovereignty of the broadband delivery enterprises. In order to fully understand the meaning and the regulatory ecosystem in the US, the reader must be familiarized with the origins of the debate and its subsequent amendments.

The FCC was formed by the *Communications Act of 1934*, which regulates communication mediums like television, radio, wire or satellite. The act was divided into the sets called "Titles", where the most relevant in the context of this discussion was *Title II: Common Carrier*. Accordingly to [80], common carrier meaning can be interpreted any business entity whose main business is transporting things on behalf of people. The idea of this law was to guarantee that the businesses being paid for transport (goods/people/data) must do it in the agnostic and neutral way, regardless of the type of good or content of data. In the framework of data delivery, industries considered under Title II of 1934 act being a common carries mean that they must be end-to-end indifferent for the transportation of the data; the service providers could not charge more based on the dialling the number, person being connected or the content of the talk. As it can be read:

"It shall be unlawful for any common carrier to make any unjust or unreasonable discrimination in charges, practices, classifications, regulations, facilities, or services for or in connection with like communication service, directly or indirectly, by any means or device, or to make or give any undue or unreasonable preference or advantage to any particular person, class of persons, or locality, or to subject any particular person, class of persons, or locality to any undue or unreasonable prejudice or disadvantage [81]."

Consequently, as [82] explains, telephone lines as the main communication medium have been classified as a common carrier, which allowed the FCC to took over the regulation management. Everything had changed in the 1980s when the digital transformation enabled to commercially use dial-up modems for internet connectivity and as a result, the type of information has shifted from human voice to computer files. However, the mechanism for the delivery had not changed at all. The DSL providers, who were utilizing the telephone wires to transmit data packages were still identified as a Title II Common Carriers and consequently, not allowed to throttle, discriminate or differentiate the data based on content. The next stage of the process was the Telecommunications Act of 1996, which outlined the distinction between the services that relays on the network operations like websites or Pay-Per-Call Information Services (provide users with the telecommunications services, including audio information, entertainment or conversation [83]) to be classified under the Title I (Information services) while the transmission of those services over the existing telephone systems would prevail as Title II. However, as [80] notices, the 1996 act abstained from the classification of the upcoming new, faster

broadband ISP to Title II as common carriers. As a result, new “high speed” technologies remained unregulated and sought to reduce the regulatory impact in order to lessen the entry barriers for telecom and broadband providers. In the beginning, there was a lot of competition at the US telecom market, however, last 20 years have been moulded by the massive consolidation of players like Comcast, AT&T, Time Warner Cable, what led to regional monopolies in many locations. This type of strategy created the situation where the consumers had fewer choices than ever [84]. FCC in their report [84] identified that for the service at least 25 Mbps downstream and at least 3 Mbps upstream, over 50% of households have zero or one choice for a provider. Inf 8 years after the incorporation of the Telecommunication Act of 1996, decided to reshape the regulations and classified new broadband internet providers as a weakly regulated Title I Information Services, as there was no control over the ISP. Following this decision by FCC, professor Tim Wu created the term ”Network Neutrality” in his famous [68] and the public debated on regulations has commenced.

The discussion resulted in the series of lawsuits and legal challenges whether FCC can regulated ISP with regard to net neutrality concepts. Among the most frequently cited is the 2014 Verizon Communications Inc. v. FCC, when the court determined that FCC did not have rights to impose the net neutrality regulations over the broadband providers and as a result [85] . Other famous case was in 2007 when Comcast was caught throttling widely unpopular BitTorrent protocol, frequently utilized for pirating software and media [86]. This case was also lost by FCC, as the judge assessed that FCC did not have rights to force Comcast to stop the throttling. In response to these events, in 2015 the FCC proposed clear and transparent rules to enforce rules to preserve and guard the open internet as a medium of free expression and new innovations. In other words, legal authorities reclassified broadband providers under *Title II the Communications Act*. As FCC explains in [87], this strategy aimed at assuring the open internet practices like no blocking, no throttling and no paid prioritization.

The major update in the FCC’s approach towards net neutrality was introduced on 11 June 2018, when current chairmen Ajit Pai repeal the non-discriminatory policy, enacted in 2015 [88]. FCC’s *Restoring Internet Freedom Order* provides a rules framework, which structures the regulations and guides through the legal area for the MNO and content/service providers. As FCC’s explains in [89], the model paves a way towards better, faster, more reliable and cheaper internet services for all US citizens. As main pillars, the agency identified customer protection, transparency and the removal of unnecessary regulations to promote broadband investment. By introducing a new framework, FCC forecasts the significant investments in the network infrastructure. The problem, which FCC tries to fix is the lack of funding to deliver high-quality internet services in remote, rural areas. [89] lists small-town operators, fixed wireless companies, municipal

broadband providers, electric cooperatives and many others as the key bodies, which will benefit from new rules as these are the companies which suffer from lack of the funding. Consequently, hardly accessible areas will have internet connectivity, which previously was only in densely populated areas. [90] outlines that rules from Title II of The Communication Act like blocking, throttling and paid prioritization will be now accepted. However, [90] states that on the other hand, the aspect like free-speech and innovations might prominently suffer from the new framework as there is not an equal ground for start-ups to compete with IT giants as they cannot afford the prioritization fee.

3.3 Network slicing in context of net neutrality

This section outlines why network slicing might be seen as a violation of net neutrality.

As stated one of the traits of network slicing is Slice-aware RAN, which means that depending on the network congestion, the network is able to redirect and reorganize the resources, the way where is needed. However, what in the scenario where f.e. media services consume the data committed for ultra-low latency cases? This is, of course, one of the exemplary scenarios, where data from one source is throttled because there is a lack of data in other use cases. It is a widespread argument, [18] that industry poses a question whether the implementation of the network slicing is the violation of equal-data treatment policy adopted by the EU in "Regulation (EU) 2015/2120 of the European Parliament and of the Council of 25 November 2015" where accordingly to the Article 3, paragraph 3 no data throttling is allowed [77]. It is important for the reader to acknowledge the sense of convergence here because the net neutrality and 5G are comprehensive concepts, where network slicing is their common point.

3.4 Subconclusion

It can be concluded from the state of the art that both - net neutrality and 5G technology are broad concepts, which influence many different areas of business, industry and law. The upcoming standard is forecasted as a technology beyond a regular faster upgrade from the LTE. To deliver a wide array of use cases, 5G is composed of many elements such as MEC, SDN, NFV and Network Slicing. Cloud-related approach helps MNO to scale their businesses in regard to customers' demands. The second scrutinized pillar was net neutrality regulations in the EU and the US. While the EU has pro- equal data treatment regulations, the FCC in the US decided to remove net neutrality and allow MNOs to charge more for the prioritizing lanes for content/service providers to reach their products faster. Chapter set a knowledge foundation for the pillars of this project, which are utilized in the subsequent chapters.

Chapter 4

Literature review

In this chapter, a literature review is conducted on the topic of network slicing and its influence on the net neutrality concept. Here, several relevant articles are reviewed to convey ideas and knowledge established in the field. This knowledge will be then used as a foundation for the coming chapters associated with the analytical model, field study and finally the core chapter 7 - *Net neutrality & 5G analysis*. Additionally, the knowledge assists in the process of creating questions for the stakeholder interviews.

The broad literature review process resulted in identifying key papers, where scholars had already touch and discussed the subject. It must be mentioned that besides the scrutinized research papers, blogs have also been reviewed, however, because of the academic character of the project, the following chapter analyses academical-oriented studies.

One of the initiatives taken in the researched field was done by the Netherlands Organisation for Applied Scientific Research (TNO) in [18]. Based on the multiple sources (government authorities, industrial and standardization bodies) the [18] provides the assessment of 5G/Net neutrality rules correlation. The analysis firstly involved the identification and characterisation of essential connectivity parameters of the envisioned applications in three sectors chosen by TNO: Media, Intelligent Transport Systems and Public Safety. Secondary, based on standardized by 3GPP architectural models, the research recognised technical options of 5G roll-out. Thirdly, the mapping process between European Union Net Neutrality Regulations and Guidelines to these options, in the context of selected application domains has been performed. Lastly, the consolidation evaluation between 5G and net neutrality was done. Authors researched similar fields related to the problem in both - engineering and regulatory aspects. Starting with 5G ingredients, researches reflected in regard to elements like Network Slicing, Edge Computing and QoS differentiation (described in sub-chapter 3.1.1). Following that, researchers indicated pivotal points in EU Regulations and BEREC Guidelines like the importance of SpSs, IAS

and the scrutiny of the relations between distinguished net neutrality articles and paragraphs in the framework of 5G. As a result, a broad analysis has been obtained, where authors developed nine scenarios of various data flows schemes and analyzed if flows can deliver the connectivity in regard to the potential regulation interpretations. Models involved a wide array of diverse options like QoS differentiation within IAS, impact SpS on IAS or multiple IASs with different traffic management settings in one network. This internal overview of the already performed work helps to shape the following work as the repetition would not provide the novelty in the academical environment. Nevertheless, the report provides a set of intriguing statements, which significantly enrich the debate. The most important statement is that the nine scenarios do not indicate any contradictions between 5G and network slicing. Consequently, the subsequent statement has been made:

"The technological neutrality of the Regulation allows 5G network technology itself to develop. There is no a prior ban on any 5G technology ingredient [18]."

Authors indicates that the problem is not in the type of utilized 5G ingredient but, what matters is the way 5G slices support services and applications rather than the technology itself. Following that finding, the next one was made:

"The assessment of the alignment of 5G with net neutrality rules depends not only on the 5G technologies but also on the specific combination of services, applications and network architecture. It is not possible to come to an overall assessment with a single outcome on the alignment of 5G technology with net neutrality rules [18]."

The researchers highlight the fact that the assessment of the compliance with net neutrality rules is whether the supported services adhere to the conditions and rules of previously mentioned IAS and SpSs. It is these conditions assess the possible space for the MNO to deploy the slices.

The investigation evaluates the highest level of complexity is expected to occur in two models: *The impact of Specialized Services on Internet Access* and *The Objective need for optimisation in Specialised Services.* In the holistic view, in the first model IAS, which the regulation aims to protect from degradation, can be in the same slice or in the other slice where the SpS is provided. In addition, in one slide there might be a high number of IAS provided with different traffic management settings, which potentially might lead to the traffic flow prioritisation based on QoS differentiation. Authors outline the fact that in the following circumstances, the question of whether the slice is able to be flexible enough, or in other words - has enough resources - to fit SpS and IAS without the QoS

trade-off is crucial. The second model, which may pose a challenge for the MNO - *The objective need for optimisation in Specialised Services* - asses the necessity of the QoS usage based on a specific level of quality. In other words, the researches emphasise the fact that the QoS requirements are usually expressed in ranges (f.e. 20-40 ms latency in VR or 10-100 ms latency in URLLC) rather than point values. Consequently, there is not an ultimate parameter which would be able to asses the alignment with net neutrality regulations. Finally, it may be concluded that expected complex topics are unsuitable for a generic "rule of thumb" approach and require deep and detailed analysis by NRS and MNO.

The research is being closed with a three-step procedure that provides the recommendation for MNO how to succeed in the slicing creation in regard to data non-discrimination policy [18]:

1. Determination of QoS requirements in the use case.
2. Development of the 5G architectural options to support the defined requirements.
3. Evaluate the possible alignment of services combination and architectural with net neutrality rules.

The next scientific research in the context of potential conflict between net neutrality regulation and future 5G services, particularly regarding network virtualisation was done by [91]. The main goal of the research was to present the discussion on the challenges of whether traffic optimisation is objectively necessary for a complex technological environment that envisions creating on-demand, priced network slices accordingly to the QoS requirements.

[91] starts the study by presenting the state of the current status in regard to technology and regulations. As the main enabler that is perceived to underpin the 5G connectivity is network slicing. Authors highlight the fact that because of the wide use case diversity, ability to design and implement the logical channels is essential for the upcoming standard. In addition to the overall debate, [91] explains that the possibility to lease and utilize slices by the third parties (non-telecom related companies) from the infrastructure providers (telecom-related companies) will help to build better, more complementary or new services in the network resources optimised method. Besides slicing, Mobile content delivery network as a service (CDNaaS) together with Traffic Offload as a Service (TOFaaS) and Machine Type Communications as a Service (MTCaaS) are described. The authors justify the importance of enabling new capacities of the 5G network in regard to ETSI NFV or virtual network infrastructure (VNI) to handle the unexpected and abrupt network growths. These concepts are based on described earlier (sub-chapters 3.1.3.2 and 3.1.3.3). When it comes to the traffic management and net

neutrality rules, [91] analyses the set of rules in EU which have been analysed in the sub-chapter 3.2.4.1. Consequently, the authors explain the roles of NRSs, DSM strategy and cite Article 3, paragraph 3. Regulation 2015/2021 where the equal data treatment is introduced. Authors also acknowledge the BEREC interpretation guidelines and the IAS/SpS correlation. As a result, it might be concluded that the state of the art analysis between the following project and [91] are aligned. The core of the paper is chapter 4 - *Policy discussion*, where the authors interpret Article 5(3) of the DSM Regulation (network resources optimisation in the context of meeting the services requirements).

The debate was four pillars: the need for the optimisation in order to meet the requirements, an extension of the CDN to the mobile, users' rights in the resource-sharing networks and the aspects of the 5G innovation in regard to net neutrality rules. At first, the authors highlight the fragment of Article 5 of the DSM Regulation, where EU states:

"The optimisation is necessary in order to meet requirement [...] if the network capacity is sufficient to provide them in addition to any internet access services provided [77]."

[91] argues that from a purely technical point, wireless network resources in 5G are, by definition, already optimised to provide the appropriate performance required by the applications. In [91]'s view, paid prioritisation case seems to be easy to interpret accordingly to the current rules and state-of-the-art technologies as the only form of data favouring is allowed when it deals with the services, where traffic optimisation is crucial to meet the requirements. Authors argue that as network slicing concept was planned to enable better network capabilities accordingly to the requirements of application-layer services and because of that it arguably constitutes a for of the traffic discrimination on commercial grounds. In the context of the second issue - CDN to mobile, [91] analyse the situation of services like IPTV, which are steer end-to-end by the operators with all necessary QoS. Authors highlight the fact that the utilization of new virtualisation functionalities, which interconnect the private networks and cloud services directly to the base stations, will allow better QoS to the end-users and the creation of an alternative route to provide demanded services. Consequently, the approach of the congestion-free network, which is able to enhance the user's experience has not been controversial for the net neutrality advocates. The third analysed aspect is the users' rights-related. This argument was already studied in the following work while discussing the pros and cons of net neutrality (sections 3.2.2 and 3.2.3). [91] indicates paragraph 122 from BEREC guidelines as a key to understand the overall issue:

"While IAS and specialised services directly compete for the dedicated part of an end

user's capacity, the end-user himself may determine how to use it [79]."

Thus, as [91] explains, NRA should not recognise an infringement of Article 3(5) as a paragraph 122 of BERREC's guidelines continues to be analysed:

"Detrimental effects should not occur in those parts of the network where capacity is shared between different end-users [79]."

Authors state that in the wireless networks, current technologies enable to allocate the radio spectrum resources to the users in a dynamic way, consequently, the user rights are not jeopardized by the 5G commercial deployment. Finally, the last pillar - innovation aspects in regard to the 5G network. It is important that in contrast to the following work, the following domain was framed in the overall picture of pro/against net neutrality debate, while [91] sharpen this argument in regard to 5G. This tactic allowed to avoid the duplication of the academical research and provide smoother knowledge transfer. Nevertheless, the [91] mention that EU regulation recognises SpS, which cannot be delivered without best-effort network and traffic optimisation necessary in those cases. In addition, authors notice that against net neutrality rules might threaten to achieve full innovation potential in regard to enablers like cloud services, which the key to the disruptive and entrepreneurship digital transformation of many industries. [91] describes the correlation between the general increase of the service quality in the broadband networks through higher investments in the infrastructure, rather than a better resources optimisation. This aspect is analyzed by authors also by citing BEREC guidelines where accordingly to paragraph 112:

"A service that is deemed to be a specialised service today may not necessarily qualify as a specialised serviced in the future due to the fact that the optimisation of the service may not be objectively necessary, as the general standard of IAS may have improved [79]."

Given these points, authors close the discussion with a few crucial for overall assessment remarks in relation to the 5G/net neutrality debate. [91] emphasises the meaning of technological evolution and its influence over the innovation as 5G networks will dramatically lower the entry barriers to the infrastructure through converting special needs into the operational expenses for the new use cases, which cannot be currently predicted. [91] statement in this debate is the fact that the problem of imposing the neutrality will prevent fast and slow lanes but rather the significance of the technological breakthroughs which will be essential to meet growing heterogeneous demand in a more efficient and transparent way.

The last examined study was [92] done by Rysavy Research - a consulting company, which is specialized in wireless technology-related projects like standards evolution, spectrum requirements or system design. The reason, why this particular document was selected to showcase the reader is the fact that Rusavy Research is an American company and as explained in sub-chapter 3.2.4.2 the net neutrality debate there has a different trajectory than in the EU. It is important to mention that the project is created in the year 2017 when the FCC reassigned broadband under *Title II the Communications Act*, after the series of lost processes against the agency and before the newest updated done by the FCC under current chairmen. Consequently, even though the paper expresses the opinion in regard to previous regulation, the work still significantly enrich the discussion by providing the comments in regard to pro-net neutrality approach in contrast to the current against-net neutral strategy.

In the beginning, the authors frame the collision between Title II-Based Open Internet Rules and 5G standard. Consequently, the fact that 5G classification as a *Title II Common Carrier* service and it intends to keep the technology neutral, happened already previously with former wireless technologies like LTE, where QoS management was first introduced in order to enhance the user experience. In [92] opinion, assigning the 5G under Title II may significantly undermine the profitability of the investment and provide hurdles during the commercial roll-out. Furthermore, it is accentuated that instead of supporting packet non-discrimination policy, MNO should be allowed to use QoS differentiation in order to serve different use cases and experiment with various business models that could support them. [92] communicates strong concern whether Title II as the baseline regulation for 5G is a good choice. Authors alert that heart monitoring transmission to the hospital emergency room must not be managed the same as video streaming. Following that, it is stated that in the worst scenario, the full potential of 5G may never be reached. Then, in the next section, [92] elaborate about the mechanism of the QoS and packets flow. It is emphasised that, in contrast to the LTE, 5G employs more sophisticated data transmission design, which are able to handle various types of traffic flow. Authors refer to the network slicing architecture and describe the validity of QoS employment as one of the essential elements of network slicing. The third paragraph discusses the negative impact of the pro-net neutrality on the 5G standard. [92] begins the discussion with the explanation of network traffic congestion and limit amount of available capacity in the cellular networks. The perceived problem is the fact that when demand exceeds capacity, the network congestion influences the system performance and eventually the quality of services drop. Furthermore, as the congestion gets worse, the packets delays or drops increase to the point where the network cannot function properly and fails entirely. The way MNO mitigates the negative effects of the exceeded network traffic is by the deployment of more cell sites, buying more spectrum licenses and more

sophisticated equipment. However, as [92] notice, it is impossible to fully eliminate the congestion. An interesting example might be even a small group of users, who decided to stream high-definition video (eMBB category of use cases) in VR glasses, which can eventually consume all the resources from one cell. Furthermore, the authors argue that MNO cannot predict the number of users present at any moment in any location, nor can they know which application they will use. It is stated that modern telecommunication systems require state-of-the-art congestion management tools, which provide full network reliability, especially in regard to medical devices or autonomous cars. Finally, [92] states that 5G environment can ensure critically, life-threating connections being protected from congestion effects only if QoS and congestion management tools, build into the standard has a full allowance to perform otherwise open internet rules might significantly undermine the economic and engineering potential of the upcoming standard.

Chapter 5

Introduction to the analytical model

In this chapter, the analytical model utilized for the research is discussed and applied for the study. The model is the next step in the adapted methodology (figure 2.1), after the *Literature Review* and before *Field Study*. As explained in chapter 2, this conceptual framework is incorporated to examine how different theories, methods, approaches can be used to combine into one final 5G/Net neutrality debate. More specifically, this part frames the knowledge from the previous literature-based section into the most relevant dimensions of the debate. This tactic allows to plan and organize question forms for the interviewees as they play various roles in the overall telecommunication ecosystem. As a result, in the holistic view, the reader obtains well-structured study in regard to the complex and multi-faced problem which is 5G/Net neutrality dispute. The knowledge is framed within four sectors: *Use cases provision*, *Network engineering*, *Innovations facilitation* and *Infrastructure investments*. The detailed descriptions of why the following areas have been chosen and what exactly do they involve is included below.

However, it is crucial to highlight that with the intention of achieving the best possible knowledge transfer and the research organization, this part outlines only the pillars of the debate. The interviews management process (introduction of interviewees, questions categorizations and correlation) can be found in the next chapter 6.

5.1 Use cases provision

Above all else, the aspect related to the use case provision must be researched. A broad literature study indicated that 5G is envisioned as much flexible concept, rather than typ-

ical faster and more reliable upgrade from LTE. Furthermore, the use cases significantly vary - starting with high data demanding content streaming services, through oceans of IoT devices with huge coverage needs to ultra-low latency scenarios like e-health, military or autonomous cars. The chapter 4 outlined some of the scholars' opinions in that field like the statement in [92], where the author considers equal data treatment regardless of the scenario is impossible. However, the study conducted by [18] indicates that among nine scrutinized scenarios only two might pose a challenge because of engineering capacities of the network (next section). An answer whether the whole potential of 5G can be provided, without the glitches or brakes must be certain. Even though the EU [77] has regulated SpS, there are still unclarities and discerns if MNOs have the possibility to deliver the services on time and with all demanding conditions. For example, lack of the connectivity for the critical use cases which require special data treatment like e-health, autonomous cars or smart grid might result in huge economic losses (because of the electric power generation retention or calamities like car accidents), consequently, this pillar is considered as the most important in the overall discussion.

5.2 Network engineering

The second highly critical pillar is the engineering side of 5G and its capacitive possibilities. As stated in section 3.1.2, the upcoming standard is specified as cloud-based architecture, rather than an upgrade from previous standards. As there is a strong connection between EU pro-net neutrality regulations and engineering possibilities of 5G (section 3.2.4.1) this aspect must be asked while interviewing the experts. Even though the fifth generation of the wireless systems is equipped with new building blocks, concepts and technical solutions, evading the latency completely is impossible (statement shared by [92], explained in 4). As such, the next pillar of the following master thesis is the technical side and the discussion on how to enforce proper QoS in regard to the engineering side of 5G.

5.3 Innovations facilitation

Providing equal chances for small players against corporations, who can already afford an extra fee for MNO, is one the principal arguments of pro-net neutrality proponents (section 3.2.2). This problem, in regard to the 5G, was perceived by [91], where authors indicate that the real 5G/net neutrality challenge is within the frame of innovation. Paid data prioritization might hamper the true disruptive potential of many start-ups, which are seeking for their business opportunity in 5G as a broad and flexible technology. As explained in the section 3.1.1, the standard operates within the areas of IoT, Automotive,

Media, e-Health and many other industries. Consequently, it opens new, engineering possibilities for still-developing companies to move their products into a higher level. The third selected pillar of the analytical model is the research whether the commercial deployment of 5G and net neutrality rules will be beneficial or rather against incubating companies.

5.4 Infrastructure investments

Similarly to the third pillar, the network investment issue is also a part of the larger net neutrality debate, not necessarily 5G-related (see section 3.2.3). However, one of the arguments of against-net neutrality advocates explained at [92], is the fact that if MNOs charge content providers more for dedicated, prioritized pipelines, this money can be spent on network equipment upgrades or more spectrum acquisition and eventually eliminate the possibility of life-threating scenarios (like in the scenario where the autonomous cars lack the connectivity because of the nearby VR massive content streaming). As such, the analytical model applied for this particular debate, must take under the consideration issues related to the investment as the balance argument for against-net neutrality proponents.

5.5 Anaylitical model summary

The following pillars have been distinguished as core points of the discussion based on the previously performed literature study. The next chapter 6 *Field study* matches the identified areas with the answers from the interview, yet without performing any deep analysis and discussion as this part was incorporated as the chapter 7 *Net neutrality & 5G analysis*.

Chapter 6

Field study

Accordingly to the methodology model adopted in chapter 2, the following part is incorporated to properly frame the answers from the interviewees in regard to the four pillars indicated in the previous chapter 5. This way, the reader will understand the meaning of the questions and the answers as the questionnaire experts represent various segments of the overall ecosystem, consequently, the statements can be biased. Firstly, the reader is acknowledged with the stakeholders' roles in the holistic picture, and in the second part the claims obtained from the interviews are categorized and showcased.

6.1 Stakeholders' mapping

Telecommunication environment is complicated regularity, where different bodies represent diverse businesses. For the purpose of better stakeholders understanding, a concept of "A Two-sided Market Model" has been adopted. It must be emphasised that the model is based on the discussion between ISP and content/service providers, which has been described in chapter 3. However, as this particular chapter refers to the distinct bodies, it was decided to introduce the model here, rather than in the previous chapters.

Researches in [11] consider the internet market as a two-sided network which is connecting the end users on the one side and content and applications providers on the other. Furthermore, as [11] continues to explain, the network is controlled by ISP, which offers the customers access to the whole internet through physical or virtual pipes of certain bandwidth. On the other side, the ISP carries the digital services provided by the service/content providers. The concept introduced by [11] involves considerations in regard to fees, monopolies or demand albeit as mentioned in the Delimitations section 1.3, the internet economy is not the part of this research. A simplified version of the model was adopted and showcased below as a figure 6.1.

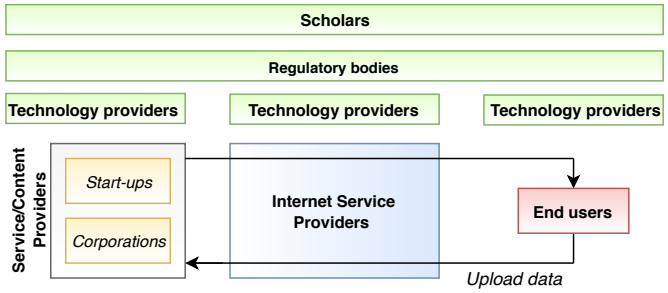

Figure 6.1: Stakeholders' correlation (own picture inspired by [**11**]).

The three blocks connected with the arrows showcase the described relationship between the ISP and content/service providers. As stated in section 3.2.2, one of the arguments of pro-net neutrality proponents is that the non-discriminate web allows small companies to became next Google or Facebook, because they would not have to pay an extra fee for ISP. Consequently, while looking at the debate the enterprises can be divided into two camps: start-ups (which cannot afford the fee) and the corporations (which can get access to prioritized, faster internet lines). These companies provide services to the end user via the physical equipment, managed by the ISP to the end users. On the other side of the platform - the end users can be also considered as content providers, because of all the data in form or pictures, videos, emails or personal information is being sent back to the content/service providers. The overall system can be considered a feedback loop between content/service providers and end users, with the utilization of the network infrastructure managed by the ISP. Above this correlation, three green rectangles symbolize the entities indirectly involved in the process: Technology Providers, Regulatory bodies and Scholars. To begin with the Technology Providers, at each of the steps, distinct engineering products are needed to launch the service and to properly manage it from the network side. These hardware/software products can be special terminals like tablets, smart-phones, AV/VR glasses or TV, which are able to receive a particular service from the content/service providers, through ISPs' lines to the end user home. Other examples are the vendor providers, which build the physical network for MNO and equip their clients with telecommunication products like antennas, core network elements or fibres. In order to highlight the differences between the vendors' profiles, Technology Provider rectangle has been divided into three particular parts, where each of the strips, corresponds to different stakeholder, that supplies. Next, the regulatory bodies, like NRAs, which monitor eventual abuses of power and frame the laws over all the entities. Finally, the Scholars, who research the correlation between the stakeholders.

As the aim of this thesis is to provide a debate about whether the net neutrality might pose a challenge for the 5G, besides the literature review, the interviews must

have been accordingly adjusted and incorporated. As a result, the following list involves questionnaired bodies:

- **TDC** - The first contacted stakeholder was the representative of the ISP. TDC is Danish MNO, which brings the connectivity in Denmark via the digital communication services, mobile, televised and digital content [93]. The company signed contract with Ericsson (vendor provider), to roll out nationwide, commercial deployment of 5G standard, which will enable to bring the country on next level of the wireless connectivity [94]. As the MNO is strongly interested in 5G, it opens a great possibility to obtain the perspective of MNO in regard to the scrutinized net neutrality regulations. However, instead of the regular interview, to bring the higher quality and insights to the project, the strategy adopted for this stakeholder were two consultation sessions. The summary of the consultation sessions was attached at the end of the project as a appendix B.1.

- **TT-Network (TT-N)** - The next reached body is a company which is engaged in the unification and development of the telecommunication infrastructure for Telia and Telenor, which are Danish MNOs. Accordingly, to the [95], TT-N mission is to develop and improve RAN operability for both of the operators. The company managed to succeed in merging two radio networks for the previous generation of wireless generations (2G, 3G, 4G) and currently working on technological upgrades, which utilization will be the key component for approaching 5G standard. As TT-N closely cooperates with MNOs, the company's profile is rather ISP than regulatory or content/service provider. The transcription of the interview can be found appended as an appendix B.2.

- **Teleindustrien (TI)** - TI is the voice of the industry during the social and political discussions, in other words, the body represents companies like TDC, Telia or Telenor interests, policy and businesses. The scope of the TI are fields like cybersecurity, masts database management, indoor connectivity and net neutrality [96]. The TI is responsible for managing and administering the net neutrality forum where all the issues in the subject can be discussed by the companies. The bodies involved in the forum creations are Danish MNOs like TDC or Telia, content/service providers (Facebook, Microsoft) together with Danish regulatory body - DEA [97]. TI after the TDC and TT-Network is the third body, which represents the ISP, rather than content/service providers or regulatory body. The interview was appended as an appendix B.3.

- **DEA** - the body manages telecommunication related aspects like frequency regulations and licensing, masts and antennas, roaming and, conducting the market

research and imposing obligations on suppliers and finally as a BEREC enforcement, the net neutrality EU law [98]. DEA takes the responsibility for negotiating the telecommunication directives and implementing the directives in Danish legislation [99]. The profile of this regulatory body perfectly matches the scope of this research. The transcription is attached as an appendix B.4.

- **TNO** - This stakeholder represents the Scholar group, which has a neutral approach, without any biases towards ISP or content/service providers. The interview was conducted with the authors of [18], who made research on net neutrality and 5G coexistence. This study was detailed in the chapter 4, where the [18] was one of the three scrutinized works. The scope of the researches covers with the main subject of the following master thesis and creates a perfect candidate to interview and reflect. The conversation can be found as an appendix B.5.

- **Absolute Zero** - is a Danish start-up, which is specializing in designing, manufacturing, developing 3D 360° cameras, together with dedicated cloud services for the user to upload and manage their content. Their main product - "Thor" camera is able to record and capture immersive VR content in various resolution models like 4K and 8K [100]. Moreover, Absolute Zero entered one the biggest telecom operator's innovation program for young enterprises - Deutsche Telekom's 5G prototyping program "Hub:raum", where the company seeks the opportunity to utilize the full spectrum of new standard features like low latency or extream data pipelines [101]. As a start-up in the telecommunication field, Absolute Zero is an excellent stakeholder to share insights on the innovations in 5G and net neutrality. The talk with the Absolute Zero's delegate was added as an appendix B.6.

6.2 Knowledge framing

The following part organizes data acquired from the interviews. Knowledge has been categorized into four categories, which corresponds to four main scopes of the debate (identified in the chapter 5) and accordingly fulfilled with the statements collected from the experts in particular fields. This part, similarly to chapters 3 and 4 is neutral, which means no analysis or deduction. The main debate is included as the dedicated chapter 7, where the statements from interview and literature are contrasted and studied. The second prerequisite which must be indicated is that part below highlights only the most crucial statements from the interviews, rather than outlines all the gathered data.

6.2.1 Use case provision knowledge framing

In the first instance, answers with respect to the 5G's use cases provision are presented. As the analytical model indicated, the question about full 5G standard's potential utilization and not being jeopardized by equal data treatment regulation must be answered. Starting with the ISPs' opinions in this regard, TDC does not perceives the hassle or risk in the provision of all 5G cases (appendix B.1). The company aims at realizing the adopted strategy for 5G connectivity provision. The next ISP-related company - TT-N, asked about the coexistence between net neutrality and 5G, provides the following argument:

"I have to provide society a secure service, means that you need to block others yes from having a decent service then we need to debate if that should happen. To begin with if you can provide a slice without having anyone else suffering from then I do not see the problem. If you cannot do that, then you need to sort of have a debate if we should prioritize these types of services and I believe we should because that 5G is different from 4G. We see other types of use cases (B.2)."

Author's discuss the fact that 5G takes the wireless industry beyond mobile applications industry. This insight is further debated in the next chapter.

TI explains the 5G/Net neutrality convergence in the following way:

"There is a high degree of uncertainty. Uncertainty in itself creates in our view a barrier to the development of 5G services because 5G is really expensive, it demands a lot of investments and if you do not have that certainty for business plan or services, then you are not that willing to invest your money [...]. That is basically as we see the problem right now and then we have a good dialogue with our administration our regulation. They have so far had a pragmatic view and this and that and I think in practice we have not had any problems with net neutrality (B.3)."

In the author's view, the uncertainty factor related to the net neutrality regulations poses a challenge for achieving full ROI from the upcoming 5G standard. On the other hand, the harmony between the neutral data policy and the promised 5G's use cases is perceived by regulatory side of discussion - DEA. As it was stated during the interview:

"The DEA finds that the flexibility of the EU Regulation and BEREC Guidelines on net neutrality makes it possible for 5G and net neutrality to coexist. The DEA is not aware

of any concrete examples of problems between 5G and net neutrality rules (B.4)."

In the view of TNO's representative (scholar group), the current market is still waiting for the case that only 5G can deliver (rather than old LTE architecture). Scholar highlights the fact that these type of SpS must be introduced to NRA whether they can be classified as cases with special QoS requirements.

"I think that everyone is looking at the first example of SpS but the new ones - not the one which runs over the LTE, these are the old ones, not very exciting but really new ones like automotive or factory. That will be introduced by the operator and studied by NRA and there is an outcome or judgment whether it will be allowed or not (B.5)."

Similar observations are stated by the start-up community, which highlight the youthfulness of the technology by stating that:

"If the technology delivers the promised data rates [...] then it will be an enabler for us to actually make video streaming in 8K (B.6)."

The aspect of the immaturity of 5G will be considered further in the next chapter together with the debate and analysis.

6.2.2 Network engineering knowledge framing

The second identified pillar of the discussion - *Network engineering* involves architectural aspects of 5G, together with the enforcement of proper QoS requirement with respect to the particular use case. As explained in the 5G network architecture subchapter 3.1.2, the element responsible for the QoS execution is UPF. Consequently, some answers are regarding this particular network element. However, the QoS requirements discussion is not only about how to enforce them with the new cloud-based architecture, but aspects like values of the particular parameters are equally important.

TT-N expresses opinion, that there is a divergence in context of the QoS requirements. As an example, author illustrate situation with the autonomous cars segment (which requires ultra low latency and high reliability network slices):

"We have been speaking with Volvo and Bosch and there is no chance that 5G will be able to handle that. Most of those autonomous case is being done in car. This vehicle-to-vehicle communication. I went to the government's 5G plan presentation and again

you hear politicians talking about the need for the low latency because of the autonomous cars. Two week later, I went to see Volvo's presentation and I heard that they say we do not need 2 ms of latency (B.2)."

In respect to the engineering changes, TT-N highlights the importance of cloud-based enablers to fulfill the wide spectrum of forecasted use cases:

"I think that for some of the low latency services you would definitely need a virtualized core very close to say the where the application is delivered. So the cloud computing power of close to the application (B.2)."

The next interview with TI, brings next insights in regard to QoS. The interviewee asked how important are the particular values answered:

"All these parameters can have different values on during the day, depending how do you manage your network. Because they change over the day, it should not be taken as an indicator for the net neutrality problem. You cannot look at these things. As a regulator, you need to look at the competition (B.3)."

The parameters fluctuation and change over the time of the day is one of the concerns raised during the interview. This matter is debated further on in the next chapter. In addition to that, the questions in the relation to technical aspects and QoS requirements have been also asked to DEA. The regulatory body asked about the possibility of inspection of the technical aspects like network architecture, stated that:

"This would only be relevant in relation to a specific case of non-compliance (B.4)."

Discussed aspects like QoS enforcement, network engineering and absolute value of measure was prominently commented by TNO's researched, who asked about the importance of value (in order to prove NRAs that the specific use case requires dedicated network resources) explained:

"The value is also important. As it is written in the guidelines, you need to demonstrate that you cannot achieve the desired quality of service over the regular internet. It would not be sufficient if you would say that I need low latency and the regulator would like to see how many levels of the low latency you would like to see or what is the difference so it is also the value (B.5)."

Subsequently this claim was further developed by the example:

"If you would say that you need 2 ms, that would be impossible to achieve with the current internet. If you would say at least 50 ms or 100 ms then that is a completely different matter. 100 ms can be achieved by the current internet. That depends on the guarantee if you are looking for. However the value itself is also important (B.5)."

Finally, the researcher explains functioning of UPF element:

"UPF is in the data plane and on top, there is a control plane which performs all the session management functions which control the connection the UPF supports. The UPF is a switch or router or intelligence that sets the priorities. [...] It does queuing, filtering and other related functions (B.5)."

The discussion regarding the values of 5G cases was enriched by representative of Absolute Zero, who provides specific value range in regard to the developed 5G-oriented product.

"That would be milliseconds. The current LTE infrastructure is not sufficient to deliver that for sure. When it comes to speaking about the network infrastructure yes, only 5G can deliver such low latency (B.6)."

The statements provided in respect to the second pillar have a significant meaning while debating aspects like QoS. This topic is also debated in the next chapter.

6.2.3 Innovation facilitation knowledge framing

In terms of the third pillar - *Innovations facilitation* all the interviewed bodies stated their opinions. Starting with the operators' position, three different opinions are claimed. Firstly, TDC does perceive any discrepancy between new wireless standard and start-up environment. However, the TT-N explains the origins of the net neutrality and why the regulations were applied at the first place:

"I think innovations are important because to utilize you can say the possibilities in 5G, we would need someone to grab the opportunity (B.2)."

TI's representative asked about the innovations while discussing the net neutrality/5G convergence, explained:

"They are not important It is not really the issue. We support net neutrality because we want to make sure people can access the content they want. Also, have free speech and leave room for innovation, which means that if you have a dominant position you could not keep your competitors away by making the network not neutral. I think in practice when we speak about 5G and network slicing this is not really the issue (B.3)."

Then other claim can be heard from the scholar's position. Accordingly to TNO's scholar representative:

"If you see at the placement of net neutrality is because of two reasons: for protection of end users that they can access the content application that wants over the internet. The second is to promote the internet as an innovative ecosystem (B.5)."

This statement can be followed by the DEA's representative, who explains that net neutrality and innovations facilitation are functioning in harmony, which helps early-stage companies to mould and adjust their business models:

"The EU rules on net neutrality aim to safeguard and guarantee the functioning of the internet as an engine of innovation. In this regard, the DEA believes that the rules on net neutrality provide ample opportunities for companies to invest and discover innovative business cases (B.4)."

Interesting insights in regard to both 5G standard and net neutrality were stated by the representative of Absolute Zero. On the one hand, start-up perceives 5G standard as a significant enabler for faster connectivity for the products (subsection 6.2.2) yet, on the other hand, interviewee expresses his doubts in regard to 5G in general by stating:

"It is too early to state the potential 5G in regard to start-up environment because 5G itself is a start-up and consequently it is very hard to be a 5G start-up. The performance which 5G promises is not seen in reality yet. It is hard to build a hypothesis based on the hypothesis (B.6)."

Next crucial remarks have been declared with respect to the pro-net neutrality regulations in the EU:

"My answer would be pro. It is such a fundamental infrastructure - the internet. Everybody should have the best possible to reach it. At least from the start-up perspective. If

you build the start-up you want to reach your customers as soon as possible (B.6)."

These remarks are be further analyzed in the subsequent chapter.

6.2.4 Infrastructure investments knowledge framing

The last identified aspect of the debate *Infrastructure investments* analyses argument of against-net neutrality proponents, who claims that by charging the content/service providers better and more reliable infrastructure can be deployed (this aspect was explained in the subchapter 3.2.3).

Starting with TT-N opinion, the interviewee answers the following way:

"I think back in the days when we were trying to block companies like Skype the basic argument was that they did not invest in the network. This is just having as a simple voice application on top of everyone else network. Today I am not sure if that is really true. If you look at the facebook or Apple - they are building a huge data centre. I do not think that you can actually accuse them of being a free riders as on anyone's network anymore (B.2)."

This argument is presented under different angle by TI. The interviewee asked about the possibility to charge content/service providers (like Netflix) answers:

"If they want to pay for a higher quality Netflix delivery then why not. [...] It is probably more the opposite way that Netflix. They are in a position where they can come and say to an ISP if you want to have my service in a high quality to your customers you should give me access to put my equipment through your network goes to the customers at a very low cost (B.3)."

An opinion in this regard was expressed by the start-up's representative. As mentioned against-net neutrality regulations might hamper the innovation ecosystem and decrease the possibility for young companies to become the second Google. Asked about the prioritized access to the internet Absolute Zero's representative stated:

"My initial answer would be no. I would not like to pay. I would expect we get a fast 5G for negligible cost. [...] I feel that there are other ways, which are much more democratic rather than commoditizing internet (B.6)."

6.3 Subconclusion

The following chapter is committed to all interviews-oriented activities like showcasing the dependencies between the bodies (figure 6.1), introducing the contacted stakeholders and finally the organization the knowledge acquired from the interviews. The chapter showcased only the most relevant to each of the pillars from chapter 5, statements and opinions. All the answers utilized in this chapter have been gathered in the forms of tables and attached as the appendix C.

Chapter 7

Net neutrality & 5G analysis

At this stage of the project, when the reader acquired the data from the literature and interviews, the full debate on 5G and net neutrality can be conducted. As the methodology diagram 2.1 indicates, after the *Field study* segment, *Net neutrality & 5G analysis* is the consecutive part. Firstly, the reader obtains the description of the debate organization, analysis and finally, the chapter is closed with the concluding remarks.

7.1 Debate organization

This chapter is built upon the knowledge gathered from the chapters 3, 4, 5 and lastly 6. The data, arguments, claims and descriptions from previous parts are correlated and scrutinized. The debate is divided into five parts: four debates in regard to identified pillars (chapter 5) and conclusion section. As the net neutrality and 5G convergence is a multi-layered topic and each of the pillars involves more than one argument (like *Network engineering* pillar, which covers QoS requirements and technical analysis of 5G) the debates aims at covering all the related arguments per each of the pillars. Each of the arguments has its own table which consists of the argument itself, data section and comment. Firstly argument in the overall debate is presented, in the form of claim, short data scenario or question, secondly, all the related data is provided and finally the author's comment on the overall issue. To help the reader understand the debate's organization, figure 7.1, depicts the overall process below:

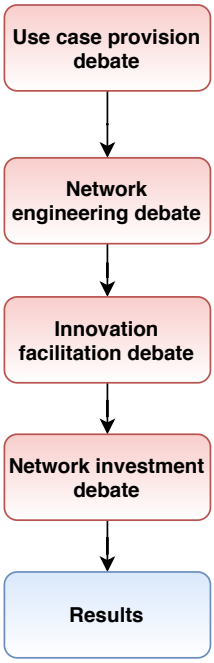

Figure 7.1: Methodology diagram (own picture).

In order to maintain constant flow of discussion and to showcase that the arguments from separated pillars are interconnected, the main debate chapter is not divided into the subchapters. In addition to that, the results are also presented in the form of the table.

7.2 Main debate

This chapter presents four debates based on four identified pillars of the Analytical Model.

Table 7.1: **Use case provision debate** - Perception of net neutrality

Argument:
Equal-data treatment in the EU refers to all groups of signal equipment like fixed and wireless. Not only is net neutrality debate about the network slicing but also the proper enforcement of QoS. In order investigate 5G case, the general overview on net neutrality must be obtained. Due to this fact, the first asked question was **What "net neutrality" really is?** Firstly debated issue is how this concept is being perceived and is there is a harmony or rather disharmony among the bodies involved in 5G.
Data:
Literature: Net neutrality prohibits ISP from speeding up, slowing down or blocking Internet traffic based on its source, ownership or destination. *EU regulations:* Providers of internet access services shall treat all traffic equally, when providing internet access services, without discrimination, restriction or interference, and irrespective of the sender and receiver, the content accessed or distributed, the application. *TI:* Customers should have access to the content of their own choice and the best quality they can have. The starting point is that the free choice of the customer. To access whatever content they want and have the quality they can have. *DEA:* The safeguard of equal and non-discriminatory treatment of traffic in the provision of internet access services and related end-users' right to access and distribute information and content, use and provide applications and services. *TNO:* Protection of end users that they can access the content application that wants. *Absolute Zero:* Me being able to make a choice of what do I want to see or use the internet for.
Comment:
The concept of neural network and non-data discrimination policy was coined in 2003 by Tim Wu in [68]. The term was adopted by the EU's authorities in [77]. The statements claimed by all interviewed sides are aligned with the adopted policy. Stakeholders highlight the freedom of choice, the importance of net neutrality and the need for safeguarding the current status.

Table 7.2: **Use case provision debate** - Purpose of net neutrality

Argument:
The next question which can be asked is why does the EU want to have pro-net neutral policy rather than against? Why against-net neutral approach was not incorporated together with the possibility to throttle the data accordingly to the ISPs' policies?
Data:
TT-N: I think that in some cases you would see some operators are starting to throttle or starting to discriminated that type of traffic. I think that is the first thing sort of service out there was with that experience was Skype kind of. To keep their the revenues for themselves they could do that kind of throttling all blocking of that service that was the sort of the invention of the net neutrality term [...]. It was specifically to prevent, you can say, over the top type of players like Google, Skype, Netflix, Apple and so on to sort of take the revenues that the operators had in the service layer. I cannot see that happening anymore. Facebook is not competing with operators. On the contrary if Facebook did not exist people will not buy the access from operators. *TI:* There was a situation with Skype and I think it was worldwide operators is considered whether they could to avoid Skype in their networks and they prepared themselves to do it but they never did.
Comment:
Pro-net neutrality policy was implemented to protect service/content providers from being blocked if their services were in the competition model with products offered by MNO. The first and main example of such practice was blocking Skype, which offered service similar to voice connectivity offered by MNOs. However, the current market situation is different. Customers buy network subscription to have access to products offered by giants like Google, Apple, Netflix of HBO, rather than for services offered by MNOs. Consequently, the next question arises - Can we regulate 5G standard with rules applied for purpose of protecting the customers' choice and disruptive companies like Skype, which were in competition model with ISP?

Table 7.3: **Use case provision debate** - Can we regulate 5G with net neutrality regulations?

Argument:
The previous comment yields the question if net neutrality invented for protection of content/service providers businesses has applicability for the 5G standard which is a new approach toward wireless communication, beyond typical voice services. This question arose during the interview with TT-N.
Data:
TT-N: But the important things to me is really that that is was invented in a different time yes and in a different technology regime. I think it is an outdated term today. It was invented for a different world, for different technology regime and for different services. [...] I believe that when we take the internet we used to know, which was, you are going to say optional news for fun also, some sort of communication and we moved into being more critical national infrastructure taking care off basic installations in our society that the very society is dependent upon. As things like a mission-critical cases. We are mixing terms here. That is my firm believe and unfortunately, the most people then when they get the question they replay: "I don't know how to answer". My honest believe is that net neutrality regulations today is not fixing it, because no one can tell if the network slicing is the violation of the net neutrality. This is alone is a problem. It is six years behind. When it was developed, there was no network slicing back then. If the network slicing is a problem? I do not know but at the minute it gets a problem like Skype, it must be regulated hard because it is not about preventing anyone to get an access to anything. I say let's take a new look at this because the technology is moving so fast. It is outpacing the regulations.
Comment:
The author emphasised that applicability of net neutrality has rules for the upcoming 5G standard is inadequate. The arguments raised behind why are the following: 1. Confusion aspect - the author explains that current regulations/guidelines do not provide clear structure, which can help the industry to manage a profitable business endeavour. 2. A new approach towards wireless standards - specified by 3GPP network architecture allows accommodating more diverse use cases, beyond typical upgrade from 4G. 3. Outdated regulations developed to protect the content/service providers from MNO's throttling.

Table 7.4: **Use case provision debate** - How relevant is the first argument raised in the previous section - general confusion about the regulations?

Argument:
Based on the previous table, the question if the regulations are perceived as unclear by other stakeholder can be asked.
Data:
TI: There is a high degree of uncertainty. Uncertainty itself creates, in our view, a barrier to develop 5G services because new standard is really expensive, it demands a lot of investments and if you do not have that certainty for business plan or services, then you are not that willing to invest your money. The uncertainty in itself is a very important development of 5G. That we do not have this complete transparency and predictability in the regulation. It is a barrier for investments. It is not us as attractive to invest in as a market where you do not have these rules. It will be a barrier for the investments. The most concrete thing we have is that you can the whole regulation about specialized services and what you can do. It also the regulation says that you can do this, but it should not decrease the quality of the general access. How do you measure that? How to look into that in practice?
Comment:
In addition to the outdated regulations, there is an investment problem because of vagueness aspect. Lack of transparency and predictability are mentioned as traits of current regime. 5G is not an usual upgrade, yet expensive investment (because of the software-based architecture, rather than hardware-based as explained in chapter 3). Moreover, aspects like management of specialized services, which can be life-threating scenarios (military, e-health, automotive) is unclear. Considering importance of these use cases, the regulations must speak clearly and explicitly. Next significant insight can be drawn from the statement *It is not us as attractive to invest in as a market where you do not have these rules.* A good example of against-non neutrality market is the American one, regulated by FCC. Consequently a question about applicability of against-non neutrality regulations in the EU can be asked.

Table 7.5: **Use case provision debate** - What is the perception of FCC's regulations in the EU?

Argument:
As described in chapter 3, FCC established new regulations in the framework of equal data treatment. The main pillars of this policy envision customer protection, transparency and the removal of unnecessary regulations to promote broadband investment. The previous tables outlines gaps in the current pro-net neutrality regulations, questions about the FCC were asked to the stakeholders.
Data:
TNO: Well, that will be an interesting experiment as in the US they do not have a rule in the EU we do have rules. I think it also relates to the commercial arrangements [...] Time will tell whether the operator will find it more attractive to invest in 5G if there are these rules. Hard to comment. *TT-N:* I am a big fan of what they did because they it is it has nothing to do with the free internet it had nothing to do it is not about blocking a throttling anyone it actually is more about developing networks more in line with the needs of the society [...]. I like the fact that FCC is doing this because net neutrality was born out of this competing situation with the operator but everyone now and then we just to talk about this freedom of speech, democratic angle. I do not see it anymore. I drive on the motorway it everyday I do not see any anti-democratic in the fact that I can be overtaken by the ambulance on the fast lane. *TI:* We have discussed when the American administration took the decision to roll back the net neutrality regulation. We considered should we also do this here in the EU and in Denmark. The conclusion was that it is not possible for us to go back now that the reality would be. Impossible to carry out, but in theory I agree with the view the Americans have that if you have competition. If you have complete transparency and you have the general competition rules. Then you solved everything.
Comment:
After the revision of the statements it can be concluded that FCC's regulations provides clearer structure for *developing networks in line with the needs of the society*, which is crucial if MNOs want to manage a wide spectrum of 5G's use cases. However, telecom industry looks different in US. One of the main reasons why FCC introduced against-net neutral rules, was lack of infrastructure investment in the rural areas form the ISP's side. The European n market is extremely competitive (as stated in B.3), consequently argument that there is no proper broadband connectivity is not as relevant as in the US. In addition, there is an aspect of immaturity of 5G and only after the commercial deployment it can be assessed which approach is more profitable.

Table 7.6: **Use case provision debate** - Scenario I: Accident scenario because of data throttling

Argument:
In addition to the questions, two scenarios have been created and asked during the interview. This way it can be validated whether all the stakeholders answer the same way. The first one is about the ULL connectivity, throttled because of the degradation of other services: **Who would be responsible in the accident scenario where because of the lack of the capacity and net neutrality restrictions, the operator could not deliver the high-priority connectivity?**
Data:
TNO: How make a guarantee that it will work? Is the operator? Is it a car manufacturer? Road operator/manager? Depends on the arrangements they do have. This shows why it is not trivial to come to this use case, which depends on the high reliability. Similarly to the accidents with Tesla, where the autopilot did not see the pedestrian and the accident happen. Who is to blame? Driver, software, or Tesla? Again, it is hard to say, depends on the agreement between the bodies. Maybe in future, there will be a regulation which deals with this. *TT-N:* If you provide a service and your state that this service has a quality that we as a society can depend upon and that we can depend. Would you label mission-critical application on that? Then it needs to come with the responsibility from the operator as well. Which of course will be reflected in the price of the slice. *TI:* I do not think that this scenario would happen. If you have a surgery in the hospital I am pretty sure, that no one would argue that making a SpS would be jeopardize by the net neutrality rules. I hope in practice this scenario would not happen. In practice, this a good scenario to discuss it, but in the reality it would not happen. Then again we have this uncertainty element here. *DEA:* The DEA is unable to answer this question.
Comment:
The answers provided state the complexity of the issue. Both TNO and TT-N stakeholders ask who made the promise that the connectivity would be provided? Then other voices like impossibility of the following scenario can also be heard in the discussion. The responsibility in this scenario is questionable and there is no clear answer. As the TI's representative adds *Then again we have this uncertainty element here*, which strengthen the insecurity aspects outlined before. Considering the huge economic losses (smart grid) or customers' accidents this example should be answered clearly and in the unified way if the net neutrality rules would work properly.

Table 7.7: **Use case provision debate** - Scenario II: Sudden network traffic

Argument:
The next scenario developed was the situation when ISP must react for the sudden traffic activity, which might pose a threat for the delivery of SpS like ULL cases. Consequently, the following question has been asked and researched in the literature: **Do you consider in your network planning process, the sudden network resources extension because of sudden traffic as a result threat for ULL scenarios like the autonomous cars?**
Data:
BEREC Guidelines: ISPs would not be obliged to expand the network capacity if current QoS requirements are fulfilled, but NRAs are obliged to promote the continued availability of IAS at levels of quality that reflect advances in technology. For those purposes, NRAs may impose requirements concerning technical characteristics, minimum QoS requirements and other appropriate and necessary measures on one or more ISPs, ref. Article 5(1) of the Regulation. *TT-N*: In this scenario, I would say yes, the operator needs to discriminate. That does not mean that other users should not get what they are paying for, but then they need to find another operator, which will provide the capacity they need or maybe operator do have a slice for that. You cannot expect buying a best-effort service will be prioritized in the network. *TI*: I do not know in practice. I am sure that our regulator would accept that if there is a sudden resource extension then you as an operator, can discriminate your traffic and manage your network so that you can deliver the services to the ULL car scenarios. I am sure that they would not see or not consider that a breach of net neutrality. I am sure. *TNO:* If an incident like this would happen then that would be allowable possibly. It about the availability of the general quality of Internet Access Services. How much in detail you measure that? If there is congestion in one location because of some Specialized Services instances like a large accident or concert or something else that would be allowable. Yet, if we would have something more restricted than it would not be allowed. As a result, then we would talk about the extension of the capacity. *DEA:* The DEA will assess a situation like this on a case by case basis. Any justification for ISP to do traffic management must always comply with the rules of the EU-regulation on net neutrality.
Comment:
The statement analysis indicated harmony in the answers in this regard. The gathered data states that the sudden network traffic would be justified in order to deliver the ULL cases.

Table 7.8: **Use case provision debate** - Unclear regulations inquiry

Argument:
Literature review performed in chapter 4, highlights the fragment of Article 16, where is stated: *"National regulatory authorities should verify whether and to what extent such optimisation is objectively necessary to ensure one more specific and key features of the content [77]".* [102] argues that the NRA may require operators to show that the required level of quality cannot be assured over the IAS as a result (because of timing, costs, innovations, administration burden) it might hamper the fast deployment of 5G. As these regulations have been indicated as unclear, it opens possibility to find harmonic/inharmonic statements among the stakeholders.
Data:
TT-N: If the SpS means that not everyone can get an equal access to the network, that it is a capacity problem. If you need to discriminate based on this, then I think the regulator should be involved. Forget about the net neutrality regulations as it was develop in the different times for the different technology with different competition scenario we were dealing then. What we should focus now is the world, where the operator are not to the same extent competing with Netflix, Google and so on. We should now consider how we can provide mission-critical cases prioritization without the discriminating. Yet, if we should discriminate, there should be rules and guidelines on how to discriminate to get the priority if needed. *TI:* I think you should do it and then if the regularly to ask you should argue how and why. This of course can increase the uncertainty aspect. Every paragraph, an administrative burden increase the uncertainty because how is this rule is going to be used. We also can see across borders in the EU that the regulators look at this in different ways and we also have this agenda about the digital internal market in the EU. This is what would when rules are used differently in different countries, of course, it is a barrier. I do not know in practice but I can see of course, because we have different countries with different regulations that apply differently. Then the business case, in making across border autonomous drive is of course, more difficult.

Table 7.9: **Use case provision debate** - Unclear regulations inquiry

Data:
DEA: Regulation on net neutrality does not require the NRA's to do an ex ante assessment of the operators' specialised services. The operators are fine as long as they adhere to the rules in the Regulation. As of now the DEA is not able to elaborate on the process, but any assessments will be done according to the Regulation taking into consideration the BEREC guidelines. *TNO:* This is the requirement that SpS is technically needed to obtain the quality, the operator has in mind and it cannot be done via the normal internet. This is one of the most difficult things in the regulations be this is also what we have written down in the our report. You are comparing the quality of SpS over the quality of IAS. The problem of IAS is that is best-effort so the quality is not stable and can vary over time vary from location to location. Depends on what do you think as a quality this is a challenge but still there are many cases around in automotive few that are completely obvious that you cannot this over the normal, best-effort internet these days in that case. It would not stop the use case and it would not stop the deployment of 5G because of that. Other case if you come closer if the quality differs between SpS and IAS becomes smaller this thing becomes more difficult. It is also in the regulations somewhere that the SpS today is not necessarily SpS in two years because the regular internet has improved. This is a tricky argument.
Comment:
Comments on Article 16 on the EU net neutrality regulations, showcased many different cases, which might pose a challenge for fully profitable 5G investment. TNO's representative argues that the comparison between IAS and SpS is challenging to perform because regular network services parameters can vary over time and from location to location (this subject is continued in the next section). In addition to that author discuss that because of the improvement in the regular internet, the SpS today can be IAS tomorrow. While the TT-N highlights that net neutrality rules today do not provide clear guidelines on how to discriminate if the service requires special treatment. Next argument is provided by TI's representative who claims every addition paragraph increase mentioned earlier uncertainty aspects. Furthermore, discrepancies between EU's members are outlines - *different countries with different regulations that apply differently.* As it was described in chapter 3, each of the countries has own NRA which has to safeguard the equal data treatment. To sum up, all stakeholders raised various challenges in the regard of net neutrality regulations and necessity to prove the real need for special QoS requirements for the SpS.

Table 7.10: **Network engineering debate** - The importance of the parameters

Argument:
Following the previous argumentation, a question in respect to the meaning of the parameters can be raised. How operators should prove that a service deserves special treatment? In addition to that, TNO argue that IAS services parameters are not stable and can vary over the time. Consequently, one of the question asked was in regard to parameters. **While discussing the alignment with net neutrality rules - should we look more for the type of the requirement (f.e. latency, data rates) or the specific value which will assess if particular use case should be prioritized? If the value can you give some examples?**
Data:
TI: I think you should not look into the parameters. It is very complex to run the network. All these parameters can have different values on during the day, depending how do you manage your network. Because they change over the day, it should not be taken as an indicator for the net neutrality problem. You cannot look at these things. As a regulator, if you would like to see whether it is a problem, you need to look at the competition, you need to look into the details of what is happening. You cannot make use of the specific values whether there is a specific problem or not. It is more complex than that. *TNO*: The value is also important. As it is written in the guidelines, you need to demonstrate that you cannot achieve the desired quality of service over the regular internet. It would not be sufficient if you would say that I need low latency and the regulator would like to see how many levels of the low latency you would like to see or what is the difference so it is also the value [...] The problem of IAS is that is best-effort so the quality is not stable and can vary over time, vary from location to location. Depends on what do you think as a quality this is a challenge but still there are many cases around in automotive few that are completely obvious that you cannot this over the normal, best-effort internet these days in that case.
Comment:
The answers provided by the stakeholders shows both harmony and inharmony. On the one hand, both TNO and TI perceive the argument that the parameters can change over time and location. On the other hand, TNO explains that value itself is important while TI convinces that the specific value is not an indicator for the net neutrality problem. Rather than parameters, TI claims that the regulator should look into aspects like market competition. The overall impression is that stakeholders perceive the complexity of assessing the importance and the role of the parameters and their specific values while discussing the compliance with net neutrality.

Table 7.11: **Network engineering debate** - Network architectural changes

Argument
Chapter 3 stated that 5G is cloud-based technology, which involves new concepts like slicing. A question how MNOs need to change the network can be asked.
Data
TT-N: New NR radios for sure. If you want to consider media services then you would need the 3.5 GHz millimeter wave. [...] You need to move the network resources, even core closer to the application.These are huge developments in the network [...] When it comes for the ULL, then you will need a decentralized processing power like Edge Computing. You need to move the network resources, even core closer to the application. Some of control functions but also process of functions application processing much closer to where it is needed. These are huge developments in the network. *TNO:* They have to build the 5G instead of 4G architecture or in parallel, but once you have that the full 5G, You do not need to upgrade architecture to have a slice.
Comment
Major improvements like new spectrum and processing power closer to the application (MEC enabler) are forecasted. All these new technologies require high investment rates from the MNOs' sides. As a result, the MNO is able to manage fully software-bases network architecture, which is aligned with the 3GPP's requirements. In addition to this, the operators can facilitate a wide array of different slices. It is important to highlight fact how costly 5G is in the discussion, because against-net neutrality proponents argue that by charging the content providers a safer network can be build.

Table 7.12: **Innovations facilitation debate** - What is the role the innovations in the 5G?

Argument
Detailed earlier [91] argues that the problem is not about imposing the net neutrality but if the technology will fulfill the demand on more diverse use cases. Consequently a question about the relevance of innovations can be asked.
Data
TI: We talk about IoT than 5G. We work with industry of the other sectors like robotics etc. than 5G itself and also about the IoT that runs over the LTE. *TNO*: The claim here sounds like there is no scarcity of the resources anymore. That would change the picture dramatically because the thing is about not enough capacity, if there is enough of the capacity for everyone then you have little problem left [...] One of the questions is whether the 5G will bring the innovations though SpS when you optimize the slices for the specific use cases like automotive and because of quality in the connection or processing, you will get a new service that you would not get if had a regular internet this could be a business case behind automotive or entertainment.
Comment
Market still waits for the 5G use case, rather than one based on LTE. The importance of innovations might change after the factories or cars will utilize new standard. Following that statement, TNO's representative explains that the main core of the debate is lack or resources and consequently necessity to discriminate. It can be concluded that because there are no real 5G cases, the main problem is the lack of spectrum to accommodate all the services.

Table 7.13: **Innovations facilitation debate** - How important is 5G for start-up environment?

Argument
As indicated, there are not 5G products on the market yet start-ups are utilizing 5G infrastructure already to develop the applications. How relevant is 5G for the start-up world?
Data
Absolute Zero: It is too early to state that because 5G itself is a start-up and consequently it is very hard to be a 5G start-up. The performance which 5G promises is not seen in reality yet. It is hard to build a hypothesis based on the hypothesis We need to do a lot of assumptions. The potential of 5G for start-ups is not that interesting. It is not a short term start-up bet. There must be a long term commitment. You have to be a start-up for two-three years when the 5G is actually delivering and you can add your value proposition.
Comment
Absolute Zero's claim in respect to 5G covers with the previously indicated aspect - immaturity of 5G. It is too early to discuss whether new standard will be a profitable investment. Still, many young companies try to build upon. Other highly relevant fact is the uncertainty aspect. However, as raised maybe the against-net neutrality approach would be better? Yet, against approach might undermine the innovations. Consequently a question whether 5G start-up can be throttled like Skype arises.

Table 7.14: **Innovations facilitation debate** - Would start-ups be throttle by ISP in 5G regard?

Argument
The net neutrality rules imposed by the EU were to protect the innovations like Skype to be throttle by MNO. If the new net neutrality rules would be applied, would that open a possibility to diminish the innovations environment (because of lack of the funding for the network investment).
Data
TT-N: I do not see 5G coming in now and all of a sudden operators will reinvent themselves as a Netflix or gaming platform. I mean that opportunity space is long gone and they are not capable anymore of grabbing that opportunity. You will not see this capability within the operators anymore. You do not see any operators today who are trying to fencing their 5G in cost of others. If you want develop your own 5G company, go ahead. I do not see why operators should block you. Your business is not in competition to their. *TI*: I do not think it is relevant because if we if you have competition we have three competing networks. That it in self it is a guarantee that you as a startup can get access to whatever you request and on a commercial basis. So that the competition protects the start ups and ensures this equal ground for for competition. *Absolute Zero:* We need to do a lot of assumptions while we work with Deutsche Telekom.
Comment
Analysis indicated no incentives for MNO throttle new, 5G-based innovations. Current MNOs are not service providers (*I mean that opportunity space is long gone and they are not capable anymore of grabbing that opportunity*) and they are not in the competition model with innovations like Netflix or Absolute Zero. Moreover, MNO wants to cooperate with start-ups in order to test their networks and open new innovatory programs for early stage star-up. A good example here is Absolute Zero, which is in the acceleration program of Deutsche Telecom. Next argument why there would be no incentives for MNO to block start-ups in different net neutrality regime, is the fact that current telecommunication ecosystem is extremely competitive (*I do not think it is relevant because if you have competition we have three competing networks.*), due to this fact, an entrepreneur can use the network of other ISP.

Table 7.15: **Infrastructure investments debate** - Can against-net neutrality regulations help building a better network?

Argument
Against-net neutrality proponents argue that extra fees will contribute to the network investment. Considering the fact that 5G is a non-usual upgrade from 3G to 4G yet broader change, which is perceived to open many new businesses. Can against-net neutrality regulations help MNO to achieve safer, more robust network with faster ROI and better financial results (because of extra fees from content providers like Netflix)?
Data
TT-N: It probably would but I think we also need to be aware that the 5G like 4G, 3G and to most extend 2G is born in the competitive market. The prices there will not be any sort of monopoly pricing going on. You would have a number of operators offering that service and so I think that puts a limit to you know what type of profit you can make. That's personal believe that net neutrality or not I don't see the operators as being the ones mainly benefiting from the networks they build now now. *TI:* Well, of course if we could have charged money from more parties we would have more money to invest in networks. Obviously yes. But would it be a good idea to start charging money? I do not know. It depends on who it is and how you do it. Well, my view on this has always been well if the customer requests something and they want to buy for it pay for it [...], More realistic scenario in that it is actually Netflix demanding something from the ISP than the opposite way around. *Absolute Zero:* My initial answer would be no. I would not like to pay. I would expect we get a fast 5G for negligible cost. But we are half a year, maybe a year from now until products hit the market. Then our requirements will dictate but it seems like it is an argument whether the money coming in, can help improve the infrastructure. I feel that there are other ways, which are much more democratic rather than commoditizing internet.
Comment
Answers provided by the stakeholders emphasised a wide spectrum of counterarguments. Firstly, it must be noticed that as long as market is competitive, there would be no monopoly activities. As a result, ISP in order to deliver the highest possible quality will adjust their business models to build robust network architecture. Secondly, current content/service providers are in the position to claim their demands, as the customers buy the network subscription to use their products, rather than MNO. Finally, start-up environment would expect to have access to 5G network for the *negligible* cost, rather than spending resources on reaching the customer. This issue connects with arguments provided in the table 7.14. Why ISP would charge start-ups if they are the ones, which brings the innovations and new products?

Table 7.16: **The results of the debate**

General comment
The following chapter contrasted arguments and opinions in regard to the net neutrality and network slicing. All distinguished pillars in the Analytical Model have been covered and discussed. This table incorporates the main findings in the form of the bullet list, with all founded harmonious and non-harmonious findings. The sections is closed by the answer whether net neutrality pose a threat for commercial deployment of 5G technology.
Research's findings: • Net neutrality was imposed in the EU to protect content/service providers from being throttled if their services were in competition with MNOs' services (Skype example). This is not happening anymore, as MNO are cooperating with start-ups to bring their innovations on the market. In addition, as telecommunication market in the EU is competitive, even if the new product would be in competition to MNOs' services, start-up can use network of the different provider. • While net neutrality was imposed there were no network slicing or NFV enablers, consequently, currently the EU regulates new telecommunication standard, with the regulations created in the different technological regime. While the 5G technology is broader and will accommodate more use cases (including life-critical ones), it is regulated by the net neutrality invented for the different purpose and times. • The most recent update of net neutrality was done by FCC, which dismantle equal data-treatment in the US and proposed more transparent and clearer structure on how to manage the network traffic. In contrast, the EU's rules are not clear enough (like the Article 16) and as a results it might increase the uncertainty aspect and in the end decrease the amount of investors. • The second argument in regard to the uncertainty is the fact that there were non-harmonious answers provided (tables 7.8, 7.9 and 7.10) in essential aspects like the importance of parameters and the responsibility in the asked scenario. As the 5G will include life-threating use cases, the full and sharp alignment should be found, while discrepancies in the opinions have been identified.
Does net neutrality pose a threat for 5G?
The initial answer would be no. The 5G and current regulations are harmonious, additionally BEREC will update their guidelines in the range of four years. Due to this fact, the NRA can follow the updates and improve their cooperation with MNO. However, the question if the other, more transparent, against-net neutrality regulations would not be a better choice for the EU can be posed.

Chapter 8

Discussion

The discussion reviews the progress made in the report and presents the answers to the specified problem formulation. It also touches upon the matters of the implementation of further developments. At the project's closure, all the objectives described in the 1.1 Objective subchapter have been achieved. The debate performed in the previous chapter brought answers for the questions stated in the 1.2 Problem definition subchapter.

8.1 Problem formulation solution

The project shows the multi-faced and complex convergence between net neutrality and 5G standard. In order to fully close the research, the project's research questions are answered below.

What are the major challenges in network neutrality regulation and commercial deployment of 5G networks?
The debate conducted in the previous chapter indicated that current regulations have been developed for the different technologies and purpose rather than to regulate new wireless standard which will accommodate new use cases. The current innovation market differs from the one when the net neutrality was imposed. Now, the customers pay for the subscription to get access to the content/service providers' products rather than IPSs' products. In addition to that, there is a nonharmony with respect to answers about the importance of parameters and the possibility of the created car accident scenario. All these mentioned factors might suggest that the EU needs more transparent, clearer and less complex regulations, which will help 5G to be fully profitable and operational technology, without strong regulatory constraints.

Subquestions:

What are the main quality of services parameters, needed to be considered while discussing net neutrality in regard to 5G?
As it was debated in table 7.10, two voices can be heard - the necessity to consider the specific value of the parameter (bandwidth, latency, reliability) in regard to the particular use case or consideration of aspects like a competition rather than the value of the specific parameter. However, both sides agree that the specific values differ within the time frame. In other words, a parameter can have diverse value during the day or during the night. Consequently, answers are nonharmonic in this respect. How MNO should verify that the service deserves a special data treatment in the network? This aspect has been highlighted as one of the main problems with current net neutrality rules. As DEA stated, the regulation does not require the NRA's to do an ex-ante assessment of the SpS. The most important factor is that MNO must be adhered to the rules and does not discriminate other services like IAS to deliver the SpS.

Which use cases will be influenced by net neutrality regulations?
The net neutrality rules are applicable for every network service regardless or the type or QoS requirements. Network services are considered as two types: IAS and SpS. While the first group does not require special data treatment and enforcement of QoS and can be delivered via the regular internet connection, the second will require special adjustment in the network planning. However, it is crucial to outline that these cases are still not available commercially. In other words, the market is waiting for cases beyond LTE like autonomous cars. Furthermore, as the analysis indicated there is a possibility that, because of the improvements in the regular network, use cases considered as SpS, can be delivered as IAS in the future.

How can the 5G use cases be matched with net neutrality regulations?
All the 5G use cases (IAS and SpS) are regulated by Regulation (EU) 2015/2120 of the European Parliament and safeguarded by the national NRA, which are comply with the BEREC guidelines. Every use case must be aligned with the equal data treatment policy in Europe. Even though 5G provides a wide spectrum of various use cases (eMBB, ULL and mIoT) there regulator does not divide the regulation per category, due to this fact, all services are governed by the one set of regulations. If the regulator would divide the regulations into the three particular groups, which corresponds to 5G use cases, that might pose an incentive for ISP to classify the services under the category MNO likes best. In addition to that, it is uncertain which way the technology will go and then the re-assignment process would be needed. Ultimately, the regulator provides one set

of regulations for each of the use cases and guidelines for NRAs on how to process and manage the net neutrality enforcement.

How can telecom industry adjust their architecture models to be in line with regulatory laws?
In order to accommodate all the forecasted 5G use cases, 3GPP specified a new, flexible architecture, which is not a usual upgrade from 4G, yet a cloud-based solution. The MNO must adopt the new architectural patterns accordingly to the specification in order to maintain the cooperability and unification between the equipment of the different providers. The issue is not about which software or hardware will be used for establishing the design but how the MNO will use the elements to provide the connectivity. Both - literature study and the interviewed experts stated that the element responsible for the QoS differentiation is the UPF, placed at the user plane route. The element works as a filter, which is easily steered by the MNO from the control plane. There are not predicaments to use Network Slicing feature, as the EU's net neutrality regulations clearly state that the enabler can be fully utilized. Consequently, if the MNO adapt the architectural model accordingly to the 3GPP's specification, the regulatory bodies should not have any objectives.

8.2 Project limitations

The research scrutinized the correlation between 5G and net neutrality. Both of these concepts involve many subtopics with different level of relatedness to the main debate. Consequently, the research must have been put in the appropriate frames in order to deliver the highest possible value. These limits are presented in the following subchapter. First and foremost, access to the interviewees and unexpected events while waiting for the answers must be emphasised. Because of the administrative issues, only mail interview has been acquired from DEA rather than a live talk which could have been a discussion and provide more value. The next constraint is related to technology maturity. At this moment, 5G is not commercially deployed, and as indicated in the interview with TNO's representative (appendix B.5), the current BEREC's guidelines are very likely to be changed and accordingly updated. Another aspect of immaturity is the fact that the DEA did not receive any 5G-oriented request from operators in the framework of the SpS and consequently special QoS data treatment (appendix B.4). In addition to that, the expert also suggests that some of the SpS might be considered as an IAS, because of the improvements on the regular internet and as a result, some services might be updated in regard the way they are classified. Considering all these arguments, the 5G current development stage must be highlighted as a constraint.

8.3 Future Improvements

Although broad research has been performed, it is still vital to perceive the problem from the wide and holistic view and indicate further developments. The following subchapter outlines the possible advancements, which could have been incorporated into the end structure, yet because of the level of relatedness and limitations indicated in the previous subchapter had to be delimited.

- **Equipment provider interview** - The main net neutrality debate is conducted between telecom operators and service/content providers yet strictly facilitated and regulated by bodies like FCC or DEA. This project was successful in regard to the data gathering from both of these sides. However, in regard to 5G technology equipment providers, which are building the infrastructure are also relevant. Consequently, an interview with the equipment provider can be identified as further development. The verification whether the opinion of equipment providers like Nokia, Ericsson or Huawei Technologies is align to the conducted debate. A report with a similar profile ([18] scrutinized in the 4) was built upon the interviews with many bodies, also with these particular companies.

- **Interview with American-based company or regulatory** - Even though this project introduced the FCC's regulations (subchapter 3.2.4.2), the main data analysis was in regard to the situation in the EU. The reason for that was because access to the interviews from the US. Still, it was perceived as a further development to interview a regulatory body in the US (FCC) or service/content provider, who is forced to pay an extra fee because of the against-net neutrality regulations approach like Netflix, HBO or Google. Another additional improvement would be a possibility to interview the MNO from the US like Verizon or AT&T, which is allowed to charge more in regard to the agreement signed with the content/service provider. However, in order to cover the against-non neutrality approach argumentation, the questions about the FCC's approach have been asked to the interviewed experts and interwoven into the discussion.

- **Interview with corporation** - One of the included interviews is with a start-up company in the field of the eMBB. However, the start-up's profile differs significantly in many aspects from the more mature and grounded companies like corporations. Consequently, it would be another improvement to include the opinion of the huge enterprise, especially if the produced service requires strict QoS differentiation like ultra-low latency or extremely high reliability like in case of the autonomous cars or e-health. Consequently, a good example of such companies would be Tesla, Mercedes-Benz or Google.

- **Compliance with further guidelines updates** - At the moment of writing this master thesis, 5G is not commercially available yet. The regulations on net neutrality released by the EU or FCC are applicable not only for wireless standards like 5G or LTE but also for fixed networks like fibres or DSL. As TNO's expert explained (appendix B.5), the EU rules on net neutrality are already a compromise, however, he predicts that BEREC's guidelines are likely to change (also because the real-life scenarios, where the technology is fully operational in the society). In the framework of this master, it might mean the necessity to be updated accordingly to the BEREC or FCC changes.

Chapter 9

Conclusion

The main aim of this research was to assess whether the net neutrality poses a challenge for full commercial deployment of upcoming 5G standard. The main four stages of the working process involved firstly the gathering of the data from the accessible literature, then based on that - the distinction of four main pillars of the discussion, data acquisition and analysis from the interviews and the final debate. In the end, the reader obtains a wide panorama of various aspects related to convergence between 5G's enabler - network slicing and net neutrality regulations.

The specific conclusions which can be drawn from this report are related to how the net neutrality is perceived and what are the main drawbacks of the current approach. Primarily, the research proved that there are discrepancies between the stakeholders in essential aspects like the significance of the parameters and their values and possibilities of the different network scenarios. The current, complex and complicated methodology created for managing both IAS and SpS might pose a challenge for eventual investors, who would like to see clear and the more transparent way toward the regulations. As a result, companies which invested in new, cloud-based architecture might wait longer for the return of the investment. The subsequent conclusion is the fact net neutrality was imposed at different times and purpose. Consequently, the industry does not speak in aligned and harmonious way. Considering the fact that 5G use cases are perceived in life-threating scenarios, any doubts and uncertainties should not exist.

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