Exploring the Possibilities for Collaboration among Dutch Mobile Network Operators for C-ITS ready 5G networks

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Master Thesis

CoSEM

I & C Domain

Delft University of Technology

Master Thesis - Complex System Engineering and Management March 2024

Integrated Design of I and C Architectures

CoSEM

Master Thesis

-

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March 19, 2024

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Preface

Dear Reader,

This preface marks the start of my master thesis report. The thesis is the final project of the master program Complex Systems Engineering and Management (COSeM) at TU Delft. With this thesis, I aimed to contribute to understanding conditions under which and in what forms Dutch Mobile Network Operators can cooperate in the creation of C-ITS ready 5G networks. Prior to this thesis, I had no knowledge about the telecom sector and the working of mobile networks. I can state that I have learned a great deal over the course of this master thesis about the working and future of mobile networks. While the market is very consolidated and competition is relatively low, network operators are facing serious challenges for the future. Therefore, I aimed to contribute to anticipating these challenges by researching possibilities for cooperation. With that, this master thesis have thought me a great deal about mastering and understanding very complex technologies such as 5G and understanding what factors make cooperation difficult. I have attained skills in performing interviews, analyzing results and writing proficiency. On top of that I have learned a lot on a personal level.

With years of study coming to an end, I am very happy with the end of the thesis process. This could not have been possible without the help of some very special people who have helped me unconditionally during the entire process. I would like to express my gratitude towards these people.

Firstly, I would like to thank my supervisors; Jan Anne Annema and Mark de Reuver. Jan Anne has always been there for me and helped me at crucial moments of the research. His down-to-earthness together with his enthusiasm, humour and approachability have helped me to move forward at times when i was completely stuck in the process. He always made time for me and provided me with constructive feedback. I also want to thank Mark de Reuver. When needed, Mark was there for me to help me out. We even did an interview together which was a very nice experience. He always provided me with constructive feedback on how to move further.

I also want to thank all my family and friends who always gave me support and helped me to get back on track when things got tough. Without them, I would not have been able to write this master thesis.

Enjoy Reading!

Mark van den Oever

Amsterdam, March 2024

Executive Summary

Dutch road transportation networks are confronted with significant challenges related to congestion, safety issues and environmental pollution. With the growing demand for more connectivity and an increasing trend of urbanisation, these problems are anticipated to worsen in the coming years. However, solutions are emerging in the realm of information and communication in the form of Cooperative Intelligent Transport Systems (C-ITS). C-ITS are believed to significantly contribute to resolving issues surrounding congestion, safety and environmental pollution, by making road transportation more efficient. However, the implementation of C-ITS faces hurdles in terms of legal, technological, organisational and economic challenges that impede the deployment of these services.

A major obstacle to implementing C-ITS is the absence of a robust network infrastructure capable of facilitating seamless, safe and secure data transmission across all types of users and infrastructure components. Preliminary research indicated that Dutch mobile network operators will play an pivotal role in establishing and operating these critical network infrastructures. However, Dutch MNO's are dealing with their own challenges in making their current 5G networks profitable. Considering the dramatically increasing number of cells, user planes and broadband capacity associated with C-ITS ready 5G networks, substantial investments loom again for MNO's. These high investments intensify pressure to devise sustainable business models. Adding to these challenges is the growing resistance from society against a rising number of cell sites and inefficient operations of MNO's. Collaborative efforts between MNO's hold the potential to realise synergy gains which could contribute to the creation of profitable business models and mitigate societal resistance. However, a knowledge gap in existing literature was identified regarding the conditions and forms of collaboration that support effective collaboration among Dutch MNO's for C-ITS ready 5G networks. Therefore, this research aims to address this knowledge gap by answering the following research question:

Under which conditions and in what forms can Dutch mobile network operators collaborate to establish C-ITS-ready 5G networks in the Netherlands?

In order to answer this research question, a set of sub question was formulated. These sub questions structured the research in two main parts: a literature review and an empirical study in the form of interviews.

The literature review identified five potential forms of collaboration: knowledge sharing, joint R&D, resource sharing, establishment of a joint venture and a merger or acquisition. Additionally, reviewing acknowledged theoretical frameworks dealing with collaboration between private competing companies provided insights into that influence the willingness to collaborate. These factors include the enforcement of cooperative agreements, conflict and opportunistic behaviour, interdependencies, shared vision, market concentration, technological feasibility and befits for MNO's.

Based on the findings of the literature review, interview questions were constructed. A stakeholder analysis formed the basis for the selection of interviewees. This marked the start of the second phase of the research; the interviews.

From the results of the interviews followed that the set of factors from the literature review were overly broad. Analysing the interview results, delivered a specified set of factors that influence the willingness for collaboration amongst Dutch MNO's. These conditions include trust, technological challenges, the institutional environment, governance & coordination mechanisms, interdependencies,

risk of opportunistic behaviour and conflicts, a lookout for potential unattainable profits, a shared vision across the entire network operator domain and a shared vision across private and public domain.

The interviews also yielded new insights in potential forms of collaboration. Both experts and public regulating bodies stressed the importance of maintaining both redundancy and competition. Eliminating redundancy makes critical services such as C-ITS vulnerable to network errors and outside threats. Low competition, and thus high market power, can lead to unfair pricing and reduced innovation in the long run. Therefore, active network sharing, establishment of joint venture and, mergers and acquisitions are no feasible options for collaboration. This resulted in three remaining potential forms of collaboration; knowledge sharing, joint R&D and passive network sharing.

To ensure the success of potential collaboration forms, several conditions must be fulfilled. Development of use cases is crucial to establish the viability of C-ITS. Subsequently, the creation of business cases is essential, potentially supported by financial incentives from the Dutch government. These cases will determine the desirability of collaboration and the desired form. A mutual understanding of the necessity for collaboration must emerge among MNO's, often driven by economic shifts or regulatory changes. Such interdependencies foster a shared vision in the network operator, and can even extend to the public domain. Getting the public domain on board a collaborative vision can assist in getting the institutional environment right and may provide opportunities in the form of a coordinating and governing independent body such as the RDI. This independent referee can coordinate the creation of a cooperative agreement, outlining the goals, responsibilities and obligations of the collaboration. Moreover, this independent body can enforce this agreement through governance mechanisms to prevent conflicts and opportunistic behaviour from arising initially. this can prevent the collaboration from collapsing.

In the interviews, the interviewees shed their light on potential forms of collaboration. The opportunities that were identified encompass transsectoral sharing of data, joint R&D for development of use cases or intensified standardization of technologies and, splitting the active and passive network infrastructure market, enabling MNO's to share the passive infrastructure. Also suggestions were made on making the higher spectral bands free and collaborating with other connectivity solutions such as Low Earth Orbit (LEO) satellites or the Lorawan network. Further research into these topics should indicate where the preferences of the stakeholders in the mobile network operator domain lie and and how the first steps can be taken in the realization of these efforts.

While this research has delivered potential forms of collaboration and a set of conditions that needs to be met to realise successful collaboration, it is important to view these results in a broader perspective. In order to realise collaboration, it is important that a feeling of needing each other emerges. The mobile network operator market is a fiercely competitive market which causes that this 'feeling' is currently far from prevailing. Without these interdependencies, collaborative efforts are likely to fail due to distrust and a high risk of potential conflicts. Moreover, this feeling of needing each other is something that will be difficult to achieve across all three Dutch MNO's. Competitiveness is deeply rooted in the Dutch mobile network operator market and this competitiveness resonates deep within the organisation of MNO's and in the regulation of these markets. MNO's feel they can handle the current prevailing challenges on their own, but also foresee that these challenges may become more problematic in the future. In order to address these potential challenges through collaboration, a fundamental shift in vision and perspective is needed across both the public and private domain to jointly set a new course. Getting the public domain on board is crucial to get this institutional environment right which is currently focused on preserving the currently desired levels of competition for the sake of innovation and redundancy. Aligning these very differing visions is likely to be the main limiting factor for collaboration in the future due to differences in knowledge, perspective and desires. Therefore, collaboration between MNO's will probably only happen as 'a last resort' option to address emerging (societal) challenges. Considering the current visions of both the public and private domain, a lot needs to happen before collaboration will ever be a viable option.

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List of Acronyms

3GPP	3rd Generation Partnership Project
5GC	5G Core Network
ACM	Authority Consumers & Markets
API	Application Programming Interface
BBU	Baseband Unit
C-ITS	Cooperative Intelligent Transport Services
CapEx	Capital Expenditures
GDP	Gross Domestic Product
IAAS	Infrastructure-as-a-Service
IEEE	Institute of Electrical and Electronics Engineers
IoT	Internet of Things
IP	Internet Protocol
IPv6	6th version of Internet Protocol
ITU	International Telecommunication Union
LEO	Low Earth Orbit
LTE	Long Term Evolution
MBB	Mobile Broadband
MEC	Multi-Access Edge Computing
MIMO	Multiple-Input Multiple-Output
MNO	Mobile Network Operator
MOCN	Multi-Operator Core Network
MORAN	Multi-Operator Radio Access Network
MVNO	Mobile Virtual Network Operator
NFV	Network Function Virtualization
OBU	On-Board Unit
OpEx	Operational Expenditures
PPP	Public Private Partnership
QoS	Quality of Service
RAN	Radio Access Network
RDI	Dutch Authority for Digital Infrastructure (Rijksdienst Digitale Infrastructuur)
ROI	Return On Investment
RRU	Remote Radio Unit
RSU	Road-Side Unit

SDN Software Defined Networking

UE User Equipment

WiMAX Worldwide Interoperability for Microwave Access

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1
Introduction

In this chapter, the problem background will be presented. Than, the research gap will be identified. Based on the research gap, a research question will be formulated followed by the associated sub questions. The chapter will be finalized with an outline for the remaining part of the thesis.

1.1 Problem Background

1.1.1 The Transport Landscape in the Netherlands

The geographic location of the Netherlands has allowed the country to develop itself into a global key player in the field of transport and logistics. With a location on the crossroads of some of Europe's most important trade routes, the Netherlands have developed one of the world's leading transport infrastructures. With the Port of Rotterdam, Schiphol Airport and, the Dutch road, water and rail network, the Netherlands have become essential in internationally spanning supply chains acting as an important hub, connecting western Europe to the rest of the world. The geographical location of the Netherlands, in combination with the business-friendly climate, an innovative and advanced transport system and a high skilled workforce available in the Netherlands, have attracted global leading transport and logistics companies to station in the Netherlands. Besides generating and making business transactions, these companies generate a lot of employment for the Dutch society. With that, the Dutch transportation sector has proven to be invaluable to the Dutch economy, contributing to around around 4% of the Netherlands' Gross Domestic Product (GDP) over the past years (Statistics Netherlands, 2021). A great share of this economic value can be attributed directly to road transportation, generating around 2.3 % of the Netherlands' GDP, since nearly two-thirds of all goods are transported by road (Statistics Netherlands, 2021). Additionally, road transportation plays an important role in the life of Dutch citizens, allowing them to commute and perform their day-to-day activities.

Since the road transportation sector is of great importance to the Dutch economy, innovating the sector has a high priority on the Dutch political agenda (Government of the Netherlands, 2021). Maintaining and pursuing a high quality state-of-the-art road transportation sector is of great importance to maintain a competitive advantage over other countries in order to keep attracting businesses that will contribute to the Dutch economy. Therefore, the Dutch road transportation sector is a leader in terms of innovation, making the sector one of the most innovative and advanced in the world. According to the 2020 Global Innovation Index, the Netherlands ranks second in the world in the area of transport infrastructure and connectivity, which highlights the country's focus on innovation and technology (Dutta et al., 2020). This understates that the Netherlands are on the forefront of implementing innovative and sustainable solutions in the road transportation sector.

1.1.2 Challenges in Dutch Road Transportation

Although the Dutch road transportation is one of the best and most innovative of the world, the sector is facing challenges that could impact its future growth and sustainability. According to the Government of the Netherlands (2021), one of the most significant challenges is the increase in traffic congestion. With the Dutch society expanding each year, the emerging trend of urbanisation and an increasing demand for more mobility, congestion is expected to cause significant societal problems in the future, resulting in high social, environmental and economic costs (European Environment Agency, 2020). This will have a negative impact on the environment, economy and quality of life of citizens. Especially business operating, and people living in urban areas can be severely impacted by this problem. On top of that, the Dutch road network is facing challenges regarding safety and sustainability (Government of the Netherlands, 2021). These challenges are caused by congestion, aging infrastructure sections, having a shortage of skilled drivers, and an increasing demand for more sustainable transportation options (European Environment Agency, 2020). With the breakthrough of electric powered vehicles and the emergence of hydrogen powered engines, the shift towards more sustainable modes of transport has taken a giant leap. On top of that, maximum speed allowance has dropped to 100 kph with the aim of reducing carbon and nitrogen emissions, contributing to sustainability goals set by the European Union. However, it cannot be stated that these measures completely dissolve sustainability challenges. Also, the aforementioned measures and developments do not resolve challenges in terms of safety and congestion. For that, the Dutch government has to turn towards other policies. Over the past decades, improving road transportation always resulted in the same conclusion; more asphalt. The focus was on physically expanding the infrastructure instead of managing and exploiting the existing infrastructure. Considering the impact on the environment and the technological breakthroughs of the past years, governments are shifting their focus to Information and Communication Technologies for new methods to tackle the aforementioned attributable societal problems. Information and Communication technologies are believed to significantly improve road usage, road efficiency and safety (Hamida et al., 2015) Therefore, The Dutch government is also shifting its focus to these technologies in order to explore and implement concepts of smart mobility (Government of the Netherlands, 2021).

1.1.3 Innovations in Dutch Road Transportation

Over the past two decades, Intelligent Transport Services (ITS), also known as telematics, have increasingly been deployed in the Dutch transport systems in order to improve traffic management and road safety (Government of the Netherlands, 2021; Ministerie van Infrastructuur en Milieu, 2016). ITS provide users with real time information on traffic situations through data exchange between road users and infrastructure (European Commission, 2021a). However, a new form of ITS is just around the corner. Recent developments in the information and communication sphere, are the development of so-called Internet of Things (IoT) services. IoT services are known for their high degree of connectivity which allows for automation. This makes that IoT services are believed to disrupt multiple sectors and markets over the coming decade(s). In the (road) transportation sector, the dawn of so-called Cooperative Intelligent Transport Services (C-ITS), an evolution of ITS and a form of IoT, has arrived.

C-ITS refers to the establishment of services in which vehicles connect and cooperate with each other and other infrastructure components to overcome, manage and avoid undesired traffic situations (European Commission, 2021a). These services are based on the creation of VANETs (Vehicular Ad-Hoc Networks), where vehicles are equipped with on-board units (OBUs). Through these OBUs, information systems in vehicles like cars, motorcycles, and trucks will be able to communicate constantly with each other (V2V communication). Road infrastructure sections are in turn equipped with RSUs (road-side units), that allows data to be transmitted from the infrastructure to vehicles (V2I communication), or to other infrastructure sections (I2I Communication). With that, VANETs are based on the V2X (Vehicle to Anything) communication principle, where OBUs, RSUs, pedestrians and other sensors, devices and servers are constantly transmitting data to one another regarding real-time traffic situations. Based on this information, road participants and the infrastructure cooperate in using the infrastructure as efficient and safe as possible. Hence the name C-ITS. This allows amongst others for detecting potential car crashes, traffic jams and it also adapts driving styles which allows for shrinking fuel usage (Al-Holou et al., 2012; Singh et al., 2012). With that, C-ITS is regarded as 'vital' by the European Commission (2021a), and as the next step in automating the transport sector, tackling problems related to safety, congestion and environmental pollution. In general Car 2 Car Communication Consortium (2021) distinguishes three types of C-ITS: awareness driving, sensing driving and cooperative driving. Where awareness driving provides drivers with information on upcoming events on the road, sensing driving provides road users with roadside information, scanning the environment (Car 2 Car Communication Consortium, 2021). Cooperative driving is the sort of driving where road users actively cooperate to overcome traffic situations. A higher goal in the C-ITS sphere are the fully autonomous vehicles that operate without interference of human drivers (Ministerie van Infrastructuur en Milieu, 2016). These type of vehicles and also partially autonomous vehicles trust heavily on information that they obtain from other vehicles and devices through data distribution. This highlights the importance of a state-of-the-art data infrastructure that facilitates the data exchange between vehicles and infrastructure components.

ETSI, the European Telecommunication Standards Institute, has designed a designated communication technology to make the construction of VANETs possible. In the telecommunication sphere, these designs are referred to as standards which comprise a set of technical specifications, guidelines and protocols. This is further explained in chapter 3. For C-ITS, ETSI ITS-G5 is developed based on the IEEE 802.11p standard. ETSI ITS-G5, also known as Dedicated Short-Range Communications (DSRC), provides a short-range wireless communication platform that operates in the 5.9 GHz spectrum band which is a designated band for C-ITS services in the EU. While ETSI ITS-G5 is considered a promising technology in the realisation of C-ITS, it also has its shortcomings and challenges. Most of these challenges are mainly prevailing in themes such as safety, security and privacy (Ali et al., 2018; Camacho et al., 2018). Challenges regarding addressing of data, risk analysis and management, trust around data, secure localization, prioritization of data packets and reliability and interoperability of various networks (Camacho et al., 2018). Since ETSI ITS-G5, or DSRC, leverages short-range communication with data transmission over a maximum distance of 1000m, the communication technology relies heavily on the presence of vehicles to obtain, process and distribute data (Ali et al., 2018). To resolve these issues, 5G, the fifth generation of mobile communication technologies will be used to complement and maybe compete with ETSI ITS-G5 networks (Ansari, 2021). Both networks will operate in the 5.9 Ghz spectrum band (Ansari, 2021).5G offers, amongst others, lower latency, higher data rates, better security and massive connectivity which can enable a whole new field of C-ITS services such as CCAM (Cooperative Connected and Automated Mobility) (Elia et al., 2019). Therefore, 5G is believed to play an important role in the realisation of C-ITS services by realising Cellular V2X communication (C-V2X). On top of that comes that telecom providers may play an important role in the development, implementation and operations of ETSI ITS-G5 networks. That is why in multiple recent pilots, regional authorities rely on the assistance of telecom providers in setting up and testing of network(s) (Elia et al., 2019). This highlights the amount of stakeholder interdependencies.

1.1.4 Importance of Cooperation

In C-ITS services, different devices such as OBUs, RSUs, devices carried by pedestrians and other devices will cooperate by sharing data regarding traffic situations to ensure an efficient, safe and secure flow of traffic. This also means that devices which are operated by various stakeholders such as car manufacturers, road operators, telecom providers and C-ITS service providers. This highlights the complexity of the matter. In order to realize this cooperation is of undeniable importance. According to the European Commission (2021b), C-ITS can only be realized when all associated stakeholders work closely together on themes such as interoperability, standardization and harmonization. In this collaborative efforts it is crucial that both public and private parties join the table (Lu et al., 2018). Lu et al. (2018) complements this by sating that is crucial to develop collaborative business models with all associated stakeholders. Only than, wide-scale adoption is possible. Recent efforts regarding such collaborative approaches resulted in a number of consortium's where agreements are made with varying stakeholders.

1.2 Research Gap

1.2.1 Knowledge Gap and Research Question

The literature review indicated that technological, organisational, legal and economic challenges delay the development and deployment of C-ITS. The main challenges are centralized around the network(s) that will be utilized for C-ITS. Privacy, security and localization and addressing issues makes that networks are not ready for deployment of C-ITS (Camacho et al., 2018). As highlighted by the European Commission (2021b) and Lu et al. (2018) cooperation is crucial for further development of C-ITS. Without cooperation, no economies of scale can be achieved and wide scale adoption is far way. Although there are some consortium's on an European level where car manufacturers and telecom providers cooperate to ensure interoperability, little is known about final network designs. For the Netherlands, this is the case as well. There is no information in existing literature on who will run and operate which networks and how the final network design will look like. Apart from a few pilot tests, no concrete steps have been made to join efforts and overcome network shortcomings in the Netherlands while information sharing is known to be crucial. ETSI acknowledges that final network designs will vary among different countries due to varying economical, regulatory and organisational conditions. With that, the Netherlands have to be on the forefront of development to ensure a state-of-the-art road infrastructure in present-day and also, in the future. Therefore in this thesis the focus will lay on the of cooperation on the network side of C-ITS since most challenges are centralized around the network(s). By researching the network side of C-ITS in the Netherlands, this thesis aims gain an understanding on under which conditions telecom providers are willing to cooperate in order to lay a solid foundation for further C-ITS development. With that, the research question in this thesis will be:

Under which conditions and in what forms can Dutch mobile network operators collaborate to establish C-ITS-ready 5G networks in the Netherlands?

1.2.2 Sub Questions

In order to answer to answer the main research question, the following set of sub questions has been formulated. By providing an answer to the formulated sub questions, an answer to the main research question can be constructed.

1. *Which collaborative approaches for realizing cooperation between competing commercial companies can be identified in existing literature?*
   (a) *What potential forms of collaboration between competing commercial companies can be identified in existing literature?*
   (b) *What are potential barriers or opportunities for collaboration between competing commercial companies according to existing theories in the literature?*
2. *What insights can be gained from interviews with stakeholders and experts regarding their perspectives on collaboration in the 5G for C-ITS context, and how can these insights contribute to the overall understanding of effective collaboration strategies?*
   (a) *What are the technical, organisational, institutional, and economic considerations according to the interviewees to collaborate in the construction and operation of C-ITS ready 5G networks?*
   (b) *What are the potential challenges and opportunities in implementing a multi-operator approach in the creation and operation of C-ITS ready 5G network(s) based on the interviewees, considering the specific characteristics of the Dutch telecom market?*

1.3 Thesis Outline

In this introduction, the problem background is sketched and the research gap was identified. Based on this research gap, a research question and associated set of sub questions have been constructed. In chapter 2, the research approach and consulted research methods will be discussed. This chapter aims to substantiate the choices of the researcher for the selected research methods. In chapter 3, the concept of 5G will be analysed. This chapter acts as a learning trajectory for both researcher and reader on the promises and technologies of 5G. While this information does not cover one of the identified sub questions, it is believed that the chapter is very valuable for the interviews. In chapter 4, the literature review will be conducted to provide an answer to sub question 1. After the literature review, the input for the interview questions is obtained and the interviews will be conducted. The results of the interviews will be discussed in chapter 5. After the analysis, a reflection on the results will be presented in chapter 6. Here, the resulting model of the research will be presented. The research will be finalized with a conclusion in chapter 7 and a discussion in chapter 8.

2
Methodology

In this research, the aim is to identify the conditions under which Dutch telecom providers are willing to cooperate in building networks for C-ITS that will enable faster deployment of C-ITS services. The main research question is presented in section 1.2. Based on this research question the sub questions were formulated in section 1.2.2. In order to answer the research question, an exploratory research will be conducted based on a literature review. The literature review will form the basis of the interview questions that will be formulated to conduct the semi-structured interviews.

2.1 Research Approach

Sekaran and Bougie (2016) state that the nature of the study, and the associated methodology, are strongly determined by the availability of knowledge in existing literature. With regard to this research, the nature is exploratory since there is no knowledge on under which conditions Dutch telecom providers can and will cooperate in the realisation of 5G networks for C-ITS. Therefore, a qualitative research approach will be followed in this research, since this type of research is most suitable when the research has an exploratory nature (Bachiochi & Weiner, 2002). Qualitative research approaches allow for exploring the viewing point of both heterogeneous and homogeneous stakeholders (Choy, 2014). This can mainly be valuable in situations where little is known about the to be researched problem. With that, qualitative research allows for designing complex system interventions by answering questions such as: "what works for whom when, how and why" (Busetto et al., 2020). It allows the researcher to make use of what is not written and explore possible designs of novel system interventions. According to Hunter et al. (2002), qualitative research gives the researcher room for creativity by exploring the new.

A selection of data collection methods associated with qualitative research are: workshops, focus groups and interviews. In this research, prior to the data collection, a literature will be performed. Than the results from these studies will be used as input for the interview questions. Through personal interviews, interviewees will get the chance to further elaborate on answers which helps in gaining a deeper understanding into the matter (Sekaran & Bougie, 2016). It also allows the interviewer to dive deeper into new findings that can be encountered during an interview. According to Tucker et al. (1995), a combination of multiple techniques in qualitative research, delivers more accurate and more valid conclusions which contributes to the scientific contribution of the study. The research methods that will be used will be explained in the following sections.

2.2 Literature Review

The first research method that will be performed in this research is a literature review. First, the literature review will be used to gain an understanding on what 5G networks entail, how they are constructed, and how they are operated to understand the viewing points and considerations of telecom providers. With that, chapter 3, helps the researcher and readers of this study to understand the technicalities of the study. Than, the literature review will be performed in chapter 4 to answer sub question [1]: *Which collaborative approaches for realizing cooperation between competing commercial companies can be identified in theory and existing literature?*

According to van Wee and Banister (2015), a systematic literature review helps the researcher in getting an up-to-date and well-structured overview of existing literature in a specific field of topic. This allows the researcher to gain an substantial amount of knowledge in the research area. Knopf (2006) complements that literature reviews are useful to reveal what has already been done. On top of that, a literature review can deliver new insights to the researcher that can be used in his own research (Knopf, 2006).

The aim of the literature of twofold. Firstly, the literature review aims to provide an overview of the various collaborative approaches that can be consulted to bring telecom providers closer together and work together towards a common goal. And secondly, factors that will contribute towards successful collaboration and barriers for successful collaboration will be identified. Based on the gained information from the literature review, a conceptual model will be constructed. In the creation of the conceptual model, the researcher can use its creativity and knowledge to identify and select factors that were not covered by the literature review. These factors can than be verified through some additional literature review. Based on the conceptual model, interview questions can be formulated that will be consulted in the second phase of the research.

2.3 Interviews

This section will describe the adopted interview process. After this, this section will dive deeper in how interviewees were selected, how interview questions were constructed and how the interviews were conducted and transcribed.

2.3.1 Adopted Interview Process

Figure 2.1 provides a simplistic overview of the adopted interview process. Step 1 in this research was identifying what information what is needed. This was done in chapter 1 by formulating the research question and associated sub questions. After this step, the required information was gathered through a systematic literature review in chapters 3 and 4. The gathered information was conceptualized in the conceptual model. After selection of the potential interviewees, interview questions were formulated based on the information presented in the conceptual model. The interview questions are tailored to the selected interviewees, resulting in a unique set of questions for each interviewee. With that formulated questions and set interviews dates, the interviews were conducted. The information obtained from the interviews was transcribed after which the results were analyzed. These results where than processed in this research report.

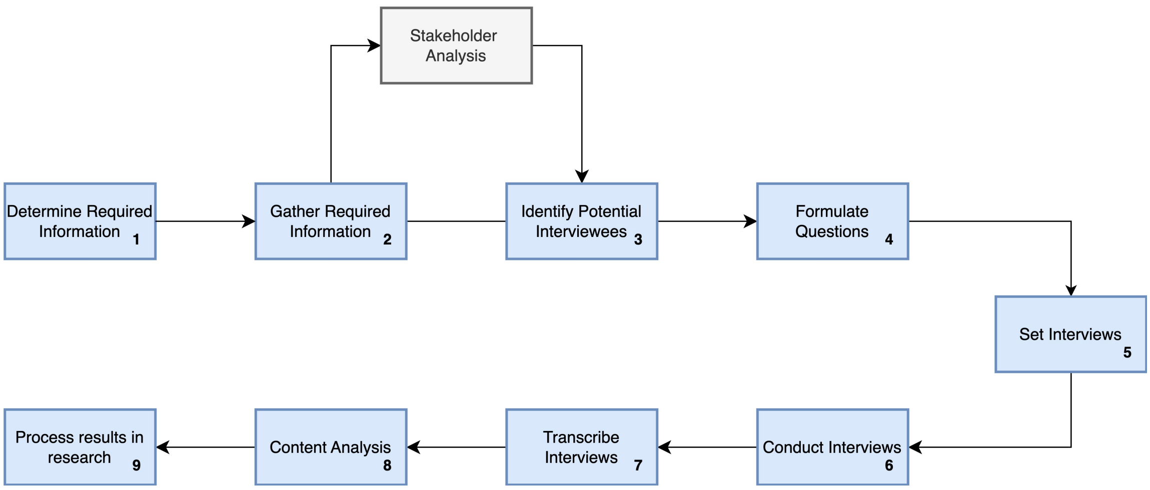


Figure 2.1: Interview Process

2.3.2 Selection of Interviewees

According to DiCicco-Bloom and Crabtree (2006), selecting interviewees is an important part of qualitative research. Selected interviewees need to be " fairly homogeneous" and above all, have a stake in the outcome of the research question. Therefore, the researcher aims to choose interviewees in such a way that broad and rich data can be gathered to answer the research question (DiCicco-Bloom & Crabtree, 2006). In this study, the researcher aimed to choose the interviewees through a comprehensive stakeholder analysis. By means of the stakeholder analysis, the researcher was able to identify all stakeholders that relate to the research question. With the identified set of stakeholders, the researcher was able to target potential interviewees. Making a well-considered division of interviewees, should deliver the researcher a broad set of viewing points and considerations regarding the research topic. Bolderston (2012) refers to this method as purposeful sampling. In purposeful sampling, the identified interviewees resemble the to be studied stakeholder group. The identified stakeholders are presented in section 5.1.1. From this analysis, the to be targeted interviewees where selected in section 5.1.3. This delivered the final set of interviewees.

2.3.3 Construction of Interview Questions

Firstly, information needs to be gathered related to the research question. This will be performed through the literature review in chapter 4. The obtained information from the literature will be used to create a conceptual model in section 4.4.2. The conceptual model is shown in figure 4.2. By means of the conceptual model, interview topics were identified and interview questions could be designed around these topics. According to DiCicco-Bloom and Crabtree (2006), constructing good interview question is crucial to obtain good and useful results. Interview questions need to have a clear and short design and have a conversational tone. On top of that, interview questions need to have an 'open' nature to eliminate 'yes or no' responses by the interviewee. This allows the interviewee to elaborate on its response and tell its story (DiCicco-Bloom & Crabtree, 2006). Based on these qualifications, a set of interview questions was designed. The interview questions are presented in Appendix B.

2.3.4 Conducting and Transcribing the Interviews

After the selection of the interviewees and the formulation of interview questions, interview appointments were made. The interviews occurred in a 'live' setting either face-to-face or through a video call. The interviews were performed though the application of the semi-structured interview technique. The semi-structured interview technique combines prepared interview question from structured interviews with the open-ended exploration of unstructured interviews (Wilson, 2013). This allows the researcher to obtain information on a set of predetermined topics, while also exploring new identified topics and findings (Wilson, 2013). This is particularly useful when identifying attitudes and opinions towards a certain topic, in this case cooperation between telecom providers. The researcher determines when sufficient information is gathered on a certain topic, and continues following the set of pre-determined question when needed.

At the beginning of the interview, prior to asking the interview question first question, the researcher asked the interviewee for permission to record the interview. All interviewees gave consent for a recording of the interview so that the researcher could analyse the results. The recordings were than transcribed through a transcribing tool called GoodTape. From there, the researcher could analyse the obtained results. The transcriptions of the interviews will be provided in a separate document. In Appendix C to H, the most important statements are presented.

2.4 Analysis of Interview Results

After conducting and transcribing the interviews, the gathered data was systematically categorized in four themes corresponding with partial question 2a; economic, organizational, institutional and technical statements. These categorizations of statements per interviewee are presented in tabular format in Appendices C to H.

2.4.1 Thematic Mapping and Categorization

In chapter 5, the gather data underwent a further mapping. The statements from all interviewees were examined and similar statements were consolidated per theme. This allowed for the construction tables 5.2,5.3, 5.4 and 5.5. The statements were grouped based on the overarching principle of the statement. This resulted in a set of of overarching categories per theme. These are presented in table 2.1 below.

Theme	Category
Economic	Business models
	Joint Business Models
	Regulatory Economic Push
Organizational	Shared Vision
	Interdependencies
	Trust & Opportunistic Behaviour
	Governance
Institutional	National Regulation and Cooperation
	European Legislation
	Innovation, Consumer Protection and Competition
Technological	Redundancy and Network Resilience
	Technological Feasibility
	Cost of Technological Development
	Gaps in Technical Knowledge

Table 2.1: Categories of Statements per Theme

Per consolidated statement, the researcher mapped which interviewees made that particular statement. This provided the researcher with a view on how widely carried the statements were across the interviewees. After this mapping, per category the researcher analysed the findings from the interviews. In the process of analyzing, quotes were presented to give clarity, context and richness to the findings.

2.4.2 Synthesis of Findings

After the categorization of statements, the researcher can pursue answering sub question 2b by identifying the main challenges and potential opportunities in realising collaboration between MNO's. The main challenges can be identified from the analysis of the results, followed from the thematic mapping and categorization. During the interviews, the interviewees were asked about the potential forms of collaboration. Following the application of semi-structured interviews, the researcher was able to dive deeper in potential opportunities for collaboration that were mentioned in the interviews. These opportunities for collaboration will also be identified and provided in section 5.5.

2.5 Reflection on Results

In the reflection of the results in chapter 6, the researcher will present his insights in the results. Following from the analysis of the interview results, the factors that limit potential collaboration will be mapped. From there, the researcher will explain why and how these factors can arise and influence a potential collaboration. Also, the researcher will present his insights in the potential forms of collaboration. Than, the insights in the overall understanding of collaboration will be presented. With these combined results, a resulting model of the study will be constructed. The conceptual model will be updated for to do so. The researcher will also reflect on significant variances in the in interviews and aim to identify why these variances emerged.

2.6 Thesis Flow

In order to fulfill the thesis in a structured way, a thesis flow diagram has been constructed. The flow diagram indicate which steps need to be taken per chapter and what the results of these taken steps are. The figure is presented in figure 2.2 below.

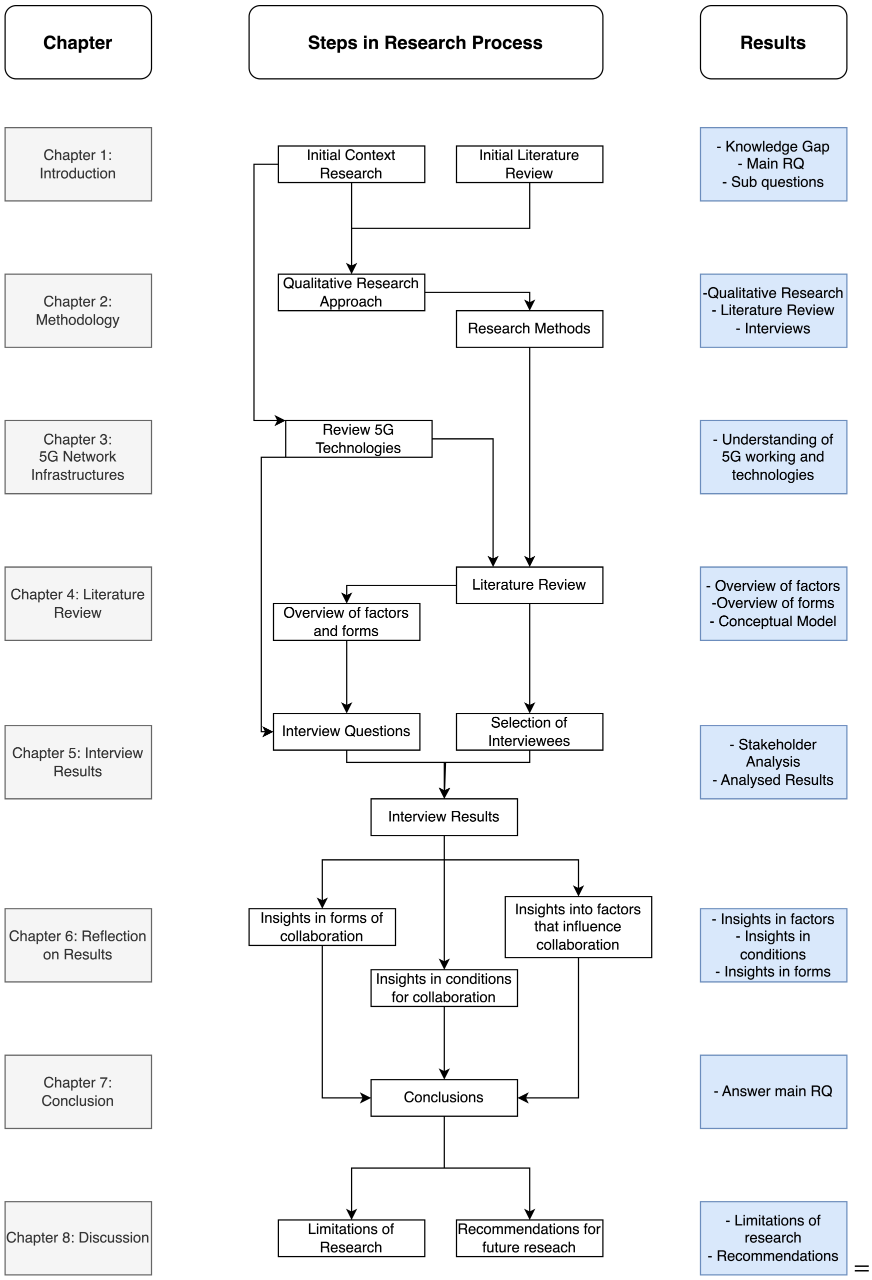


Figure 2.2: Thesis Flow Diagram

3
5G Network Infrastructures

3.1 Introduction

In this chapter, literature will be consulted for the researcher to gain knowledge about the technicalities surrounding 5G. This literature review will be used to understand what 5G entails, how 5G networks are constructed and how standardization is realised. On of of that, this literature review will identify what new technologies distinguishes 5G from its predecessors and what new technologies used in 5G, mean for the capabilities of 5G. With that, this part of the literature review acts merely as learning path for both the researcher and reader(s) of this thesis. This knowledge can be applied in the further phases of the study.

3.2 What is 5G

5G is the fifth, and latest, generation of mobile wireless communication. Followed by the tremendous increase in network traffic volume by users and novel technologies, along with the demanded increase of network performance, the telecommunication industry made huge efforts and investments to realize this 5G network (Ahmadi, 2019). In appendix A, the evolution of mobile communication networks is discussed to indicate how mobile communication networks have evolved over the past decades. The main goal of developing the 5G network was meeting the system and service requirements of existing and future applications that will be build on this network (Ahmadi, 2019). As highlighted by Lei et al. (2020), this implies that network development went beyond the development of mobile broadband (MBB) that is used for connecting users. 5G must deal with a set of six commonly accepted challenges that are not dealt properly by its predecessor, the 4G network. Increased capacity, higher data rates, lower end to end latency, massive device connectivity, reduced costs and higher Quality of Service were the challenges that telecom providers were faced with (Gupta & Jha, 2015). Now 5G networks are increasingly rolled out all over the world and deliver a fast, secure and connected ecosystem that connects both humans and machines seaming less (Ahmadi, 2019). This opens the door to many novel applications and technologies that can be run using the 5G network. An overview of new use cases will be given after which the physical infrastructure behind 5G networks will be explained.

3.3 The 5G Infrastructure

In this section, the physical components of 5G networks will be analyzed and explained to gain a deeper understanding on how 5G networks are build and operated. In order to do so, it is important to highlight that most 5G networks are not yet stand alone networks. This means that 5G are currently operated while being supported by existing 4G, LTE networks. Since C-ITS can only be operated on the 5G network, only the 5G stand-alone network components will be described in this section. Also, over time, 4G network components will be phased out gradually up to the point where 5G can operate as a stand alone network. 4G network components are thus not relevant for the deployment of C-ITS and will be left out of scope during this research.

Telecom providers and Network operators, over time, will let go of 4G technologies, including the 4G EPC which acts as the 4G CORE (Rommer et al., 2019). Up to the moment where 4G is completely phased out and can operate as a Stand-Alone Network, the 5G network will be supported by the 4G network in a so-called Non Stand-Alone Network. In this section, only the 5G Core will be analysed since this is more relevant for this thesis.

A distinction can be made between four main components in 5G networks; the CORE network, the transport network, the Radio Access Network (RAN) and User Equipment (UE). Core and RAN networks are connected through the transport network and UE connect to the RAN network. To gain a deeper understanding in the underlying technologies of 5G networks, both the CORE and RAN network will be analyzed and elaborated upon.

3.3.1 User Equipment (UE)

As mobile wireless connection changed dramatically over the past years, the possibilities of the internet paved the way for new types of devices known as user equipment. In the 2G era, only (mobile cell) phones were able to connect to the network. In the 3G era, smart phones, tablets and computers with mobile broadband access where added to the pool of UE. Over the past years, multiple smart devices such as smart watches but also smart home devices gained access to the internet. Now the 5G era has arrived, a broad variety of devices can be added to the pool of UE. In order to facilitate the aforementioned use cases of 5G, IoT devices will use the 5G network to realize connected services where thousands of devices are connected against ultra low latency. All these devices have certain requirements from the 5G network while it also requires a huge network capacity. UE are connected through internal antennas to the Radio Access Network, the RAN which is first station in accessing the internet.

3.3.2 Radio Access Network (RAN)

The Radio Access Network acts as the bridge between the 5G core network and UE. This connection is enabled through the deployment of cells. Like previous generations of mobile communication networks, 5G is a cellular network. The RAN network is the radio element of this cellular network. First, it is important to understand the basic composition of a cellular network. A cellular network means that the 5G RAN network is composed by cells that cover carefully selected land area's. UE that are within the coverage area of a cell connect to that particular cell through the internal antennas built in UE. This connection between a cell and the device is made through radio signals over which data is transmitted. Cells are placed in such a way that they don't interfere with each other. Parts of the 5G radio spectrum are assigned to cells in such a way that neighbouring cells are not broadcasting in the same range of the spectrum which potentially could cause interference. Compared to previous generations of cellular networks, 5G networks leverage a way higher number of cells in creating a network that features high performance and high capacity.

The cells in cellular networks are placed on so-called cell sites and are key enablers of the RAN. In 5G networks, these cells exist in multiple forms and can be classified based on their size and range. Where macro cells can transmit radio connections that can carry vast distances, coverage from small cells or even femto cells is much lower. However, there is an important difference between these cells since it is not only about signal propagation. The main difference between macro and small cells is in the frequency in which radio messages are transmitted. Low frequency radio signals from macro cells carry kilometres while high frequency radio signals from small cells can cover a few hundred meters. In the case of femto or even micro cells, observations are similar. Femto cells send and receive radio signals with a higher frequency than small cells, but coverage is limited to tens of metres. One major advantage of deploying small cells instead of femto cells is that is significantly lowers CapEx for network providers. That is why 5G networks leverage way more cells than in previous mobile wireless networks. Figure 3.1 provides a simplistic overview of the differences between macro, small and femto cells.

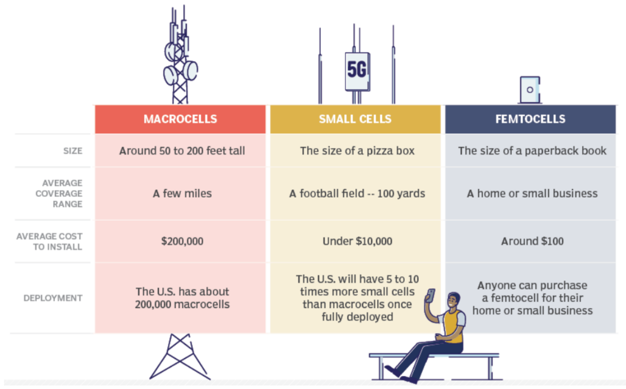


Figure 3.1: Macro vs. Small vs. Femto Cells (TechTarget, 2023b)

The RAN consists of three major components. Firstly, there are the antenna's. Antennas convert electrical signals into radio waves from which they are emitted to UE and vice versa. The electrical signals are send to the second main component, the radio units, where the electrical signals are converted into digital signals. The remote radio head is placed very close to the antenna to avoid loss of signal quality and also filters and amplifies signals. Through optical fiber, the RRH is connected to the baseband unit, or base station, which processes the digital signals. The baseband unit is a complex device that features extremely high data processing speeds and provides a set of processing functions that enable wireless connection. These functions include: signal processing for multiple antennas, signal processing for wireless error detection and correction, ensure the security of the wireless connection and managing the resources between the devices within the network. The BBU is connected to the 5G core network through the transportation network.

The 5G Spectrum

The 5G spectrum refers to the range of frequencies in which electromagnetic waves, that carry data, can be emitted between UE and cell towers. The cells that make up the RAN utilize the 5G spectrum by emitting and receiving electromagnetic waves through the antennas and the remote radio heads. The frequencies on which telecom providers broadcast the electromagnetic waves are part of the so-called licensed spectrum. This implies that telecom providers must acquire the right to broadcast and emit signals on that particular frequency. Followed by the increased amount of devices that need connection to the internet and the associated increase in data traffic, international efforts have been made to develop a plan to allow network providers to increase network capacity. To ensure that this was conducted in a globally coordinated efficient way, management for the global radio frequency spectrum has been assigned to a an international body; The International Telecommunications Union (ITU) (ITU, 2021). The ITU is an international body, created and controlled by the United Nations which means that all member states of the UN are expected to adhere to the agreements and decisions made my the ITU. The ITU has three main tasks: the creation of inter operable standards, frequency band allocation and ensure interoperability of varying international networks (Commission, 2022; ITU, 2021).

On a European level, arrangements, rules and decisions are made in compliance with member states concerning the frequencies on which telecom providers can build their network and broadcast signals. This has been enabled by the 5G Action Plan for Europe, a commission established to realise appropriate coordination of 5G development across EU member states (Robles-Carrillo, 2021). The commission has enabled the expansion of the licensed spectrum within Europe which allowed telecom providers to operate in a broader range of frequencies which dramatically increased network capacity. Input for the 5G Action Plan are the decisions, agreements and guidelines as provided by the ITU (Commission, 2022). By fixing the frequencies on a European level, telecom providers, users and service providers using 5G enjoy the benefits of interoperability while significantly reducing the chances of interference. Member states adhere to the agreements set by the EU, and within their country these frequencies can be assigned by a national commission (Commission, 2022). By operating the spectrum in such a coordinated way, the opportunities of 5G can be exploited while reducing economic and societal challenges (Commission, 2022).

In the Netherlands, these frequencies are controlled by the Radio Communications Agency (Ministry of Economic Affairs and Climate, 2022). This Agency assigns and monitors the usage of frequencies in the Netherlands (Ministry of Economic Affairs and Climate, 2022). The Ministry of Economic Affairs and Climate, auctions frequencies through a so-called Dutch Multiband Auction (Government of the Netherlands, 2020). This is referred to as frequency allocation. In the Netherlands, frequency allocation goes through auctions. Telecom providers can bid on frequencies within spectrum bands to obtain the right to broadcast signals in that particular part of the spectrum. If a telecom provider wins the auction, it owns that frequency and can use it to broadcast and provide coverage for a period of 20 years (Government of the Netherlands, 2020). Telecom providers must adhere to some imposed minimum performance indicators as imposed by the Ministry of Economic Affairs and Climate in order to maintain ownership over that particular frequency. These performance indicators are centralized around providing sufficient coverage and network security and integrity (Government of the Netherlands, 2020). Frequencies that go up for auction are a part of the so-called spectrum bands that are defined by the EU. For 5G, a distinction can be made between three spectrum bands that are used in the EU:

- Low-Band: 700 MHz
- Mid-Band: 3.3 - 3.8 GHz
- High-Band: 26 GHz

The previously mentioned spectrum bands, each have their own characteristics and thus provide opportunities to various use cases. The frequencies in the lower spectrum bands are mostly used by macro cell sites. As briefly touched upon in section 3.3.2, macro cells operate in lower ranges of the spectrum when compared to small(er), femto and pico cells (T-Mobile, 2020). In general, the lower the frequency in which a signal is emitted, the longer the wave length and thus the further a signal propagates. This is illustrated by figure 3.2 This means that one macro cell covers a larger area of land than one smaller cell and thus provides better coverage. Lower frequency signals also have the power to easily pass through walls and buildings which improves coverage even more. On the other side,lower frequencies offer lower speed of data transfer compared to higher frequencies. On top of that, the distance between macro cell sites and UE is higher when compared to small(er) and femto cells. This results in higher latency, making macro cell sites not suitable for services that require the ultra-low bandwith that 5G offers(T-Mobile, 2020). This is provided by other cell cites that operate in higher ranges of the frequency spectrum. The lower frequency band is often referred to as the base of 5G. It ensures that coverage is anywhere at anytime, while higher frequency bands can offer high performance connections to realize the new services 5G was built for.

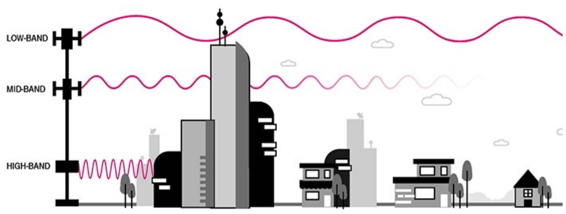


Figure 3.2: Signal Propagation (T-Mobile, 2020)

3.3.3 Transportation Network

The transportation network acts as the bridge between the 5G RAN network and the 5G core network, sending digital signals over the 5G core network from one part of the RAN to another where the signal can be emitted to a designated device. In order to allow for the ultra-high bandwith, ultra-low latency, flexible and connected services 5G offers, the transportation network needed to undergo severe changes compared to the 4G LTE network(Brown et al., 2018). Driven by the desired capabilities of 5G networks, cell deployment increased dramatically in 5G networks. As discussed in section 3.3.2, usage of small(er) and femto cells in combination with a higher number of macro cells, has increased cell density in 5G networks to achieve higher network performance and connectivity (Fiorani et al., 2015). These newly added cells all have to be connected to the 5G core by means of the transportation network while coping with the peak data rates and higher desired performance. This makes that the changes to the transportation network are twofold: firstly, amount of transport network needed and network capacity have changed. Secondly, the transport network must be able to cope with the new requirements and demands of 5G networks and deliver ultra fast, flexible and reliable transfer of data(Barakabitze et al., 2020).

For the physical layer of transport network architectures, new design choices were made. The type of architecture will mostly comprise C-RAN, a designing principle that splits remote radio heads from baseband units as elaborated upon in section 3.5.6. Application of this architecture significantly lower CapEx and OpEx for telecom providers, but also demands additional quality and reliability from the transport network (Fiorani et al., 2015). In general, a distinction can be made between two types of transportation network in 5G network with a C-RAN architecture; the fronthaul and the backhaul. The fronthaul refers to the part of the transportation network that connects radio units to the baseband units in BBU hotels, the backhaul refers to the transport network between baseband unit and 5G core. This is illustrated in figure 3.3. Application of a C-RAN architecture caused that telecom providers had to significantly adapt their transport network. From a fronthaul perspective, the deployment of small and femto cell cites will increase site densification which also means that the transport network must connect more cells to the 5G core. From a backhaul perspective, since baseband units are now in centralized locations, the amount of transport network needed is lower, but also subject to a significant amount of rerouting. The transport network mainly consists of coppers and fibers which guide the digital signals from point to point (Fiorani et al., 2015). In places where fiber infrastructures are difficult to implement, radios can be deployed to guarantee fast and stable transfer of data.

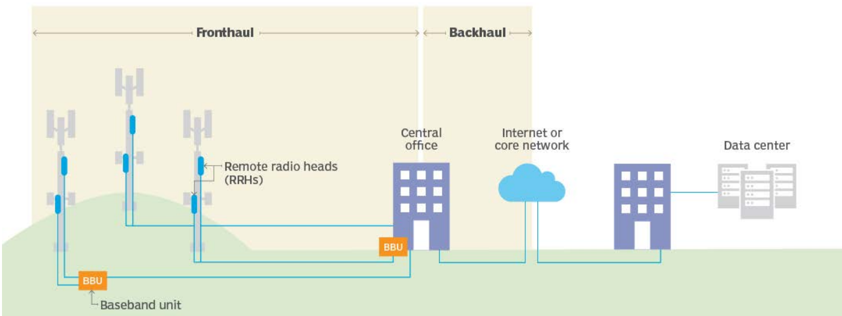


Figure 3.3: Fronthaul and Backhaul (TechTarget, 2023a)

The 5G transportation network also underwent changes from a software perspective. In order to serve and support the RAN network where needed, and enable future 5G use cases, the transport network must be able to cope with peak loads by applying load balancing techniques. Various features of 5G play a role in realizing this load balancing aspect which allows the transport network to accommodate peak loads in different places. One of the technologies that will be applied is, Network Function Virtualization uses novel COTS hardware devices which can carry out multiple tasks based on input through software as elaborated upon in section 3.5.2. SDN (section 3.5.1) enables NFV by separating data and control planes in hardware devices which allows for dynamic control of hardware through API's. SDN and

NFV go hand in hand and allow for dynamic operation of the transport network. This makes that the 5G transport network is known for its agility and flexibility.

3.3.4 5G CORE Network

As the name suggests is the 5G CORE Network literally at the heart of 5G. Without it, devices could not connect to the internet, nor to each other. It is important to understand how this 5G Core works and what it exactly is in understanding how telecom providers can operate their networks and provide connectivity to millions of devices.

At the end of 2017, the 3GPP, a global partnership between multiple standards of telecommunication, defined the 5G system architecture and with that the architecture of the new 5G CORE (Mademann, 2018; Rommer et al., 2019). A CORE network is made up by set of so-called network functions. Each of these network functions fulfills certain tasks to connect devices to the internet and to other devices. The collection of these network functions is referred to as the 5G Core. As defined by the 3GPP, The 5G CORE was to be developed through the application of a new architectural design principle, a service based architecture. This means that these network functions were connected and facilitate and utilize other network functions in the network (Rommer et al., 2019). Network Functions can act as service consumers or service producers in this relation (Rommer et al., 2019). The Network Repository Function (NRF) is of high importance here since it creates a repository of all the functions that are available in a specific network. Service consumers can access the NRF to discover available services within the network. Rommer et al. (2019) provides an overview of the Network Functions in the 5G Core Network and how these functions are interrelated. This is overview is provided in figure 3.4. Some of these network functions will be explained.

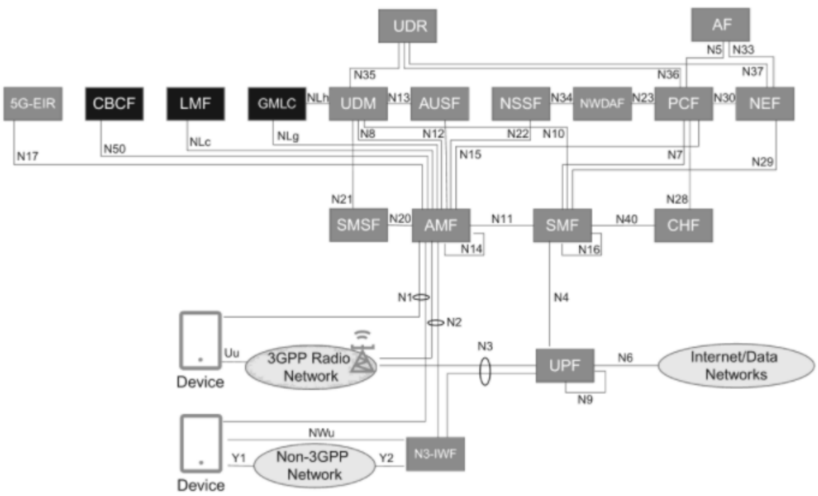


Figure 3.4: 5G CORE (Rommer et al., 2019)

Rommer et al. (2019) refers to a set of network functions as 'the core of the core'. This set of network functions is needed to establish safe and secure sessions and allow for data transfer from and to devices. Without these network function, core networks can't be deployed. The following network functions make up the core of the core:

- **UPF:** The UPF is the User Plane Function. The UPF handles all data processing and forwarding, connecting devices to external networks and the internet as illustrated in figure 3.4. Data packages from other networks can be send to the UPF that a device is connected to. The UPF acts here as a forwarding engine for data packages, sending packages across network to devices. The UPF also inspects data packages and analyzes the contents. This allows the UPF to mark certain packages by attaching priority labels. Once marked, the transport network can than prioritize specific transfer of data packages in case of network congestion. This allows for maintaining high QoS for specific types of data. Lastly, the UPF allows for buffering data, forcing devices back to active state to receive the data.

- **AMF:** The AMF is the Access and Mobility Management Function which connects and interacts with the RAN and UE. The AMF's main tasks is ensuring and managing connection to UE by supporting signalling call flows. This means that the AMF supports the routing of data packages within and across networks. The AMF allows UE to be registered and authenticated to maintain connection to the internet y using the UDM. The AMF also supports reaching devices that are in idle mode. A device is in idle mode when it is selecting a cell that offers the best radio signal quality.
- **SMF:** The Session Management Function manages all user sessions. It establishes and modifies sessions. It does so by managing the contents of sessions with the UPF, allowing the UPF to handle the data associated with the session. The AMF receives requests from UE and consults the Network Repository Function. The AMF than forwards request to the appropriate SMF to establish and manage a session.
- **UDR:** The Unified Data Repository offers a place where data can be stored. Other network functions such as the UDM, PCF and NEF can store and access data here. The types of data that is stored in the UDR is dependent of the network function that uses the UDR. The UDM mainly uses the UDR for subscription data while the PCF can store and access policy functions in the UDR.
- **UDM:** The Unified Data Management Function supports the AMF generating authentication data from devices. The UDM also generates subscription data which is stored in the UDR. This allows the UDM to provide network access to specific devices. Lastly, the UDM maps and manages which devices are connected to which SMF's and AMF's when more instances of these functions are present in a network.
- **AUSF:** The Authentication Server Function uses the authentication data generated by the UDM to provide the authentication functions to devices to gain access to the network. This information is provided to the SMF.

3.4 Standards

Standards in telecommunication refer to the application of internationally coordinated 'rules and laws' regarding the technicalities of existing and novel networks. Standards are crucial to ensure interoperability of devices and networks in the telecommunication sphere (Kurtz, 2017). If standards were not applied in telecommunication, users would need a specific device for each network or network function (Kurtz, 2017).

Standards are developed and produced by international acknowledged standard bodies. These standard bodies complement and assist each other in delivering a set of standards that allows users to benefit from inter operable telecom networks. Standard bodies focus on specific topics within the field of telecommunication. The standard bodies that play a role in Europe will be identified in this section. Also, main tasks these standard bodies fulfill will be presented.

3.4.1 ITU - International Telecommunications Union

The ITU was created in 1865 by the United Nations and is a leading body in terms of standards. Being a UN body means that all UN member states are expected to agree on decisions and adhere to the regulations and standards that are set by the ITU. The Netherlands is one of these member states. The ITU is specialized in standards in information and communication technology and is divided in three divisions (Kurtz, 2017). The so-called ITU-T focuses solely on telecommunication. Within the ITU-T member states have a vote with regard to the decisions. Carriers, equipment and software vendors, and international telecom organizations have a non-voting membership, but share information and insights with member states (ITU, n.d.). This makes that the ITU-T acts as a think thank where member states can discuss challenges, explore technologies and innovations, and set directions for the global telecommunication movement.

3.4.2 ETSI - European Telecommunications Standards Institute

ETSI is the leading standard body for information and communication systems in Europe(Kurtz, 2017). ETSI also has a strong focus on aiding the development of 5G networks. To do so, ETSI has a partnership with the 3GPP (ETSI, 2022a). Standards that are created by ETSI are acknowledged as European Standards (ENs) and applied on national levels by member states. This ensures the interoperability of telecom networks across Europe and even beyond. Since ETSI enjoys a good reputation, standards by ETSI are also applied outside of Europe. ETSI also focuses on the realization of standards in Internet of Things applications. This includes the creation of standards for Intelligent Transport Services and also C-ITS. ETSI aims to deliver standards that enable C-ITS data exchange, connectivity and security (ETSI, 2022b). ETSI also set standards regarding the usage of frequency bands for designated services (ETSI, 2022b).

3.4.3 3GPP - Third Generation Partnership Project

The 3GPP is different compared to the ITU and ETSI. The 3GPP solely focuses solely on the creation of technical standards (Kurtz, 2017). With that, the 3GPP has realized multiple technical standards for cellular technologies. The 5G CORE components that were highlighted in section 3.3.4 are an example of technical standards set by the 3GPP. In an extension to the CORE standards, the 3GPP also sets technical standards for the RAN and service capabilities of 5G networks (3GPP, n.d.). This makes that the 3GPP translates the standards from standardization organisations in technical solutions. This allows for standardization in 5G networks which allows for interoperability.

3.5 5G Features & Technologies

The advances realized in the 5G era are tremendous. Higher system capacity, lower latency, faster data exchange and higher quality of service have enabled a wealth of new applications and technologies based on 5G. These advances are not simply achieved through placing more cells, but through complex advances in technologies that have delivered very promising features of 5G. The main features and technologies that are critical to understand how 5G is build will be explained in this section.

3.5.1 Software Defined Networking

Software Defined Networking (SDN) is a new type of networking architecture that allows network operators to redefine their network configuration against lower capital expenditures (Kirkpatrick, 2013). Through standardized application programming interfaces (API's), network programmers can quickly and easily reconfigure the usage of data and/or hardware within a network without the actual change of physical equipment (5GAmericas, 2017; ACM, 2018). In SDN this is done through the separation of data- and control plane. (Xia et al., 2014). The control plane is the part of the network that controls how data is sent while the data plane actually sends the data. Through this separation of control logic from underlying routers and switches, network operators can easily program the network which simplifies network management and facilitates network evolution (Kreutz et al., 2014). Also, network programmers can program networks in such a way that performance can be significantly improved for certain services (Xia et al., 2014).

3.5.2 Network Function Virtualisation

With the arrival of 5G, network operators moved away from usage of rigid traditional specialized hardware in creating and operating networks(5GAmericas, 2017). Instead, network operators now create open platforms which are known for their flexibility and reduced go to market time for novel applications (Han et al., 2015). Network Function Virtualization (NFV) creates this desired openness by taking away software implementations of network functions from the underlying physical devices (Mijumbi et al., 2015). Commercial-of-the-shelf (COTS) hardware such as servers, switches and storage are utilized through virtualization technologies and together create a Virtual Network Function (5GAmericas, 2017; Han et al., 2015). This results in the fact that all physical hardware can execute all network functions which allows network functions to change dynamically over desired locations on demand to improve network performance (5GAmericas, 2017). This dynamic approach of NPV significantly reduces operating and capital expenses and encourages the development of novel services through increased agility (Mijumbi et al., 2015).

3.5.3 Network Slicing

Network Slicing is one of the most important and promising features of 5G for delivering tailored QoS and is empowered by both SDN and NFV (ACM, 2018). As the term suggests, network slicing is basically splitting a network in multiple virtual sub networks by means of software within the same hardware (5GAmericas, 2017; ACM, 2018). This means that these software enabled virtual networks all make use of the same physical network components from section 3.3. These so-called network slices all have a different purpose and can be designed on a per-service basis (Foukas et al., 2017). Figure 3.5 provides an simplistic overview of a number of network slices for certain application. An important advantage of network slicing for network operators is a dynamic approach for efficient resource allocation, providing only the necessary resources and tools needed for a particular slice (Alliance, 2015; Zhang et al., 2017). For new businesses and applications in different application areas, network slicing is a promising technology to obtain tailored services with desired QoS (Zhang et al., 2017). As highlighted by Zhang et al. (2017), different use cases can have varying requirements from a network. This is also illustrated in figure 3.6.

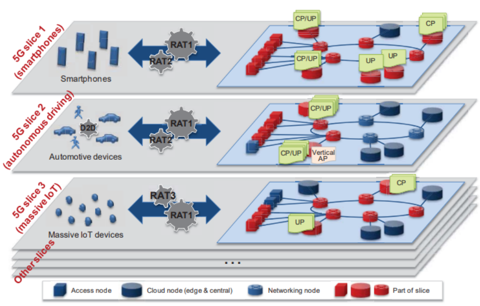


Figure 3.5: Example of Network Slicing (Alliance, 2015)

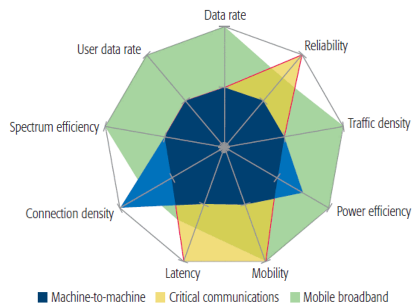


Figure 3.6: Requirements per use case (Zhang et al., 2017)

3.5.4 Massive MIMO

Multiple-Input Multiple-Output (MIMO) technology refers to the usage of a high amount of radio antenna systems that deliver data through multiple parallel data streams on one single cell or basis (ACM, 2018). MIMO antennas have been deployed in 3G and 4G networks, but 5G takes this to a whole other level through the adoption of massive MIMO. If more than one hundred antennas are attached to one base station or cell, one can refer to that system as a massive MIMO system (5GAmericas, 2017). Massive MIMO antennas can handle much more data than conventional antennas since they can transfer more data at once through the higher number of antennas (5GAmericas, 2017). Other benefits of massive MIMO are reduced latency, inexpensive low power components, increased spectral efficiency and increased area capacity (Larsson et al., 2014; Marzetta, 2015).

3.5.5 Multi-Access Edge Computing (MEC)

Multi-Access Edge computing is a key technology that is being leveraged in 5G networks. MEC is a network architecture that has been developed by ETSI followed by the increasing traffic volume and computational demands of devices (Pham et al., 2020). MEC improves matters such as throughput, latency, bandwidth, QoS and automation (5GAmericas, 2017; Porambage et al., 2018). MEC extends existing edge computing services by creating a cloud computing platform at the edge of the RAN(ACM, 2018; Taleb et al., 2017). By running 'heavy' applications closer to the devices, data is processed before it is being sent to the cloud (ACM, 2018; Pham et al., 2020). This significantly reduces network load while it also provides devices with better QoS through lower battery and energy demand (ACM, 2018). MEC is an important accelerator of IoT services where real-time response through ultra-low latency is required (Pham et al., 2020; Porambage et al., 2018). By processing data where it is created, greater performances for businesses can be achieved. On top of that, bringing data processing closer to the edge offers extra privacy and security measures and contributes to lower operational expenses (5GAmericas, 2017). For C-ITS, this MEC will be important in incrementally automating vehicles up to fully autonomous driving.

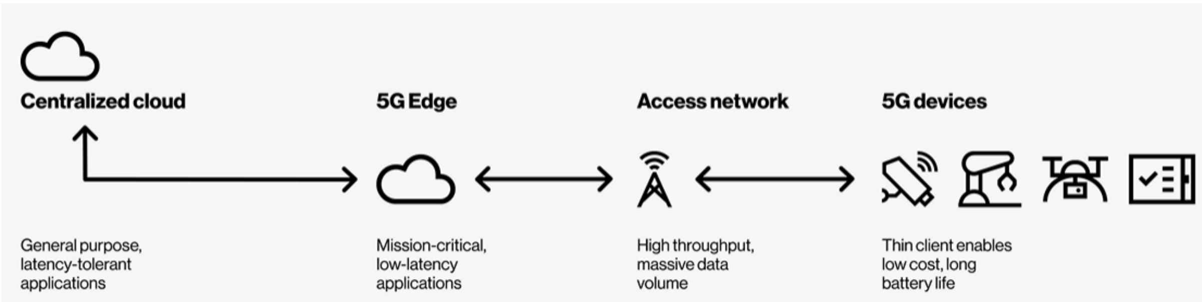


Figure 3.7: MEC overview (Verizon, n.d.)

3.5.6 Cloud Radio Access Network (C-RAN)

C-RAN is a promising architectural solution for network operators by lowering CapEx and OpEx through efficient resource management and faster RAN development, especially in the long run (Hadzialic et al., 2013; Wu et al., 2015). C-RAN also contributes to achieving the desired 5G requirements from applications. All of this is made possible through a re-division of functionalities over new devices in network setups(Valastro et al., 2018). C-RAN divides the RAN architecture in two components; baseband units (BBU's) and remote radio units (RRU's) (5GAmericas, 2017). These radio units are placed at the Edge locations of the network are connected mainly through fibers to BBU's which are situated in centralized locations,mostly cloud centres, away from the cell site. Here, the BBU's are virtualized through which they can be much more easily managed by network operators. Placing these BBU's in one centralized location offers huge advantages regarding the needed resources that empower operations (Simeone et al., 2016).

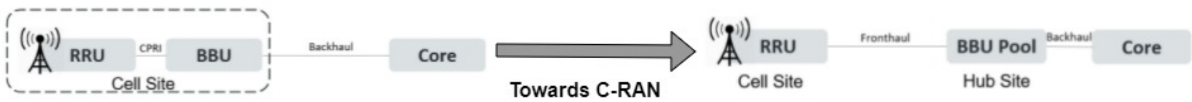


Figure 3.8: Changes in RAN (Hsu, 2013)

4
Literature Review

In this section, the literature review of this research will be performed. In the first section, the added value of a potential collaboration will be discussed. Than potential forms of collaboration will be presented. Afterwards, in literature identified barriers, that can limit telecom providers from collaborating, will be identified. In the following section, the problem will be analyzed through the lens of various theoretical frameworks that, under varying circumstances, may apply to the case of collaboration among telecom providers for C-ITS. This will deliver a set of factors that provide opportunities or barriers for collaboration. The identified factors will be used to create a conceptual model. This conceptual model will act as the input for the next phase of the research; the interviews. With that, this literature review will address sub question [1] *Which collaborative approaches for realizing cooperation between competing commercial companies can be identified in existing literature?*

From the stakeholders analysis in section 5.1.1 followed that, in the Netherlands, three telecom providers actually own and operate a physical network infrastructure; Odido (formerly T-Mobile), KPN and Vodafone. Considering this small pool of potential members of a collaboration, in combination with the limited number of comparable efforts in the Dutch telecom sector over the past years, little is known on how Dutch telecom providers can and would collaborate. A relatively recent research by de Reuver et al. (2015), researched efforts by these telecom providers to joint develop a mobile payment platform. This effort failed. Findings from this research will be incorporated in this research.

4.1 Potential Added Value of Coordination and Collaboration

The telecom industry has undergone massive changes in the past decades. Where decades ago the telecom industry started providing voice-based communication to humans, the current goal in telecom is providing massive and fast internet connectivity everywhere, every time, to all sorts of 'users'. With the technological advances made in the telecom industry, 5G is believed to become a powerful technology enabler in the near future. Many new connected services will be build, using 5G as a data infrastructure. For C-ITS, 5G networks need to connect enormous number of devices in a fast, reliable, safe and secure way. This poses challenges to individual telecom providers in the Netherlands. This section aims to address these challenges by highlighting the potential of collaboration among telecom providers.

The first benefit of a collaboration among telecom providers is **mitigating capital expenditures**. Making 5G networks suitable for C-ITS deployment will require large capital expenditures considering the required cell density (Koutroumpis et al., 2023). Telecom providers need to invest heavily in research & development to develop with network designs and associated technologies and solutions (Hagedoorn, 2002). According to Hagedoorn (2002) and Harrigan (1988), inter-firm collaboration for R&D can be particularly valuable in high-tech industries where learning and flexibility are key in obtaining and maintaining a competitive position. On top of R&D, investments need to be made in the network infrastructure and spectrum bands need to be acquired. These expenditures can be shared as well through network sharing (Houngbonon et al., 2023; Koutroumpis et al., 2023) Collaboration between telecom providers thus allows for pooling of resources (Albers et al., 2005). Through the creation of an investment or R&D pool, the investment burdens can be shared over the members of the collaboration (Hagedoorn, 2002). In this case, resource sharing would mean that individual telecom providers don't have to over-extent their own financial capabilities to obtain a competitive position (Koutroumpis et al., 2023). Instead, financial risks are taken by the members of the collaboration, utilizing each others financial strength. So while capital expenditures are mitigated, inherently (financial) **risks are mitigated** as well. Considering the flight technology has taken over the past years, the pace of new technologies that are arriving is high (Houngbonon et al., 2023). According to Yasuda (2005), this is a perfect precondition for potential inter-firm collaboration. In markets where durability of technology might be low, investments carry risk.

Besides pooling financial resources, other resources can be pooled as well. This can be in the form of knowledge such as technical expertise or research and development capabilities (Albers et al., 2005; Hagedoorn, 2002; Harrigan, 1988). On top of that, other resources such as testing facilities, spectrum resources, human capital, patents and intellectual property and data and analytical resources can be pooled (Koutroumpis et al., 2023). By pooling financial resources, skills, knowledge and other technical resources, telecom providers can **leverage expertise and resources** from each other to achieve a common goal. Telecom providers can, amongst other, use this to develop network architectures, enhance secure data transfer and improve connectivity more efficiently. In technological fields where complexity is high, pooling of resources can deliver synergy effects (Albers et al., 2005). Synergy effects are benefits that emerge from a collaboration through newly gained knowledge and resources (Albers et al., 2005). These synergy effects can prevail as lower CapEx and OpEx, but also more knowledge, skills and expertise. This can enhance the development of 5G for C-ITS.

As discussed in the introduction section of this research, C-ITS is a very promising solution towards resolving issues in safety, congestion and environmental pollution in road transportation. With that, C-ITS is a highly valued technological innovation for the future. Pooling resources such as knowledge, skills and financial resources can ensure that the knowledge and resources in the market are utilized more efficiently (Koutroumpis et al., 2023). This can lead to an **acceleration of 5G readiness for C-ITS**. Through collaboration, telecom providers can coordinate and cooperate to streamline the process of 5G development. Infrastructure architecture can be designed together along with the design of required devices such as OBUs and RSUs. Telecom providers can work together on topics such as data security, low latency and massive connectivity. By collaborating, resources and knowledge can be utilized more efficiently, ensuring the availability of the infrastructure and other critical components that are needed for C-ITS. This can result in earlier 5G readiness for C-ITS, ultimately speeding up the deployment of C-ITS.

In the telecom industry, **interoperability and consistency** across networks is of great importance. In order to realise this standardization, globally spanning standardization institutes have been established from which a few have been described in section 3.4. Without standardization, fragmentation of applied standards protocols can emerge in the market which will limit interoperability and consistencies between networks. Collaboration between telecom providers can ensure that these set standards and protocols are implemented more efficiently. Telecom providers can jointly develop tailored solutions, based on the set standards, that can benefit the local development of C-ITS. Standards act merely as guidelines which enables telecom providers to integrate the standards in a custom fashion. This can deliver more efficient use of standards and protocols which can boost network performance. By jointly testing the developed network infrastructure and associated technologies, telecom providers can collaborate to refine solutions to boost network performance. Telecom providers here again create synergy effects through collaboration by ensuring higher network interoperability.

The telecom sector has evolved rapidly over the past years as a result for more network connectivity and a demand for higher data rates. With the arrival of a new realm of connectivity based services, comparable to C-ITS, networks will need to deliver more high speed, low-latency connectivity. By collaborating and targeting a specific service area such as C-ITS, telecom providers can **enhance future prospects**. A collaboration on a specific topic field does not require full integration between the telecom providers (Hagedoorn, 2002). Lessons learned from a specific collaboration regarding infrastructure development, spectrum allocation and R&D, can provide a solid base for network development in the future to target new service areas (Hagedoorn, 2002). Through collaboration, Dutch telecom providers can thus gain a strong position towards future demand. On top of that, telecom providers can enjoy the benefits of collaboration by overtaking foreign competitors in terms of knowledge and capabilities. Lessons learned in the Netherlands can thus be applied in (new) underdeveloped markets.

To conclude, collaboration between Dutch telecom providers can be pivotal in reaching 5G readiness for C-ITS. By joining forces telecom providers can share financial investment burdens, mitigate risks, utilize available knowledge and resources more effectively, accelerate 5G readiness and ensure interoperability and consistency more efficiently. Through collaboration, telecom providers can tackle 5G related challenges for C-ITS more effectively and efficiently. Collaboration can be a sensible investment for the future, bringing more safe and efficient C-ITS transport closer to deployment. Lessons learned can be applied for accessing new markets, either jointly or separately. Lastly, collaboration can provide telecom providers with a more solid position in a rapidly involving industry.

4.2 Different forms of Cooperation

There are various ways in which telecom providers can collaborate to achieve 5G readiness for C-ITS services. Therefore, this section aims to identify these potential forms of collaboration to answer sub question A of SQ 1 [What potential forms of collaboration between competing commercial companies can be identified in existing literature?]. Each form of collaborative action is typified by its own degree of collaborative intensity. The more the collaborative intensity rises, the more interdependencies emerge and the more integration will prevail among the telecom providers in the collaboration. Therefore, telecom providers must be aware of what each form of collaboration entails before they embark on a collaboration. The potential forms of collaboration will be presented to the interviewees during the interviews. The aim is to address potential forms of collaboration that can be further researched in future researches. Firstly Loebbecke et al. (2016) identifies knowledge sharing as potential collaborative alternative for competing firms. Yasuda (2005) identified resource sharing, joint R&D and joint ventures as potential forms of collaboration.

4.2.1 Knowledge Sharing

Knowledge sharing among telecom providers has some implications and caveats. Knowledge is increasingly important over resources when aiming for competitive differentiation in competitive markets (Loebbecke et al., 2016). With that, the tiniest amount of additional knowledge can distinguish an organization from its direct competitors (Loebbecke et al., 2016). Therefore, a paradox in inter-organizational knowledge sharing can be observed. On the one hand, knowledge sharing, for example within an industry, can improve the development of new business opportunities and innovations and lift the industry as a whole. But on the other hand firms need to secure their competitive advantage that follows from knowledge discrepancies. Consequently, knowledge sharing among competing companies is often prone to antagonisms. Therefore, Loebbecke et al. (2016) designed four configuration of inter-organizational knowledge sharing that deal with the above presented antagonisms through coordination and control processes. Two of these configurations can be applied to telecom providers sharing knowledge. For these configurations, Loebbecke et al. (2016) distinguishes unilateral and bilateral knowledge exchange and identifies two sorts of knowledge: tacit knowledge and explicit knowledge. In unilateral knowledge sharing, knowledge is transferred in only one direction. For example, from vendor to clients. Typically, unilateral knowledge sharing occurs between heterogeneous actors. In bilateral knowledge sharing, knowledge travels in both directions for example between homogeneous actors within an industry (Loebbecke et al., 2016). Here, knowledge sharing is an important driver for the creation of synergy effects such as gaining complementary knowledge and creating knowledge synergistically (Loebbecke et al., 2016). Explicit knowledge refers to knowledge that can be translated in specified rules and procedures such as engineering specifications. On the other hand, tacit knowledge is knowledge that is typically embedded within organisations and employees. This 'knowledge' is intangible and is difficult to conceptualize (Loebbecke et al., 2016).

Firstly, knowledge sharing between telecom providers will comprise bilateral explicit knowledge sharing. Since Dutch telecom providers are active in the same market, knowledge discrepancies can emerge, for example, as a consequence of differing market views or differences in R&D strategies. According to Hevner et al. (2010), explicit knowledge sharing can comprise knowledge on local markets, economic developments business opportunities, business models, or product, process and service designs. Sharing this explicit knowledge can allow firms to better use their competencies (Loebbecke et al., 2016). Telecom providers must strike a balance in sharing knowledge that lifts the industry as whole, while maintaining competitive advantages. Market governance mechanisms such as contracts and agreements can specify what knowledge is shared, the process of knowledge sharing and how this knowledge is protected against opportunistic behavior of competitors (Williamson, 1996). The degree and presence of reciprocity is an important aspect of knowledge sharing since it highlights the mutual benefits associated with the collaboration (Loebbecke et al., 2016). With that, reciprocity creates interdependencies in the collaboration. Therefore, governance mechanisms must deal accurately with reciprocity by specifying deliverables and coordination meetings to manage these interdependencies (Loebbecke et al., 2016).

Secondly, bilateral tacit knowledge sharing can be applied. Since tacit knowledge refers to knowledge that is embedded in organisations, specification is difficult. Differences in, for example, organisational structures and human expertise are factors that can contribute to tacit knowledge discrepancies (Loebbecke et al., 2016). The availability of tacit knowledge within an organisation can determine how shared explicit knowledge can be applied and used within organisations of the collaboration. This can cause discussions and conflicts within a collaboration considering the leveragability of shared explicit knowledge. In such circumstances, shared explicit knowledge can be perceived as less valuable by firms from the collaboration which can result in conflicts, distrust, and increased uncertainty (Loebbecke et al., 2016). Sharing of tacit knowledge can contribute to successful usage and application of available (explicit) knowledge, leveraging each others competencies. According to Majchrzak and Jarvenpaa (2010), the establishment of working groups or joint tasks forces can deliver discussion and working arena's where knowledge can be shared, created and processed synergistic. In these arena's, workers from firms in the collaboration can learn from each others expertise and organizational structures from other firms, indicating the transfer of tacit knowledge (Loebbecke et al., 2016).

In light of this research, knowledge sharing among telecom providers will focus on knowledge that can enhance network performance and readiness for C-ITS purposes. Telecom providers will thus share knowledge on a specific topic while maintaining full control over their core businesses. Since telecom providers remain operating as fully independent economic actors, integration between companies can be typified as low. Reciprocity creates topic specific interdependencies which can be managed through market governance mechanisms such as contracts and agreements. This also protects telecom providers in ensuring sustainable competitive advantages (Loebbecke et al., 2016). Considering the low degree of integration, risks of monopolistic behaviour are relatively low and thus extensive new antitrust laws are not necessary.

4.2.2 Joint R&D Partnership

In joint R&D partnerships, two or more firms collaborate on R&D while remaining separate economic actors (Hagedoorn, 2002). Therefore, joint R&D partnerships often comprise collaboration on a specific topic over a limited time horizon (Yasuda, 2005). This allows companies in a collaboration to maintain full control over their core activities by remaining an independent economic actor (Hagedoorn, 2002). Since integration between telecom providers is low in joint R&D partnerships, competition will stay in the market, resulting in a smaller need for antitrust laws. Typically, market governance instruments are applied in joint R&D in the form of development agreements, R&D pacts and contracts, to manage coordination, conflict resolution and concessions to towards other companies' requirements (Hagedoorn, 2002; Williamson, 1996; Yasuda, 2005). In the telecom sector, technological turnover is relatively high with a turnover time of 10 years (Koutroumpis et al., 2023). Sectors prone to rapid technological turnover tend to utilize market governance mechanisms and apply a less integrative and intensive form of collaboration (Hagedoorn, 2002; Harrigan, 1988). Joint R&D partnerships thus provide a good tool to collaborate to realize shared benefits while sharing financial burdens and other risks among the members of the collaboration (Yasuda, 2005).

Joint R&D partnerships for C-ITS are already performed in internationally spanning consortiums and working groups (Car 2 Car Communication Consortium, 2021). However, Martinsuo and Lehtonen (2007) finds that innovation pace in consortiums tends to be slow. On of that, time is not used effectively. Differing motivations and dis-aligned interests limit consortiums from making big steps in innovation. According to Thiry (2002), consortiums provide an informal, inductive learning environment that focuses on finding mutual benefits and common goals in the early stages. Martinsuo and Lehtonen (2007) finds that these efforts often fail and plannings are often prone do delays by 'vague and muddled' discussions. Therefore, a more formal form and intensive form of collaboration is proposed here with less international members. This can allow for better alignment of interests and motivations and more concrete plans of action (Martinsuo & Lehtonen, 2007).

There are multiple ways in which joint R&D partnerships by Dutch telecom providers can contribute to 5G readiness and faster C-ITS deployment. There are two sides that can shed a light on this problem. Firstly, from a network point of view telecom providers can work on joint network development. In a joint R&D partnership, knowledge (tacit & explicit), network and financial assets can be shared for the sake of researching. This allows more fore efficient use of resources. Researches can comprise network infrastructure development such as higher connectivity and faster lower latency data transmission. Enhanced safety, security and reliability can also be among the to be researched topics. All research goals that deal with the shortcomings of current 5G networks in term of C-ITS. Research topics can deal with optimizing the cellular network or SDN, NFV, network slicing and other types of 5G technologies describes in section 3.5 On top of joint research, joint pilot testing can be performed. By making agreements in pilot environments, internationally set standards can be applied in a smoother and more efficient way in large scale deployment. This results in higher consistency and interoperability.

Secondly, joint R&D efforts can be focused on the C-ITS development side. Joint R&D efforts can focus on developing performance requirements and design options for operational equipment such as OBUs and RSUs. In this research groups can be formed with car manufacturers, C-ITS providers and road operators. This can ensure better integration these devices into the C-ITS ecosystem. On top of that, telecom providers can develop guideline and, in extension, specific action plans and toolkits for C-ITS providers that can boost C-ITS development. Consequently, action plans and toolkits will ensure smoother integration of C-ITS in the networks.

4.2.3 Resource Sharing

In a shared telecom infrastructure, telecom providers utilize the same network infrastructure to connect users (Koutroumpis et al., 2023). Network infrastructure includes fiber optic cables, cell towers, data centers, radio frequency spectrum and energy (Houngbonon et al., 2023). This allows for sharing specific parts of a network infrastructure (Koutroumpis et al., 2023). A distinction can be made in two main types of sharing; active and passive sharing (Koutroumpis et al., 2023). Passive sharing encompasses sharing of passive elements of a network. This can be towers, masts and cell sites. Passive network sharing is already being done in the Netherlands (ACM (The Association for Computing Machinery), Year of publication, if available). Active sharing encompasses sharing of active elements of the network such as RAN equipment and radio frequencies. A distinction can be made between two forms of active network sharing. Multi-Operator Radio Access Networks (MORAN), is a form of sharing where operators share radio access equipment but operate their individually obtained spectrum. Parts of spectrum bands are auctioned. Multi-Operator Core Network (MOCN) leverages both sharing of radio access equipment as well as spectrum sharing. Both forms of active network sharing are currently not considered in the Netherlands (ACM (The Association for Computing Machinery), Year of publication, if available). Another form of active sharing is national roaming. This form of sharing is already present in the Netherlands with for example Youfone and KPN. Youfone uses the KPN network against wholesale prices and charges its own tariffs to customers. Figure 4.1 provides a simple representation of the different types of network sharing.

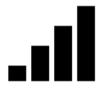
<table>
<tr><th>Operators in agreement</th><th>Type of sharing</th><th colspan="2">Infrastructure and service sharing</th></tr>
<tr><td rowspan="7">Bilateral (1-1)</td><td rowspan="2">Passive</td><td colspan="2"></td></tr>
<tr><td colspan="2">Masts, sites, cabinet, power, and air conditioning</td></tr>
<tr><td rowspan="3">Active</td><td>MOCN</td><td>MORAN</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Base station, radio access networks and spectrum</td><td>Base station, antennas and radio network controllers (RNC)</td></tr>
<tr><td rowspan="2">Roaming</td><td colspan="2"></td></tr>
<tr><td colspan="2">Signal service</td></tr>
<tr><td>Multilateral (1-n)</td><td>TowerCo</td><td colspan="2">Mainly passive equipment but expanding to active and services</td></tr>
</table>

Figure 4.1: Network sharing in telecom (Koutroumpis et al., 2023)

In network sharing various network ownership models can be observed. In full ownership one of the telecom providers sharing the network fully operates a network (Houngbonon et al., 2023; Koutroumpis et al., 2023). This is the case in the Youfone KPN where KPN owns a network infrastructure. Roaming agreements in the form of bilateral contracts are used to manage and coordinate sharing activities. Partial ownership often comprise joint ventures between telecom providers. As is the case in China where three mobile network operators established a joint venture that builds and maintains cell towers and provides facilities (Houngbonon et al., 2023). Partial ownership thus allows for network sharing between competing companies (Houngbonon et al., 2023; Koutroumpis et al., 2023). Lastly, in a no-ownership model the telecom infrastructure is not owned by a telecom service provider. This forms of ownership can be observed in Asia, India and Latin America (Houngbonon et al., 2023). In this case governments can play a key role in relieving telecom providers of high capital expenditures.

The various ownership models and sharing agreements each bring varying benefits and disadvantages in terms of network performance and competition. As became clear from the stakeholder analysis in section X, the number of telecom providers that actually own a network is limited to three. In general, telecom markets tend to be concentrated (Dasgupta & Williams, 2017). With that, network sharing could induce a loss of network-based competition which can allow for coordinated behaviour (Dasgupta & Williams, 2017; Koutroumpis et al., 2023; Pápai et al., 2020). On of that, network sharing can also reduce service differentiation, network quality and coverage when the amount of remaining competitors in the market is low (Dasgupta & Williams, 2017; Koutroumpis et al., 2023; Pápai et al., 2020). Another concern involves predatory pricing. When insufficient regulations and laws control the market, telecom providers that share a network could use predatory pricing as a tool to scare potential competitors (Dasgupta & Williams, 2017; Koutroumpis et al., 2023; Pápai et al., 2020). For the Netherlands, the ACM together with the Ministry of Economic Affairs and Climate need to design laws, frameworks and regulation in such a way that, when more intensive network sharing is applied, telecom providers are limited in predatory pricing, unfair pricing and under-investments and competition is promoted. Only than, network sharing can deliver a desired outcome for C-ITS.

On the other hand, network sharing can also deliver benefits. Lower network development costs and lower operational cost for telecom providers can translate into lower consumer prices. Sharing of investment costs can allow telecom providers to achieve higher ROI's which supports further network investments and thus network performance (Houngbonon et al., 2023; Koutroumpis et al., 2023). Lower cost structures can also result in better QoS and faster development of new technologies and infrastructure improvements (Pápai et al., 2020) This delivers potential for ensuring 5G readiness for C-ITS. On top of that, network sharing also delivers environmental and societal benefits. The European Commission (Year of publication, if available) presents the a number of benefits associated with network sharing. Firstly, through network sharing, the number of cells and other duplicate infrastructure components can be lowered. In terms of cell (site) sharing, visual pollution can also be lowered. This is very desired in areas where cell cite availability is low and cells are placed in plain sight. This sometimes results in societal opposition. Also, less fibers and other cell components are needed to connect and develop infrastructure components. This results in lower environmental pollution by used materials. On top of that, network sharing can also comprise energy sharing which results in lower total energy consumption and thus lower emissions.

4.2.4 Joint Venture

A joint venture is a new organizational business unit that is established following a collaboration between two or more 'parent-companies' (Hagedoorn, 2002; Yasuda, 2005). Ownership of this new legal entity is shared between these parent-companies on an equity basis (Yasuda, 2005). The joint venture can take many forms and often is established to fulfill a single common goal or activity by combining resources and knowledge (Yasuda, 2005). This goal can be, for example, development of technology or sales (Yasuda, 2005). Firms tend to collaborate to realise a certain goal if they are unable to pursue these goals on their own or only at great risk or expenses (Yasuda, 2005). For their remaining activities outside of the scope of the joint ventures, the 'parent-companies' remain separate economic actors (Hagedoorn, 2002). Considering that a formal firm needs to be controlled and maintained by all 'parent-companies', integration and thus interdependencies are more present than in a joint R&D collaboration (Hagedoorn, 2002). According to Williamson (1996), in joint ventures, hybrid governance structures are typically applied. Sometimes these hybrid governance mechanisms tend to come close to hierarchical governance mechanisms. The governance mechanisms that are identified in Williamson's transaction cost theory are described in section 4.3.3. According to this transaction cost theory, firms tend to choose joint ventures when they believe that the transaction costs can be minimized through the joint venture instead of a stand-alone firm (Williamson, 1996; Yasuda, 2005). Joint ventures enjoy a semi-independent status which makes them particularly effective for entering new markets (Hagedoorn, 2002). According to Hagedoorn (2002), joint ventures come at high organisational costs and are often prone to high failure rates. Therefore, joint ventures are very effective when new, stable market environments are explored where technological advances are made incrementally (Hagedoorn, 2002). This follows from the fact that the original developed collective goals of the companies behind the joint venture, may need changes when that particular market changes. This can be a problem for C-ITS related joint ventures. However, it must be stated that the competition in the market is low which may lead to more gradually technological advancements. Antitrust laws can in turn provide more incentives for technological innovation when innovation is lacking.

With regard to enhancing the capabilities to ensure faster C-ITS deployment, joint ventures can have multiple forms depending on the common business goals of telecom providers. A few design options for joint ventures that could benefit C-ITS deployment will be discussed. Firstly, a joint venture could comprise a joint venture that owns cell towers as the Chinese example in section 4.2.3. This allows for sharing of investment costs, maintenance costs and energy costs which can improve ROI's and with that, boost further joint investments that can improve 5G networks for new business area's. Also, another joint venture can be establishing a new joint telecom provider that exclusively serves C-ITS services. This new venture can utilize all existing networks from the member firms of the collaboration. This can result in better coverage and more connectivity. Another option can be the establishment of a joint R&D venture. This venture can focus exclusively on C-ITS network challenges such as security, reliability and connectivity. Lastly, telecom providers could develop a joint C-ITS platform where they provider C-ITS providers with building blocks to develop services that can enjoy seaming less integration into the 5G networks. Telecom can incorporate the set standards jointly and based on the agreements, develop these building blocks towards complementors.

4.2.5 Mergers & Acquisitions

The last discussed option for telecom collaboration for C-ITS is a merger or acquisition. Mergers or acquisitions occur often 'horizontally' within industries and can be a consequence of industry wide shocks and changes (Hackbarth & Miao, 2011). In a merger or acquisition, one or more separate economic actors are merged into one economic actor, either through a merger or a take-over where one firms buys another firm. The merger allows the new firm to create synergy gains (Hackbarth & Miao, 2011). Synergy gains can arise in multiple fields. Firstly, a merger or acquisition allows for combining both tacit and explicit knowledge from the original firms. The (newly) established firm can utilize knowledge from the 'mother firms' such as technologies, processes, (network) designs, safety and security protocols and knowledge gained from testing. On top of that, learnings from organizational structures and employees can be combined efficiently in the newly established firm, creating synergy gains (Hackbarth & Miao, 2011). This can boost internal innovation capabilities within the new firm. Another form of synergy gain is that horizontal mergers or acquisition can result in economies of scale by pooling resources and consequently, mitigate cost structures and maximizing profits (Hackbarth & Miao, 2011; Majumdar et al., 2020). In light of this research, pooling of resources can bring various benefits. Firstly, pooling of network resources can deliver networks with higher performance in terms of coverage and speed of data exchange. Secondly, pooling networks resources allows for more efficient network integration through standardization of protocols. Profits can in turn be used for network development. One danger of a merger can be so-called price setting when competition in the market is low. According to Hackbarth and Miao (2011), a positive relation between market concentration and prices can be observed after a merger. The reasoning for this is that higher market concentration entails lower competition. Therefore, a merged company can acquire anti competitive gains by setting prices on levels that competing firms can't match (Hackbarth & Miao, 2011). To resolve issues surrounding price setting, anti competitive measures are needed. In the Netherlands, these measures are invoked by the Authority Consumers and Markets (ACM). The ACM can design rules and legislation that can limit unfair pricing which can induce competition in the market.

4.2.6 Overview of forms of collaboration

Table 4.1 provides an overview of the findings of section 4.2.

	Integration	**Inter-dependencies**	**Governance Structures**	**Risk of Monopolistic Behaviour**	**Antitrust Regulations**
Knowledge Sharing	Low	Low	Market	Low	Low
Joint R&D Partnership	Low	Low	Market	Low	Low
Resource Sharing	Low - Medium	Low - Medium	Market, Hybrid	Low - Medium	Low - Medium
Joint Venture	Medium - High	Medium - High	Hybrid, Hierarchical	Medium - High	Medium - High
Merger & Acquisition	High	High	Hierarchical	High	High

Table 4.1 Overview Forms of Collaboration

4.3 Theoretical Framework

In this section, four theories will be analyzed to identify factors that deal with potential collaboration between telecom providers in the Netherlands. In literature, no theories exist that exclusively deal with the challenges and opportunities for alliances, however, various theories showcase similarities to this study. These theories will be studied here. The identified factors and challenges should contribute to understanding collaboration through alliances. With that this section aims to answer sub question B from SQ1: [What are potential barriers or opportunities for collaboration between competing commercial companies according to existing theories in the literature?] The findings from literature will be used to identify a first initial list of factors that will be used in constructing the conceptual model of the study.

4.3.1 Collective Action Theory

The collective action theory formulated by Olson Jr (1971), describes how people or organisations can collaborate to achieve a common goal. The theory describes which factors have to be taken into account to realise successful collaboration to achieve a common goal (Olson Jr, 1971). There is no one-size-fits-all principle in collective action, therefore the collective action theory describes a broad set of design principles that are learned from various collective actions (Ostrom, 2004). Successful collective actions have shown that successful cooperation is possible when the members of the collective share a vision, goal or interest. In light of this research, telecom providers would have the goal to make the fifth generation of mobile communication technologies suitable for the deployment of C-ITS services, opening a new realm of revenues, taking lessons for other practices and contribute to resolving societal issues. Many issues can arise when realising collective action. In the light op inter-firm collaboration, four potential issues where identified that have to be accounted for to realise successful collective action (de Reuver et al., 2015).

Aligning Interests

A first problem that may arise is the alignment of interests. When members of the collective can't align their interests or find a clear common goal or shared vision, problems can arise such as conflicts and free riding. Free riding may occur when not all associated members of the collective are weighing an equal importance to the collective goal (Battaglini & Palfrey, 2023). Motivation for joint action is thus crucial to cooperate is thus crucial in the light of the collective action theory (Bridoux & Stoelhorst, 2022; Ostrom, 2004). Between companies, Olson Jr (1971) finds that although the goals of the companies may seem the same, a common goal can be far away since one company's goals can be detrimental to the other company's goal. For example, if one company wants to raise its profits, it almost always results in a loss of profits for another company. This means that although the companies have the same goal, there is no common goal. Olson Jr (1971) states that bridging these differing goals, can lift industries as a whole. Finding a common goal may be difficult, but is crucial to make collective action successful.

Opportunistic Behaviour and Conflicts

Collective action is prone to multiple forms of opportunistic behaviour. These problems mainly arise when members of the collective face a tension between their own goals and objectives, and the collective goal (Bridoux & Stoelhorst, 2022; Olson Jr, 1971). Firstly, members of the collective can behave opportunistic if they do not perceive the same urge of realising the common goal, resulting in reduced input by one of the members (Albers et al., 2005; Battaglini & Palfrey, 2023). This risk of 'free-riding' becomes larger as the collaboration grows (Albers et al., 2005). Secondly, conflict may arise when one member's vision on the common goal changes over time, resulting in misaligned interests (Olson Jr, 1971) . Lastly, the collective as a whole can show opportunistic behaviour. Their strategic position and maybe even advantage might make the collective lose sight of the common goal, resulting in cartel like behaviour such as unfair pricing (Olson Jr, 1971). Outside intervention or other forms of governance may be needed to ensure that collectives don't lose sight of their common goal.

Governance

Governance is of great importance to ensure the viability and potential of success of collective action. Olson Jr (1971) highlights that organisation is crucial to make collective action successful. Ostrom (2004) highlights that an accurate division of property rights among the various members of the collective is crucial to specify obligations. A governance framework can than provide guidelines on which decisions need to be made and by whom (Constantinides & Barrett, 2015). With that, governance provides a leadership structure which is either centralized or decentralized depending on the type of collective action (Bridoux & Stoelhorst, 2022; Constantinides & Barrett, 2015). Clear specified leadership also provides trust to the members of the collective, leading towards better results (Bridoux & Stoelhorst, 2022). With specified governance, inputs of the members are fixed, and so are generated benefits (Albers et al., 2005). Also, governance plays a role in protecting (members of) the collective against opportunistic behaviour from one of the stakeholders, or the collective as a whole. Sets of rules can structure the goals of the collective, leaving less room for opportunistic behaviour and conflicts (Albers et al., 2005; Olson Jr, 1971).

Interdependencies

According to de Reuver et al. (2015), interdependencies are an important aspect of collective action. Stakeholders of collective action all bring a certain amount of knowledge, money and resources to the table for productive purposes (Albers et al., 2005; Olson Jr, 1971). In a perfect scenario all stakeholders will be be equal in terms of knowledge, money and resources, but in practice this never occurs. As a consequence, interdependencies emerge (de Reuver et al., 2015). Walter et al. (2012) states that there is a correlation between the amount of interdependencies and motivation to achieve the common goal. The higher the need for each other, the higher the motivation to realise the common goal. Bridoux and Stoelhorst (2022) states that stakeholder management is crucial to manage interdependencies. Governance can aid in structuring interdependencies by formulating costs of exit of leaving the collective (Olson Jr, 1971). This protects the collective against stakeholder leaving with acquired knowledge that can be used strategically.

4.3.2 Platform Theory

Digital platforms and the ecosystems they create and facilitate are penetrating numerous industries such as the transport industry (Mukhopadhyay & Bouwman, 2019). This is showcased by the growing number of global leading companies, e.g. Amazon and Apple, that are adopting platform business models (Beverungen et al., 2021) In light of this research, the platform that telecom providers will aim to provide, can be considered a digital platform due to what the network offers to both C-ITS service providers and consumers of these services (Ivanov et al., 2020; Mukhopadhyay & Bouwman, 2019). As a platform provider, telecom providers can provide services, technologies, software and tools that enables stakeholders to build services on the C-ITS platform. A 5G-based platform can thus form the basis for a multi-sided platform where C-ITS service providers and various consumers can interact and engage in transactions(Beverungen et al., 2021; Mukhopadhyay & Bouwman, 2019). With that telecom providers would provide an infrastructure-as-a-service (IAAS) industry platform.

In the terminology of platforms, external or industry platforms are known as products, services or technologies developed by one or more firms, which can act as a basis for new complementary innovations (Gawer & Cusumano, 2014). The idea of the platform is that a platform provides an 'open' architecture to platform complementors, in this case c-its providers, providing them with the necessary building blocks to build services on the platform. With that platforms, in transport, follow a so-called modular principle (Boudreau, 2012; de Reuver et al., 2015; Ivanov et al., 2020). This open, modular architecture should attract complementors and boost innovation, resulting in more complementary products and services. This delivers so-called network effects. Network effects are value that is created by a growing number of users and complementary services, making the platform more valuable as a whole (Beverungen et al., 2021; Boudreau, 2012; Gawer & Cusumano, 2014; Mukhopadhyay & Bouwman, 2019). This results in a self enforcing positive feedback loop (Beverungen et al., 2021). According to Boudreau (2012), this feedback loop is not infinite and saturation occurs at some point. A distinction can be made between direct and indirect network effects. Direct network effects are effects that emerge on 'one side' of the platform e.g. network effects that arise on the user side of the platform when existing users attract new users. Network effects can also be indirect when they occur on 'across sides' if for example the number of users attracts new complementors (de Reuver et al., 2015; Gawer & Cusumano, 2014). In the face of the different stakeholders that are served through a platform, platform are often referred to as multi-sided platforms (Boudreau, 2012; de Reuver et al., 2015; Gawer & Cusumano, 2014). In creating, maintaining and growing these multi-sided industry platforms, various challenge can emerge.

Platform Strategy and Interest Alignment

In term of platforms, platform strategy and interest alignment are very much related. Platform providers broadly determine the strategy that a platform follows (de Reuver et al., 2015). These strategic choices are mainly focused on business models, stakeholder management, governance and markets that platform serves. However, complementors, especially platform leaders, also play a significant role in the strategic choices and vision of platform owners (Gawer & Cusumano, 2014). According to Gawer and Cusumano (2014), platform leaders are organisations that have positioned their product or service dominant as an industry platform. From this position of leadership, platform leaders can determine the course of the platform ecosystem. Ivanov et al. (2020) highlights that aligning the interests of the platform's stakeholders is crucial in setting the right trajectory. On a stakeholder level, interests and motivations are translated into interrelated goals which aids in establishing integrated goals (Ivanov et al., 2020). This showcases the amount of interdependencies that are present in platforms. Aligning interests and setting a shared goal and visions is thus crucial for platform providers and leaders. de Reuver et al. (2015) adds to this that if the platform is provided by an alliance of stakeholders, business models and strategy can cause differing objectives and interests. Gawer and Cusumano (2014) states that motivation also plays a big role in aligning interests.

Governance and Control

When multiple actors put in resources, time and money into the realisation of a joint platform, agreements need to be made to structure both the inputs and the realised benefits (Albers et al., 2005). Governance mechanisms, e.g. contracts, code of conducts and other legally binding agreements, need to be designed to do so (Mukhopadhyay & Bouwman, 2019). Trust-based governance mechanisms, e.g. mutual trust and faith in the shared goal, also play a significant role in the collective action and decision making (Mukhopadhyay & Bouwman, 2019). One of the alternatives for structuring the inputs is establishing common resource pools (Albers et al., 2005). Another effective governance mechanism is establishing an authority. This can be one of the platform providers or an external organisation (Mukhopadhyay & Bouwman, 2019).

In order to attract users and complementors to the platform, platform providers must gain the trust of these users (de Reuver et al., 2015). The provision of clear business models, contracts and price mechanisms should contribute to this (Gawer & Cusumano, 2014). This protects user groups as well as platform providers against opportunistic behaviour. Gawer and Cusumano (2014) and Mukhopadhyay and Bouwman (2019) add that price mechanisms and business models should also provide incentives to innovate for complementors. Also, control mechanisms need to be designed to limit opportunistic behaviour and conflicts between the various user groups as well as setting quality standards (Mukhopadhyay & Bouwman, 2019). An important governance design issue that arises here is how to balance control and power in governance designs (de Reuver et al., 2015). de Reuver et al. (2015) adds that such issues also influence the designs of governance mechanisms between platform providers.

Interdependencies

Interdependencies are present in many forms when multiple telecom providers will cooperate to realise a C-ITS platform. As the collective action theory in section 4.2.1 describes, interdependencies can arise among the telecom providers when undertaking a collective action due to discrepancies in inputs. Governance mechanisms need to be in place to manage this and protect the members of the collective against abusing opportunistic behaviour. However, in the theory surrounding platforms, interdependencies also emerge between platform providers and user groups and also between user groups (Gawer & Cusumano, 2014). This can be explained by the network effects that are present platform terminology. When more users or complementors use the platform, the platform as a whole becomes more valuable resulting in higher revenues (Beverungen et al., 2021; Boudreau, 2012; Gawer & Cusumano, 2014; Mukhopadhyay & Bouwman, 2019). This creates interdependencies; user groups can partially rely on the presence of other user groups on the platform. Also, if user groups decide to leave the platform, generated network effects will lower. With that, de Reuver et al. (2015) claims that network effects increase interdependencies. These interdependencies need to be managed in order to establish a healthy ecosystem. For platform leaders, interdependencies can be problematic when the platform relies too much on its complementors (Mukhopadhyay & Bouwman, 2019). For complementors, maintaining autonomy is crucial to protect against interdependencies.

4.3.3 Transaction Cost Theory

Williamson (1975): "A transaction is an exchange of goods or services, which is organized by firms in markets or within hierarchical structures." In light of Williamson's transaction cost theory, sharing of information can be seen as a transaction. According to Albers et al. (2005), transaction cost theory describes a fundamentally different approach towards alliance formation than the collective action theory. Where the collective action theory and platform theory emphasises the importance of organisation with regard to trust, interests and governance, the transaction cost theory follows a micro economic approach and focuses on the individual transaction (Williamson, 1975). With that, the organisation that emerges can be seen as the most suitable organisation and coordination structure, as a result of transaction cost economizing (Albers et al., 2005). This means that the transaction costs, associated with the realisation of a goal, can be lowered through the formation of an collaboration, when comparing it to realizing a certain goal in-house (Yasuda, 2005). This highlights that the goal of economic actors is to minimize the costs rather than maximizing the profits. (Albers et al., 2005).

According to the transaction cost theory (Williamson, 1975), the primary goal of economic actors, is minimizing the total costs associated with transactions. Breaking down these total costs, production costs and transaction costs can be identified. According to Williamson (1975), transaction costs are determined by the following principal dimensions:

1. Frequency: is the transaction reoccurring or a one time specific transaction
2. Uncertainty: degree of uncertainty surrounding the transaction, e.g. uncertainties in the market or uncertainties about knowledge and intentions of other economic actors
3. Asset Specificity: can the asset be used only for a specific transaction or can the asset be applied in another transaction(s)

To manage these three dimensions of transactions costs, Williamson (1975) proposes three governance options that can aid in minimizing these transaction costs by providing organizational conditions for each transaction.

Governance Structures

Alliances are often prone to instability as a consequence of uncertainty. Uncertainty follows from actor not knowing the intentions of partners and absence of a higher authority that governs the relationship (Parkhe, 1993). Therefore, governance mechanisms need to be designed to limit uncertainty and manage the transactional factors (Williamson, 1975). Without governance mechanisms governing the transaction, unnecessary high transaction costs may emerge (Parkhe, 1993). Williamson (1975) depicts three predefined governance structures that can provide stability in the transaction so that economic actors can minimize these transaction costs: market-, hierarchy- and hybrid governance.

Market governance leverages classical contracts between economic actors. The transaction occurs in a traditional spot market where sellers offer their products and services at a specified price. The buyers compares prices and quality of products from various sellers and engages in a transaction. Market mechanisms are thus used to coordinate the transaction. Formal contracts are used to specify the terms and conditions of the transaction. With regard to collaboration, market governance can be useful in the case of knowledge sharing or joint R&D partnerships where actors cooperate while maintaining their independence as economic actor. Dependencies are thus relatively low when applying market governance which enables higher flexibility (Albers et al., 2005). Contracts can structure relationships by specifying prices, responsibilities and performance expectations of the collaboration partners.

Hierarchical governance is mostly selected for deeper long-term relationships (Albers et al., 2005). This follows from the fact that hierarchical governance offers a higher degree of integration between economic actors engaging in a transaction. According to Williamson (1975), hierarchical governance limits the risks of opportunistic behaviour. Since decision making lies a in a centralized position, activities can be monitored more precisely which allows for more effective management (Albers et al., 2005). In hierarchical governance multiple forms of organisation can be depicted. Firstly, in joint R&D, economic actors can maintain their position as separate actor, while intensifying cooperation on a specific topic. This form of integration creates interdependencies which can be troubling in case of (external) disturbances for a single actor (Albers et al., 2005). In, for example, a joint venture, where firms collaborate more closely and often create a new economic actor, resource input asymmetry can be present. This means that some stakeholders can be putting more at stake in a 'economic transaction', bringing more resources to the table (Yasuda, 2005). This can deliver that firm a decision-making authority. Economic actors can also go beyond joint joint ventures through mergers and acquisitions or joint ventures, where a new economic actor emerges. Firms must than redefine roles within the new entity, filling the new leadership positions based on agreements made in the negotiation process. From a merger or acquisition, the new entity can obtain a stronger position in the market which can be troubling when a monopoly emerges (Williamson, 1975). More interdependencies and integration means that the collective as a whole has a stronger position towards external disturbances (Albers et al., 2005). To manage this position of strength and limit the opportunities for monopolistic behaviour, complex antitrust laws and rules can be designed or a regulatory oversight authority can be established (Williamson, 1975). The theory described by Williamson (1975) does not describe accurate measures to dissolve vertical integration problems but acknowledge that in some cases institutions are needed.

Hybrid governance leverages elements of both *market-* and *hierarchical governance*. Alliances applying a hybrid governance, typically cooperate more closely than when market governance is applied, and are less integrated than in a hierarchical governance structure. Alliances applying a hybrid governance structure often use contracts to guide the alliance in terms of responsibilities and performance expectations. These contracts are often long term contracts that act as a framework for the cooperation (Albers et al., 2005). On top of that, alliances can additionally opt for the creation of shared decision-making and/or coordination mechanisms. These tools can be very effective when alliance are formed to work on a specific topic area since because it allows for effective governance customization that tailors the needs and challenges of the alliance. The final governance structure than provides members of the alliance guidelines towards a common goal by sharing resources, knowledge and processes, while maintaining autonomy over their business. Alliance activities such as resource sharing and joint product product development often utilize a hybrid governance structure.

Bounded Rationality and Opportunism

According to the transaction cost theory, economic actors are bounded rational and opportunistic (Williamson, 1975). This makes trusting potential alliance partners difficult. Examining the track record of potential alliance partners can deliver a feeling of trust however, information on previous activities is not widely available (Parkhe, 1993). Therefore, relationships for alliances need to be build over time, which is troubling considering bounded rationality and opportunism. Therefore the mentioned governance structures are meant to protect firms that want to enter an alliance and engage in transactions.

The notion of bounded rationality refers to the fact that economic actors lack full rationality when engaging in transactions. Economic actors are rational given their individual time, knowledge and capabilities (Albers et al., 2005). In alliances, bounded rationality entails that actors lack perfect information regarding the knowledge, resources and future goal(s) of other actors. This can result in individual optimal outcomes that produce a sub-optimal output for an alliance (Parkhe, 1993). This can trouble achieving a common goal and fuel distrust, resulting in higher transaction costs which may cause problems for successful effective cooperation.

Opportunism refers to the behaviour of economic actors when engaging in transactions. With regard to alliances, organisations can show opportunistic behaviour to maximize its own profits and pursue its own goals at the expense of an alliance partner (Albers et al., 2005). This opportunistic behaviour can undermine a trust full relationship and harm another organisation. This makes that opportunism makes cooperation difficult, because finding a common goal is difficult because the interests of both parties are not aligned. In order to protect against opportunistic behaviour, private ordering is often applied in alliances (Parkhe, 1993). In private ordering, self-enforcing agreements are created that enables firms to exit the agreement if another firm violates the formulated agreements (Parkhe, 1993). While this creates larger interdependencies, it protects alliance partners against incurring high costs for going to court or other policing bodies as a consequence of agreement infringement by other alliance members (Parkhe, 1993).

4.3.4 Neo-Classical Economic Theory

The Neo-Classical Economic Theory is a theory that emerged in the late 19^{th} century. Neo-Classical economics follows a framework that can be used to understand price forming in markets and how economic actors can maximize their profits and utility (Inoua & Smith, 2022). In order to do so, Neo-Classical economists have developed their theory on a three axioms (Arnsperger & Varoufakis, 2006). Firstly, economic actors are perfectly informed and make rational decisions based on their utility, given prices and budget (Arnsperger & Varoufakis, 2006; Inoua & Smith, 2022). This makes that consumers are price takers. Secondly, economic actors only think about preference satisfaction, meaning that economic actors only look to fulfill their own needs (Arnsperger & Varoufakis, 2006). And lastly, supply and demand are determinants for market pricing and quantities, ideally resulting in market equilibrium (Arnsperger & Varoufakis, 2006; Inoua & Smith, 2022).

With regard to this research and the creation of an alliance between telecom providers, the Neo-Classical economic theory provides explanatory factors that can be used to understand the value of a potential alliance. A higher goal in the Neo-Classical economic theory is achieving *Pareto Efficiency*. Pareto efficiency refers to a situation in which resources are allocated in an economically efficient way (Goodland & Ledec, 1987; Inoua & Smith, 2022). In this situation, no economic changes can one economic actor better without harming another economic actor (Goodland & Ledec, 1987). In terms of the formation of an alliance, it is believed that resources can be allocated more efficiently coming closer to a Pareto optimal efficient situation. A Pareto efficient situation is something that only exists in theory and is never achieved in a real market (Inoua & Smith, 2022). However, coming closer to the Pareto efficient situation, realises a more efficient market. Important to note here is that Pareto efficiency does not take a (fair) distribution of income across economic actors into account (Goodland & Ledec, 1987).

Rational Decision Making and Profit Maximization

According to the Neo-Classical economic theory, telecom providers would only be willing to engage in an alliance, when it allows for maximization of profits. This follows from the axiom that economic actors follow rational decision-making (Inoua & Smith, 2022). Formation of an alliance can facilitate profit maximization in two ways.

Firstly, **lower cost structures** can be achieved through resource sharing and joint R&D efforts (Goodland & Ledec, 1987). Through resource sharing; investment, maintenance and operational costs can be shared across the alliance members. On top of that, resource haring could allow for enjoying economies of scale benefits (Goodland & Ledec, 1987). By pooling resources and knowledge, costs can be reduced for all members of the alliance. With regard to joint R&D efforts, alliance members can combine knowledge, share R&D costs and together invest in new technologies (Goodland & Ledec, 1987). Through resource sharing and joint R&D efforts, telecom providers can thus lower their cost structures, making them less prone to risks and external disturbances. This risk aversion is supported by the Neo-Classical economic theory: since rational decision making is assumed, economic actors naturally seek to minimize risks and uncertainties (Inoua & Smith, 2022). By bringing down cost structures, telecom providers' revenue streams are more resilient towards technological disruptions, regulatory changes and economic fluctuations.

Secondly, the creation of an alliance can deliver **larger revenue streams**. By combining efforts, firms in alliances can gain a stronger competitive position by complementing each others weaknesses. By combining knowledge and expertise, telecom providers can deliver products that better serve the needs of rational consumers. As a consequence, market share and profit can rise. On top of that comes that due to rational decision making, economic actors are always looking for ways to generate new income streams and, with that, create higher profits (Glick & Ochoa, 1990). When entry barriers to enter a new market are (too) high, telecom provider(s) might choose to strengthen their position in markets where they are already active. When an alliance is created, this can change since the earlier too high entry barriers, can now be overcome as a collective (Elmuti & Kathawala, 2001). This means that formation of an alliance can allow for market expansion and diversification under the right conditions. New geographic regions can be tapped into but also completely new service fields can be explored. This can result in higher profits.

Competitive Markets

Neo-classical economists are strong advocates of free, competitive markets where supply and demand shape prices and production (Arnsperger & Varoufakis, 2006; Glick & Ochoa, 1990; Goodland & Ledec, 1987; Inoua & Smith, 2022). In free, competitive markets resources are allocated efficiently, consumer needs are met, and profits of firms are maximized. According to Neo-Classical economists, government intervention is undesired since free-market forces should lead to market equilibrium (Inoua & Smith, 2022). Competition in the market also facilitates innovation, resulting in products and services that better serve the needs of consumers. However, with regard to this research, the stakeholder mapping in section X showed that the number of telecom network providers in the Netherlands is very limited. According to Royer (2004), markets where few sellers all have a certain market power, can be typified as monopolistic competitive. The creation of an alliance can further concentrate the market, bringing potential risks of monopolistic behaviour, especially when all the network providers join the alliance. A higher degree of cooperative intensity and integration results in higher market concentration. Higher market concentration, in turn, could strongly enlarge the risk of potential of monopolistic behaviour (Glick & Ochoa, 1990). Joint R&D efforts would for example, less impact the competitiveness in the market, than a merger or joint effort. In case of a more intensified cooperation such as the latter, market power of the (new) economic actor can become too large. This can result in very low competition in the market and thus the size of the firm can equal the size of the market. This brings dangers of monopolistic behaviour such as unfair pricing and limited consumer choices (Glick & Ochoa, 1990).

Entry Barriers

From a position of strength, an alliance can create (unintended) entry barriers for new competitors (Glick & Ochoa, 1990). If a telecom alliance reaches is created, it is likely that they will enjoy benefits that are associated with economies of scale and scope. As discussed, bundling of resources, such as network infrastructure components, can deliver a network that is so large en extensive that for new entrants it is (almost) impossible to build a comparable network. This follows from the notion that market concentration raise entry barriers (Glick & Ochoa, 1990). With this large network, an alliance can serve a large customer base and create network effects. Both consumers, telecom providers and, in case of a platform, C-ITS providers benefit from these network effects. For new entrants, network effects can be problematic since even if they achieve a 'better' solution for customers, network effects limit customers from switching to the new product. This creates entry barriers for potential new entrants. Considering the beneficial potential of economies of scale and network effects, an alliance can also protect its market share though predatory pricing. Through lower cost structures and high profits, an alliance could set prices on such a low level that potential new market entrants are discouraged (Glick & Ochoa, 1990). A strong market player can do this because profit margins are high enough to lower its prices, accepting the loss in revenues. A new competitor can than never match the prices in such a way that profit margins are guaranteed (Glick & Ochoa, 1990). And according to Royer (2004), absence of potential profits can be an entry barrier on itself. Another entry barrier that can be present is the availability of resources to new entrants (Glick & Ochoa, 1990). Firstly, network providers can establish exclusive partnerships with technology suppliers, making it impossible for new entrants to buy similar products. Secondly, the allocation of spectrum bands can be problematic for new entrants. In the Netherlands, spectrum bands are auctioned by the Authority of Consumers & Markets. How this process of auctioning works is explained in section 3.3.2. When spectrum bands are auctioned they are thus assigned to a bid-winning provider for X years. This creates since entry barriers, since it can be possible that all spectrum bands are allocated. The ACM must therefore allocate spectrum bands in such a way that potential competition is not discouraged. The ACM must apply this strategy also in other fields and monitor the market and, when needed, design antitrust measures.

Antitrust Regulations

In order to ensure consumer welfare and efficient resource allocation, antitrust regulations need to be designed to protect against potential monopolistic behaviour. A potential alliance need to be managed by limiting it from gaining excessive market power which discourages potential new entrants (Royer, 2004). The ACM must constantly monitor the situation in the market, and, when needed, design and enforce antitrust regulations. This should result in lower entry barriers which should enhance competition. From the stakeholder analysis in section X, it followed that the Ministry of Economic Affairs and Climate Policy is closely tight to the ACM, providing guidance and a vision to the ACM. Courts are crucial in enforcing antitrust laws.

4.4 Conceptual Model

4.4.1 Creating the Conceptual Model

Based on the findings of the literature review, the following initial set of factors are captured by the consulted theories that deal with cooperation between private companies. These factors will be used to construct a conceptual model for this study.

- Interest Alignment
- Conflicts
- Governance
- Interdependencies
- Strategy
- Control Mechanisms
- Bounded Rationality
- Opportunistic Behaviour
- Profit Maximization
- Competition
- Entry Barriers
- Anti-Trust Regulations

According to the researcher, these factors can be categorized over a number of overarching factors that capture the essence of the more specified factors that are presented in the list above. This categorization will be used to structure and simplify the factors for the conceptual model. On top of the already identified factors, the researcher has added a number of factors that, according to the researchers creativity, needed to be included in the list of factors. These added factors are highlighted in blue in table 4.2 below.

Shared Vision	**Conflicts & Opp. Behaviour**	**Enforcement of Cooperative Agreement**	**Benefits for Telco's**	**Inter-dependencies**	**Market Concentration**	**Trust**	**Technological Feasibility**
Interest Alignment	Conflicts	Governance	Profit Maximization	-	Competition	Trust in partner's capabilities	
Strategy	Opportunistic Behaviour	Control Mechanisms	Reciprocity		Entry Barriers	Trust in partner's intentions	
Shared Goals	Bounded Rationality	Legislation	Collective Growth		Anti-Trust Regulations	Trust in received information	
						Trust in process	

Table 4.2: Categorization of Factors

4.4.2 Resulting Conceptual Model

In accordance with the identified and argued for factors presented in section 4.4.1, the resulting conceptual model of this study is presented below. This conceptual model will be used to identify interview topics and design interview question in the second phase of the research; the interviews.

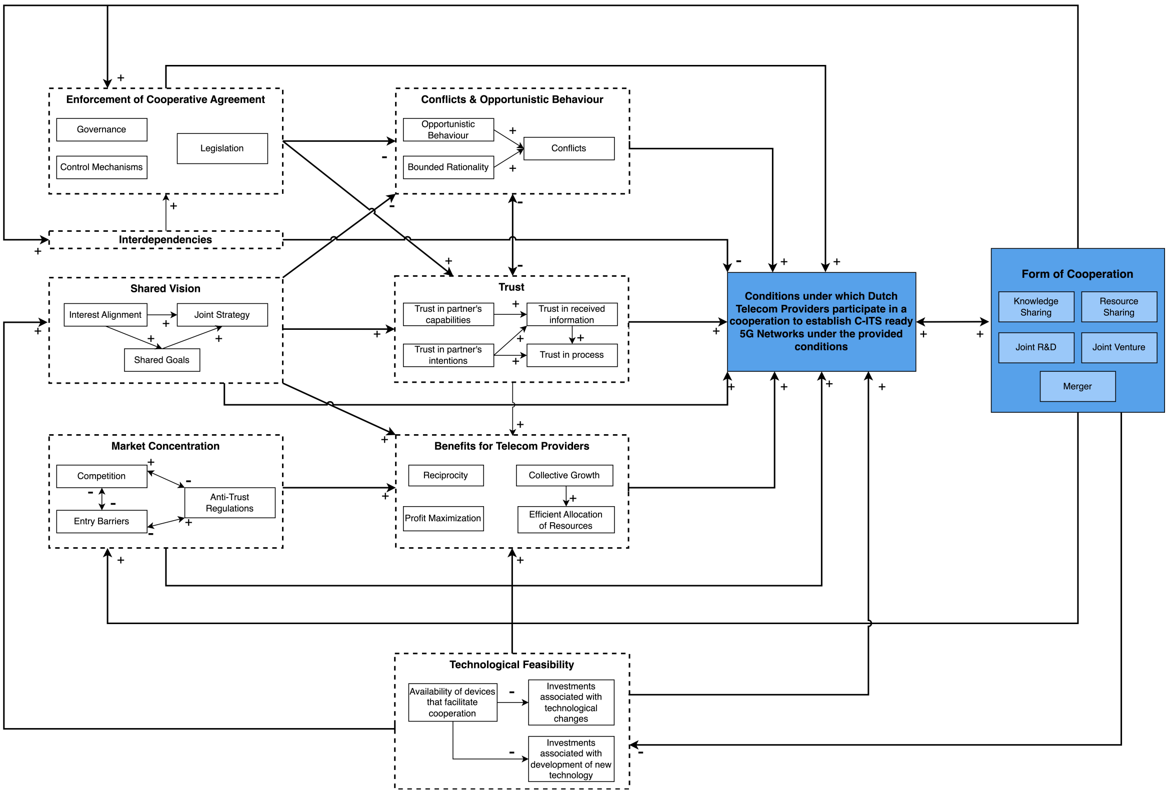


Figure 4.2: Conceptual Model of the Study

5 Interview Results

5.1 Identification of Interviewees

In this section, a stakeholder analysis will be performed from which interviewees will be selected. First, the stakeholders that are associated with the topic of this study will be identified. Than, the stakeholder interrelations will be mapped. The results of this analysis will be used to identify the interviewees.

5.1.1 Stakeholder Identification

Telecom Providers
Evidently telecom providers are the first stakeholders to be identified. A quick first distinction can be made between two types of telecom providers in the Dutch telecom market.

- Mobile Network Operator (MNO): telecom providers who own and operate a network infrastructure. MNOs own and operate all the physical components of a network. These components are discussed in chapter 3.3. On top of that MNOs own the frequency bands in which these networks are operated. In the Netherlands, three MNOs can be distinguished; Vodafone-Ziggo, KPN and Odido (formerly T-Mobile) (Rijksdienst Digitale Infrastructuur, 2019).
- Mobile Virtual Network Operator (MVNO): telecom providers who don't own and operate a network infrastructure. Instead, these MVNOs lease network capacity from MNOs. MVNOs can then compete with MNOs by offering unique service packages to consumers on a subscription basis. Investing or maintaining a network is handled by the MNO (Rijksdienst Digitale Infrastructuur, 2019).

On the basis of the above presented classification of telecom providers, MVNOs will be left out of scope in this study. MVNOs lack the power, knowledge, time and resources to join MNOs in efforts for cooperation in realising 5G networks that are C-ITS ready. A subscription model similar to the as-is situation can be a possibility in the future to induce competition, but won't be included in this study.

Telecom Hardware and Software Vendors
MNOs buy in various hardware and software solutions from vendors to establish their networks. A classification of hardware and software that is supplied by vendors will be presented here. A more detailed analysis of the various network components is provided in section 3.3.

- Network Infrastructure Components: typically supply hardware components such as cell equipment, antennas base stations, switches and other cell equipment to MNOs. MNOs use these hardware components to build and maintain their networks.
- Transmission Equipment: optic transmission equipment for the transportation network, connecting the RAN to the CORE network. Also used for long-distance data transmission.
- Data Center Equipment: equipment that is needed for the construction of data centers. Can be used for computing and hosting services.

- Software Providers: MNOs typically buy in software for network management, privacy, and security related topics.

Ministry of Economic Affairs and Climate Policy

The Ministry of Economic Affairs and Climate Policy is concerned with a variety of topics including telecommunication and the deployment of 5G networks (Rijksoverheid, 2024). A goal of this ministry is establishing fast, secure and reliable 5G networks for all types of users. In its role as policy maker, the ministry can take a coordinating and monitoring role, supporting and investing in technological advancements that facilitate sustainability while guaranteeing the availability of 5G and safety to Dutch citizens. In order to do so, the ministry can allocate funding to private companies, including telecom providers, to invest in C-ITS ready 5G networks. On top that, this ministry deals with the allocation and auctioning of spectrum bands in which the 5G network operates as discussed in section 3.3.2. As a policy maker, this ministry also deals with overseeing the Dutch telecom sector, ensuring that fair competition is in place and market power is not abused. A separate body, closely connected to this Ministry, that assists in this oversight is the Authority Consumer and Market. To guarantee the security and reliability of Dutch telecom networks, the Ministry has a established a specialized authority; the Dutch Authority for Digital Infrastructure (RDI) (Rijksoverheid, 2024).

Dutch Authority for Digital Infrastructure (RDI)

The RDI, formerly known as the Telecom Agency, is a government agency which is controlled by the Ministry of Economic Affairs and Climate Policy (Rijksdienst Digitale Infrastructuur, 2024). The RDI plays a key role in the regulating and overseeing Dutch digital infrastructures including the 5G network. The RDI oversees the digital spectrum through spectrum management and maintains and enforces broadcasting and telecommunication rules and regulations (Rijksdienst Digitale Infrastructuur, 2024). With that, the agency contributes to and oversees the creation of digital communication networks. Technological innovation in the field of 5G is thus overseen by the RDI to guarantee compliance with both national and international standards and regulations. With that, the RDI is a key stakeholder in the development of 5G networks and beyond.

Antenna Agency

The Antenna Agency is a sub division of the RDI. This education is occupied with providing education about the usage of antennas in the Netherlands (Antennebureau, 2024). Citizens and others users can consult the Antenna Agency to gather information regarding the health risks of antennas and the associated radiation (Rijksdienst Digitale Infrastructuur, 2019). There are citizens that believe that the increasing level of radiation brings severe health risks and can cause diseases. The Antenna Agency is established to resolve these concerns and provide education (Antennebureau, 2024).

Authority Consumer & Market (ACM)

The ACM is tasked with overseeing and maintaining rules and regulations in free and regulated markets to guarantee consumer welfare (ACM (The Association for Computing Machinery), Year of publication, if available). One of the markets where the ACM acts as a gatekeeper is the Dutch telecom market. The ACM ensures that the telecom market operates efficiently and transparently by fostering competition between telecom providers. The ACM carries out extensive market monitoring and researching activities and enforces regulation to ensure fair market conditions in the telecom sector to ensure fair pricing for consumers. With that, the main goal of the ACM is to protect consumers against market power abuse.

Local Municipalities

Local municipalities play a key role in the establishment and continuing development of 5G networks (Rijksdienst Digitale Infrastructuur, 2019). According to the Rijksdienst Digitale Infrastructuur (2019), the responsibilities of municipalities are threefold. Firstly, municipalities have a legal duty to participate in spatial planning, innovation and economic development. Secondly, the municipality acts as an advocate of its citizens, ensuring that citizens are able to enjoy the benefits that digital connectivity brings. Lastly, municipalities have a crucial role in the assignment of cell sites. Cell sites are typically build on buildings or land. In this case, cell sites will be placed in the vicinity of roads to ensure seaming less connection to vehicles and other road users. Municipalities provide telecom providers with permits and licences to attain cell sites and build cells to improve connectivity.

Monet

Monet is a Dutch association that acts on behalves of the three MNOs, Vodafone-Ziggo, KPN an Odido (Rijksdienst Digitale Infrastructuur, 2019, 2024). Monet coordinates and negotiates cell site placement with local authorities on behalves of these MNOs. Cell sites can be shared on between MNOs as explained in section 4.2.3. This already occurs in the Netherlands.

User Groups

User groups will be citizens, vehicles, road users and organisations who will utilize the 5G network for the usage of C-ITS (Rijksdienst Digitale Infrastructuur, 2019). C-ITS providers will run these services on the 5G network through which these services become available to the realm of user groups.

5.1.2 Stakeholder Interrelations

Figure 5.1 below is constructed by the researcher based on the information from the stakeholder identification and reasoning of the researchers. The figure maps how all identified stakeholders are related and what their relation towards one another entails.

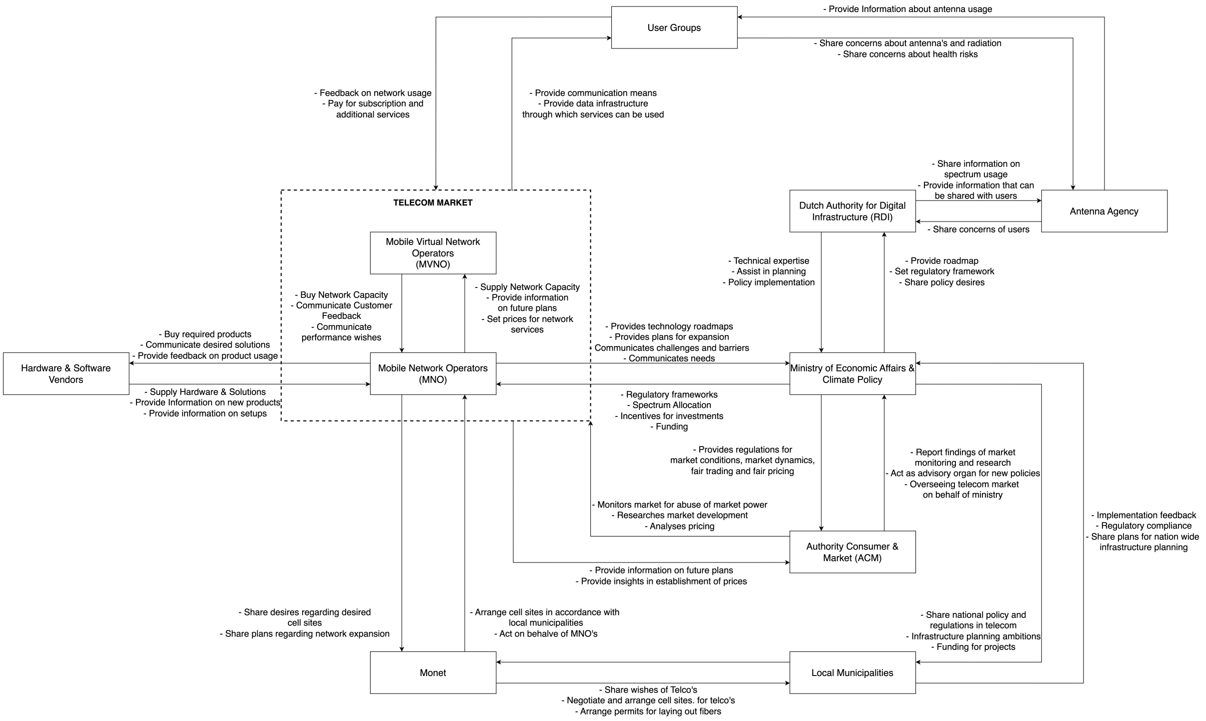


Figure 5.1: Stakeholder Interrelations in Telecom Sector

5.1.3 Selection of Interviewees

Based on the stakeholder identification and the mapping of the stakeholder interrelations, a selection of interviewees was made. This selection is presented in table 5.1 below. The selection has been made to ensure a solid representation of the stakeholder field. A choice was made by the researcher to not approach hardware en software vendors, MONET, local municipalities, user groups and the Ministry of Economic Affairs and Climate Policy. This was choice was made for the sake of time considering how approachable the various stakeholders are. On top of that, the selected interviewees are believed to provide a clear multiple angled view on the research topic. In this research, the goal is to identify under which factors and in what forms telecom providers can cooperate in constructing and operating C-ITS ready 5G networks. Therefore, it was assumed that the viewing points of MNO's is crucial. On top of that, two experts related to the field of telecommunication have been interviewed to gain an independent outsider view on the research topic. Lastly, the two Dutch regulatory bodies associated with the Dutch telecom market were interviewed; the ACM and the RDI.

Stakeholder	**Assigned Code**
Expert Digital Platforms	E.1
Expert Telecommunication	E.2
RDI	RB.1
ACM	RB.2
Technology Architect - Odido	MNO.1
IoT Specialist - VodafoneZiggo	MNO.2

Table 5.1: Selected Interviewees and Assigned Codes

Table 5.1 shows the final selection of interviewees and their assigned code. This code will be used for referencing in the analysis section of the results.

5.2 Saturation of Interview Results

The bar chart presented in figure 5.2, indicates the distribution of new identified statements across the interviewees. Understanding the saturation of results is of high importance in qualitative research, particularly in the context of interviews (Charmaz, 2016). Saturation in interviews refers to the point at which new data collection efforts deliver no additional findings and thus further data collection becomes redundant (Charmaz, 2016). For this research, saturation in thus indicated by the amount of new identified statements per interview.

Many similar statements were made in the interviews. Statements whose essence matched were modelled as the same statement. The statement was counted as 'new' if no similar statements were made before that particular interview. The bar chart indicates that E.1 and MNO.1 made substantial contribution to the identification of novel statements, accounting for 80% of the total new identified statements. Subsequent interviews noted a gradual decline of the amount of new identified statements resulting in zero new statements in the last interview. Here no new statements were identified, indicating that saturation is reached. This decline signalled the researcher that new interviews would yield little valuable new results since the interviews would merely give dept and richness to the collected data. In the previous results sections became evident that statements were often made by multiple interviewees. This highlights that the data already had richness and dept. Considering the time constraints of the research, the researcher therefore decided to proceed with the following phases of the research; the analysis.

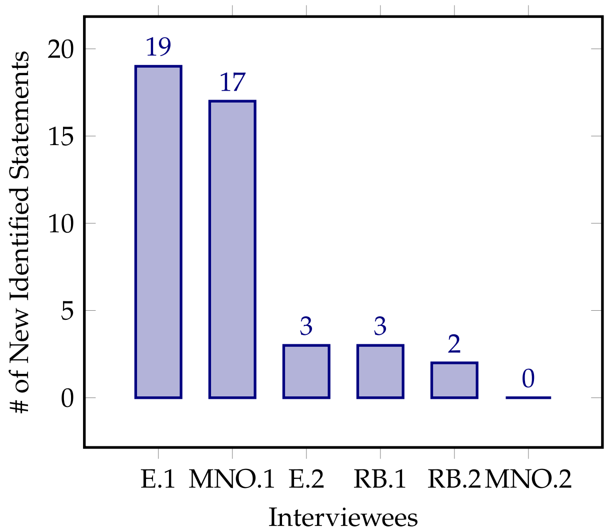


Figure 5.2: Number of New Identified Statements per Interviewee

5.3 Analysis of Results

After the selection of the interviewees, the interviews were conducted with the formulated interview question that are presented in Appendix X. As argued for in chapter 2.3.4, the interviews were conducted live in a semi-structured manner. This allowed the researcher to dive deeper into responses provided by the interviewees. The full list of interview questions is presented in Appendix B. In this section, the results of the interviews will be discussed which are presented in Appendices C to H. Firstly, the results of the interview will be used to answer partial question A of sub question 2:

What are the technical, organisational, institutional, and economic considerations according to the interviewees to collaborate in the construction and operation of C-ITS ready 5G networks?

5.3.1 Current state and Future of the Telecom Market

The interviews started off with an introduction question to get the know the interviewee. Than the interviewees were asked about their vision on the future of the Dutch telecommunication market. Here, the first discrepancies between responses were identified. Firstly, the state of the Dutch telecom infrastructures. According to RB.1 and RB.2, Dutch 5G networks and associated technologies are falling behind in terms of performance when compared to 5G networks of other developed countries. MNO.1 and MNO.2 on the other hand states that Dutch 5G networks are among the best in the world. All interviewees do state that the Dutch telecom market is a very consolidated market which makes cooperation a difficult subject. Nevertheless, E.2 strongly believes in the value of collaboration since E.2 does not believe that all three Dutch MNO's can build C-ITS ready 5G networks that are profitable. When asked about, E.2 responds: 'that means having the same business model with three competing operators, I think will be quite difficult'. MNO.1 also does not foresee three C-ITS ready 5G networks in the Netherlands in the future, co-existing fulfilling similar purposes. Societal resistance against a dramatically increasing number of cell cites is one of the reasons for this, but also environmental considerations come into play here. Statements regarding future profitability, are carried by the statements of E.1, MNO.1 and MNO.2, who state that MNO's are already having difficulties in making current 5G networks profitable. Another reason for low profitability is the fact that European legislation dictates net neutrality which severely limits passing on investment costs to users (E.1, RB.2, MNO.1). This is fueled by how connectivity is currently seen as; 'a commodity' (E.1, MNO.2). Therefore, making investments is already challenging, also considering the high quality standards by the RDI which makes network profitability in rural areas already very challenging (RB.1). In some cases, some coverage areas don't generate profits at all, and profits from profitable areas must be used to maintain coverage and cover the loss. On top of that comes the fact that all MNO's are currently dealing with high OpEx due to high energy costs. These problems regarding profitability are encountered by all MNO's. Among the interviewees there is a feeling that MNO's need to develop them self in a new direction to ensure profitability to remain existing in the future (E.1, E.2, MNO.1 and MNO 2). MNO.2 adds to this that MNO's in general have missed chances over the past years not building 'over the top' services to diversify their service portfolio. Therefore, interviewees are unsure about the future roles and function of MNO's (RB.2, MNO.1, MNO.2). The emergence of new connectivity providers such as Starlink though Low-Earth-Orbit (LEO) satellites is therefore closely monitored (RB.1, RB.2, MNO.1, MNO.2). Also, as MNO.1 stated, private networks are emerging as competitors for MNO's. He explains that from December 2023, plot holder companies were able to claim certain spectral bands that could be used on a specific plot. This allows for the creation of mini private networks. MNO's are also monitoring this development very closely since this could lead to a loss of business. RB.1 also mentioned this as a promising development for communication services.

5.3.2 Economic Considerations

Table 5.2 below shows the grouping of the economic considerations of the interviewees. For each unique statement it was indicated which interviewees shares the same vision by filling the box in the table. Also, the statements were categorized in three categories: business models, joint business models and regulatory push. Two statements are stand-alone statements which did not fit the categorization. What is very striking are the contradictory statements of RB.1. RB.1 opened the interview by stating that MNO's can easily carry investments and develop profitable business models on their own. Later in the interview RB.1, and also E.2, state that cooperation is crucial for the future existence of the MNO's.

	Statements Grouping	E.1	E.2	RB.1	RB.2	MNO.1	MNO.2
Business Models	Use cases are underdeveloped	■	■	■	■	■	■
	Use cases will come once network is built				■		
	Network will come when use cases and business are created					■	■
	Without use cases, no profitable business models and thus no ROI	■	■	■	■	■	■
	Priorities of MNO's lie in other profitable business cases					■	■
	MNO's can easily carry investments and build business models			■			
Joint Business Model	Joint business model needs to be better than individual business model			■			
	Sharing investments can deliver faster go-to-market	■	■	■	■		
	Distribution of costs and profits is problematic		■			■	■
	MNO's will always consider own competitive position	■			■	■	■
	Cooperation and coordination are crucial for the future of MNO's		■	■			
Regulatory Push	Legislation limits profitability	■	■	■	■	■	■
	Financial incentives need to be created to push development		■	■		■	■

Table 5.2: Identified Current and Cooperative Economic Challenges from Interviews

Business Models

A view that is widely held by all interviewees, is that use cases are currently underdeveloped. This brings uncertainty but is also identifies a potential deadlock. MNO.1, MNO.2 and RB.2 refer to this as 'the chicken and the egg problem'. 'What comes first'? Is the question they asked them self multiple times. On the one hand it can be stated that the creation of a sufficing network will bring a innovative push in use cases like C-ITS, but MNO.1 and MNO.2 don't take that for granted. What if the innovative push does not trigger the development of use cases? In that case, MNO's will be left with huge investments that are almost impossible to earn back. RB.2 feels that this is no problem and that use cases will develop over time when the network(s) are reaching full potential and unlock new applications. MNO.1 and MNO.2, on the contrary feel that innovation has to take place in the field of the use cases after which MNO's can build the network around these use cases. This makes them less prone to financial risks. This potential deadlock is a crucial withholding factor for the MNO's. They state that without use cases, they are not willing to build a network for use cases that are yet to be developed. MNO.2 states:"*It's a very big bet to start gearing up for a million- if not trillion-dollar investment, something in which you're not sure you're going to earn it back*". They also state that that is the reason why their focus lies on other fields of business where already profitable business cases are prevailing. They state that man power and (financial) resources can only be used once, therefore this trade-off produces a different outcome for them. MNO.2 states: *"I know our strategy and plans for the next 3 years. Any initiative on top of that, you will have to justify that in time and money, in business case"*.The fact that without use cases, no profitable business cases can be developed and thus a ROI is poor, is carried by all interviewees. E.2 also explains why the smallest cells currently deployed are small cells and not femto cells: *"Of course, you do get a slightly better network if you start using those smaller cells as well. Only the extra revenue from them is negligible"*. This highlights the considerations that MNO's are faced with. Regarding the development of use cases, no C-ITS providers were interviewed. Therefore it is not known whether these service providers are awaiting network improvements for further development. This is a limitation of the research which will be addressed in chapter 8.

Joint Business Models

According to RB.1 the joint business model needs to be better than individual business models, when engaging in more intensive forms of cooperation such as network sharing or establishment of a joint venture that will build and operate the networks collectively. This insinuates that economic interdependencies need to be present to trigger a cooperation. Although this statement is only identified in the interview with RB.2, this statement is considered of high importance. It is very likely that considering the statements of E.1, RB.2, MNO.1 and MNO.2 that the competitive position of MNO's strongly determines their strategical considerations. When a strategical choice is made to enter a cooperation, this implies that the motive for this engagement comes from economic interdependencies; MNO's can only unlock new business propositions and revenues by cooperating. However, the idea that cooperation is needed at this moment is not prevailing among MNO's. They await the arrival of use cases to assess if business cases can be created on the basis of their own capabilities. Therefore they currently don't share the vision of E.1, E.2, RB1.1 and RB.2, that sharing of investments can deliver faster go-to-market. In their vision there is no market to go to with considering the lack of use cases. MNO.1 and MNO.2 do foresee, in case of a cooperation, that distributing costs and profits among members of the cooperation is problematic. This vision is shared by E.2. E.2, MNO.1, and MNO.2 all have worked on cases where efforts were made to realise a cooperation between MNO's. The outcome was never successful. The reason behind this will be discussed in section 5.3.3.

Regulatory Economic Push

As stated in section 5.3.1, MNO's are already having difficulties in making current 5G networks profitable (E.2, MNO.1, MNO.2). High CapEx and OpEx play a role here, but also regulation. All interviewees state that legislation caps profitability. This is also enforced by the statement of RB.1 that some coverage areas are already producing losses which currently need to be compensated for by profitable areas. According to E.1 and E.2, net neutrality plays a crucial role in this since because it ensures that MNO's are not allowed to charge more for their services to protect consumers. Considering the high investments that needs to be made in a dramatically number of cell sites, this limits profitability potential of C-ITS ready 5G networks. E.2 states that while the number of cells dramatically increases, the amount of data travelling over those networks will not increase sufficiently. Services like C-ITS need massive connectivity but don't necessarily consume a lot of data. Only small packages of data are transmitted, and also new technologies such as edge computing make that these data packages will only become smaller. Therefore the earnings potential is now to limited according to E.2. Therefore, MNO's need to be able to charge more for per unit of data transmitted when compared to providing connectivity to consumers. This creates financial incentives. Taking this into broader perspective, E.2, RB.1, MNO.1 and MNO.2 all state that financial incentives need to be created to push network development considering the current lack of profitable business cases. MNO's are privately owned companies that are in the market to make money, therefore without any financial incentive from the application side or regulatory side, no MNO will shift their priorities to building a network, neither individually nor cooperatively. MNO.1 states about this that a 'premium' needs to be paid by early adopters of C-ITS ready networks to cover investments. This can be performed on the basis of forecasts of market development.

5.3.3 Organisational Considerations

Table 5.3 shows the mapping of the grouped organisation considerations of the interviewees. A classification was made into four groups of statements; shared vision, interdependencies, trust & opportunistic behaviour and governance.

	Statements Grouping	**E.1**	**E.2**	**RB.1**	**RB.2**	**MNO.1**	**MNO.2**
Shared Vision	Shared Vision between MNO's is very important for cooperation	■	■	■		■	■
	Aligning visions of MNO owners is going to be very difficult	■	■	■		■	■
	Discrepancies between visions of employees within MNO	■	■	■		■	■
	Shared Vision between private and public domain is important		■		■	■	■
	All three MNO's need to join the cooperation considering competitive regulation		■			■	
Interdependencies	Interdependencies are needed to push towards cooperation	■		■			
	Lack of business cases and regulatory push create current lack of interdependencies		■	■	■	■	■
	Shifting of interdependencies in cooperative process can be problematic for outcome	■					
Trust & Opportunistic Behaviour	Experiences that cooperation between MNO's can be subject to opportunistic behaviour and conflicts		■			■	
	MNO's don't trust each others capabilities		■	■		■	■
	Distrust and competitiveness among MNO's	■	■	■		■	■
Governance	Independent (public) body such as RDI can play a role as a coordinating body	■		■		■	

Table 5.3: Identified Current and Cooperative Organisational Challenges from Interviews

Shared Vision

The literature review indicated that establishing a shared vision among participants of a cooperation is crucial to achieve the desired results. Although this is identified as a major topic in the interviews, after the first interview with expert E.1, it immediately became clear that in the case of realising cooperation between MNO's this is too short sighted. MNO's are privately owned entities with various ownership structures. For example, Odido is private equity owned company who mostly own a company for approximately 5-10 years (E.2). MNO.1 also mentioned that these PE's typically want to see 'quick results'. KPN on the other hand is an exchange listed company with various major shareholders. The vision and strategic ambitions of in this case private equities and shareholders may vary widely and can be problematic to align. This is stated by almost all interviewees except for RB.2 who did not want to talk about aligning visions between MNO's considering his lack of knowledge regarding this topic and his position as an independent regulatory body. The disparity in visions are a recurring theme. Different departments often have diverse objectives within an organisation. MNO.2 states about this that a strategists will ' be open to talking when it serves his purpose with lower costs and higher profits'. Technology divisions on the other hand would probably be more open to sharing knowledge or more (E.1, MNO.2) E.2, MNO.1 and MNO.2 also foresee the necessity of aligning private and public visions if cooperation is pursued by both domains. MNO.2 states: *"It is a collaborative system and no one feels like carrying the depth investment alone"* In that case, regulatory frameworks need to accommodate cooperation to stimulate innovation. Without a change in vision, the ACM is likely to dismiss the idea of MNO's cooperating in a consolidated market. RB.2 also finds this alignment of visions crucial and states that 'nothing is set in stone, but the context must change then to realise this'. MNO.1 thinks that the RDI can play a role in coordinating the creation of this shared vision. RB.2 takes this into broader perspective by advocating that 'public private partnerships can play a key role in gaining a shared vision across the private and public domain'. He do ass to this: *"yes, but you should also just not think that, that is some kind of holy grail in aligning visions"*. Gaining a shared is vision across private and public domain is a process of constant rediscovering. Adding to the complexity of shared visions are the statements made by E.2 and MNO.1. They believe that a cooperation is only an option when all three MNO's join the cooperation. When only two of the three cooperate, 'the third one will be pushed out automatically'. This is probably an unacceptable scenario for the ACM. The market is already so consolidated that measures need to prevent the exit of any of the three MNO's. According to E.2 regulation can play a role in bringing all three MNO's together.

Interdependencies

E.1 emphasized the importance of interdependencies: *"Cooperation does not emerge because it is interesting to exchange knowledge, no, there needs to be a strategic interest to exchange this knowledge"*. On top of that, E.1 has experiences where interdependencies started to shift in a process of cooperation between MNO's due to technological advances. This caused that the cooperative effort collapsed since the 'feeling of needing each other disappeared'. According to E.1, these interdependencies don't necessarily need to emerge in the private domain, the public domain can create these interdependencies as well through legislation. In that case, Dutch regulatory bodies need to have a clear vision on the desirability of a cooperation. RB.2 also acknowledged the importance of interdependencies. While RB.2 does not observe interdependencies now, he believes that a change in regulation or technology can definitely create them. RB.1 also believes that interdependencies can emerge in 'acquiring cell sites considering the societal resistance against the growing number of cites'. When asked about interdependencies, E.2, RB.1, RB.2, MNO.1 and MNO.2 state that currently no interdependencies can be observed between MNO's. The primary case for this is the lack of knowledge about use cases, along with an absence of a regulatory push. MNO.2 emphasized that 'they are still in the what? Not in the how?', MNO.2 indicating that they are still analysing how and if these use cases will emerge, before considering how these services can be served with an adequate data infrastructure.

Trust, Conflicts & Opportunistic Behaviour

Both E.2 and MNO.1 have firsthand experiences in bringing MNO's together to realise a cooperation for network sharing purposes. Although results were not successful, they do deliver valuable insights with regard to this research. MNO.1's experiences indicated the susceptibility of cooperative relationships to opportunistic behaviour: 'you just saw that the counter party started to play games and deliberately was slowing things down'. MNO.1 perceived that the other MNO in the cooperation was deliberately slowing down network development for personal gains, by picky bagging on MNO.1's efforts. Therefore, MNO.1' trust in other MNO's with regard to a cooperation is damaged. He states that 'cooperation is quite vulnerable to bickering and political games'. Additionally E.2, RB.1, MNO.1 and MNO.2 state that there will always be doubts about the capabilities of counterparts in a cooperation. E.2's cooperative efforts have similarly provided him with insights regarding the level of trust and competitiveness among MNO's. He states: *"They don't give each other the light in the eyes"*. This feeling of competitiveness is felt across the various levels of the MNO's (MNO.1, MNO.2). Considering their backgrounds in working for multiple MNO's, MNO.1 and MNO.2 personally don't feel animosity towards competitors. However, they sometimes do sense competitiveness among colleagues. This feeling of distrust and competitiveness are also perceived by RB.1 who, in it's role as independent regulatory body, feels a high degree of confidentiality demands triggered by competitiveness and distrust. *"They will never show the back of their hand and they will always want their own network to be just a little better than the competitor's"*. This indicates a broader trend of distrust and competitiveness among MNO's. E.1 also has experiences with cooperation between MNO's, be it on a different topic. He remarks that MNO's are not used to cooperating with each other, which makes trust difficult. According to E.1 trust is thus mainly a consequence of good governance arrangements.

Governance

Governance was a topic during the interviews on which the interviewees have little responses due to a lack of positive experiences. E.2, in his previous strategic role at an MNO, has had experiences with trying to realise a cooperation between MNO's. When asked about governance, E.1's response was: *"we didn't get around to governance because the bickering already started in the earlier phases of the negotiations"*. This indicates how difficult it is to bring MNO's together. Economic interests and strategic vision, along with distrust, potential opportunistic behaviour and competitiveness, make that conversations quickly overheat at the negotiating table. E.1 therefore foresees a role laid out for external parties in managing or establishing a cooperative relationship. The RDI can play a role in this, but an external consultancy company may also be an option. Although E.1 feels that 'those tend to be expensive and deliver little results'. For E.1 it is clear that governance arrangements should clearly specify what information is shared and with whom. RB.1 also foresees a role for itself in managing such a cooperative relationship. RB.1 currently already discusses technicalities with MNO's in working groups. RB.1 feels it has demonstrated its competencies in this role while 'ensuring independence'. MNO.1 shares the vision of E.1 and RB.1 and also states that the RDI can play a big role in managing a cooperation. RB.2 also acknowledges this feels that they should not be entitled to such a governance managing role. 'The ACM is an independent body that acts reactive, we are not the ones telling how the world should look like'. E.2 on the other hand is more critical. He states: *"the RDI is not a regulator and does not have the capabilities to act as coordinating body"*.

5.3.4 Institutional Considerations

Table 5.4 illustrates the grouped institutional considerations of the interviewees. These statements were grouped in three categories: National Regulation and Cooperation, European Legislation and Innovation, Consumer Protection and Competition.

	Statements Grouping	E.1	E.2	RB.1	RB.2	MNO.1	MNO.2
National Regulation and Cooperation	Regulation from Ministry can steer MNO's towards cooperation by creating regulatory interdependencies.	■	■	■		■	■
	Regulation must not limit innovation, but can't force innovation either. Regulation only can steer the 'how'.	■	■	■	■	■	■
European Legislation	European vision is needed to create legislation that allows for cooperation.	■	■			■	■
	EU needs to allow MNO's to charge more for C-ITS services to facilitate the creation of business models.		■				
Innovation, Consumer Protection and Competition	ACM will have considerations regarding market performance, competition and consumer protection that will limit opportunities for cooperation severely.	■	■	■	■	■	■
	ACM needs to be flexible to allow for cooperation if it brings benefits for society		■			■	■
	Main limiting factor is reluctancy of ACM regarding a cooperation between MNO's.	■		■	■	■	
	Maintaining competition law stimulates market innovation	■	■	■	■		

Table 5.4: Identified Current and Cooperative Institutional Challenges from Interviews

National Regulation and Cooperation

All interviewees are united in the role that regulation can play regarding cooperation between MNO's. The statement regulation can't force or block innovation is identified in all interviews with the interviewees. If cooperation is desired for the sake of innovation, regulation must allow for it. RB.1 states" *"laws and regulations should not get in the way of innovation. And the moment that could possibly get in the way, the first thing that should be addressed is that there needs to be a solution so that laws and regulations do not block innovation"*. RB.2 also states that blocking a cooperation is not their goal: *"As ACM, you also don't want to say block new innovations by overly stringent regulation"*. MNO.2 also that that regulation can't force them to develop networks that are not profitable: *"we have to want to start doing that, because laws and regulations can never force Vodafone to invest millions in a network, of course"*. E.2 adds to this that shareholders if development is forced 'shareholders will opt for a buy-out to dodge loss-creating projects. On the other hand regulation can steer MNO's towards cooperation through the creation of regulatory interdependencies (E.1, E.2, RB.1, MNO.1, MNO.2). E.1 states: *What you see in a lot of other domains is that regulations now give a lot of direction to cooperation"*. Therefore, regulation can only be used as a means to 'steer the how' and not determine the 'what'. E.2 also refers to regulation that steered

MNO's towards cooperation for freeing up spectral bands for the Dutch police when the 700MHz was auctioned.

European Legislation

E.1, E.2, MNO.1 and MNO.2 state that also European vision on regulation is needed that if desired, would allow for cooperation. MNO.2 states on this: *"I believe that such a guiding agreement is necessary initially, particularly within the European Union"*. E.1 states that European and national competition law are the main limiting factors for potential regulation. The European Union has the power to do this. MNO.1 refers to an example where spectral bands were reserved for Tele2 against a reduced tariff to stimulate competition. The EU thus has tools to influence and steer national and/or European markets. According to E.2, MNO's can influence this decision power through lobbying. However, he feels that other industries such as the automotive industry have better lobbying power: *"Then you already know who has the short end of the stick, the telecom providers"*. E.2 also states that the best way to force cooperation would be through European legislation. However, as stated before MNO's probably won't be susceptible to forcing regulation. Therefore, E.2 suggests that in the case that cooperation is desired, the EU would need to create financial incentives and economic interdependencies. His vision: *"you're offering a nice incentive, and you can see everyone start moving. If there is a real business opportunity, everybody want to embark"*.

Innovation, Consumer Protection and Competition

All interviewees wonder aloud what the ACM will think of a potential cooperation. E.1, RB.1, RB.2 and MNO.1 claim that competition laws will be the crucial factor that limits opportunities for cooperation: *"Yes, I think those competition rules are the dominant restrictive ones. And you see that also in the international context"*. A clear public vision that supports cooperation is needed to break down this limiting factor. The ACM is a body that stands strives for two things: consumer interest and good functioning markets. When asked about the relation of these goals against potential cooperation, RB.2 states: *"Yes we have two hats on, which if all goes well, are not very different. Namely that consumer interests and the proper functioning of the market are both very important. They should then go in the same direction"*. Although RB.2 states that more intensive forms of cooperation are not believed to be a possibility, the context can always change and 'nothing is set in stone'. E.2 also thinks that 'if it is of national importance, the viewing point of the ACM will change'. However, E.1, E.2, RB.1 and RB.2 watch out for diminishing innovation in the long run and state that cooperation may lead to less innovation in the long ryn. One of the goals of competition law is stimulating innovation through competition. Competing companies need distinguish them self on the basis of innovative and novel qualitatively good services. According to E.1 competition also lowers the consumer prices for innovation. RB.2 states that a striking balance needs to be found between cooperation, and a healthy market and innovation: *"It must be sufficiently guaranteed that costs remain reasonable, that access is equal and that you do not jeopardise innovation in any way. That is always a tricky one"*.

5.3.5 Technical Considerations

Table 5.4 illustrates the findings of technical considerations of the interviewees. The statements were grouped in four categories: Redundancy and Network Resilience, Technological Feasibility, Cost of Technological Development and Gaps in Technical Knowledge. Each of the categories will be discussed in this section along with the identified statements.

	Statements Grouping	E.1	E.2	RB.1	RB.2	MNO.1	MNO.2
Redundancy and Network Resilience	Redundancy can be desirable in case of loss of coverage makes network less resilient	■	■	■			
	Three redundant networks undesirable in terms of environment. Growing resistance against rising number of cells		■				
Technological Feasability	A lot is possible to develop the networks but the technology needs to be controlled by MNO's			■		■	■
	Technology exists to combine slices of different networks		■	■		■	
	Technology exists that allow for joint business models		■	■		■	■
	Prioritization can be performed on networks		■			■	
Cost of Technological Development	User planes have to equipped near the RAN. This is an expensive endeavour					■	
	Free allocation of high spectrum can lower investments for MNO's				■		
Gaps in Technical Knowledge	Public domain lacks knowledge to build and operate networks		■		■	■	
	MNO's have demonstrated a lack of service-related knowledge	■					■

Table 5.5: Identified Current and Cooperative Technical Challenges from Interviews

Redundancy and Network Resilience

Three networks that almost serve identical purposes have its advantages and disadvantages. Firstly the statement of E.2 who also sees the disadvantages of redundant networks. He states that redundancy is undesirable in the future considering the growing the amount of societal resistance against a growing number of cells. Also from an environmental point of view is building three redundant networks not desired. E.2 also acknowledges the advantages of redundancy. As do E.1 and RB.1. E1 states: *"I think you want redundancy so we don't rely on just one network. This brings risks in terms of cyber attacks, loss of network and reliability in general"*. Redundancy makes Dutch communication networks resilient against external threats network malfunctions. This is a topic that concerns the RDI very much and is one of the reasons that the RDI oversees the Dutch telecom market. RB.1 states about this: *"Three errors rarely happens, but that's why you have redundancy in case of emergencies. That's also kind of nice"*. According to MNO.1, the RDI imposes strong regulation on phasing out old equipment because networks otherwise can become subject to 'network sabotage' from outside enemies. Therefore, the question remains whether eliminating redundancy is desired from a societal point of view. Though, E.2 does not see how multiple redundant networks can maintain such high quality standards and build a profitable business cases for networks like C-ITS. If only one network would be constructed as a product of cooperation, this network needs to be fully resilient against outside threats and network errors (RB.2). The question remains whether this can be achieved on a relative short horizon.

Technological Feasibility

According to RB.1, MNO.1 and MNO.2 already a lot is possible to make 5G networks ready for services like C-ITS. The main challenge lies in controlling the technology says MNO.1: *"You must first master the technology before you take the next step, and be able to consolidate with other things"*. According to MNO.2, the main technology related challenges currently lie in standardization. MNO.2 questions: *"So is there already a standardisation form across standardisation bodies or not? If so, then the follow-up question is of course of what is not there yet and what investments are needed for that?"* MNO.1 and MNO.2 remain persistent in stating that the use cases will be the main triggering factor for network development and with that technology development. They feel that vendors will shift their focus to these technologies, when demand from MNO's emerges. MNO.2 states: *"Value is the goal and technology is the means to achieve it"*. With that, MNO.2 believes that if demand follows from developed use cases, vendors and standardization bodies will be there to make it possible. Regarding network sharing possibilities, a lot of technology exists to make sharing possible for C-ITS purposes. MNO.2 states: *"Guarantees can be given through slicing or prioritisation of quality of service. In which you actually give guarantees within a selected bandwidth"*. A simple case of prioritization that was referred to by multiple interviewees are the so-called slices for the Dutch police on which data streams are prioritized against additional costs (E.1, RB.1, MNO.1). This is also achievable for services like C-ITS. According to E.1, new technologies allow for combining these prioritized slices through ultra-fast handover technology. This technology allows devices to switch between various network slices in milliseconds (E.1). These kind of technologies thus allow for the creation of joint business models such as network sharing (E.1, RB.1, MNO.1, MNO.2).

Cost of Technological Development

RB.2 and MNO.1 both provided statements on the costs of technological network development. RB.2 mentioned an idea how the costs of technological network development could be lowered. This lowering of cost structures should contribute to the realization of profitable business cases. MNO's, but also telecom providers in general, need to acquire the rights to broadcast data over spectral bands. This happens through auctioning which can be a costly endeavour for MNO's. Therefore, RB.2 suggests that high spectral bands can be allocated on a free basis, while complying with the technical requirements of the RDI. Higher spectral bands are used for services, such as C-ITS, that need lower latencies and faster data transmission. This could significantly lower investment costs for MNO's. There is a downside to this for the Dutch government in terms of revenues: *"That's always a very tricky joke with, because of course, when it comes to national licences for this kind of thing, it also brings a lot of money in the state treasury"*. MNO.1 highlighted what makes the creation of networks for services as C-ITS so costly. He states that user planes need to be brought to the RAN in order to realise ultra-low latency. User planes are one of the most costly types of equipment.

Gaps in Technical Knowledge

E.2, RB.2, and MNO.1 acknowledge that the RDI lacks the technical knowledge on network construction and operation. Discrepancies in knowledge makes creating a shared vision difficult. According to E.2 and MNO.1 the RDI 'does not have a clue' what the latest technological developments are in the telecom sector. This complicates network development for MNO's. Also the RDI does not know how MNO's construct business models around the technology. This also becomes clear from the statement of the RDI that MNO's can easily build profitable 5G networks for services such as C-ITS. Creating a shared knowledge base is thus crucial for if the public domain is to be supporting a cooperation. MNO.2 is also critical on the technological knowledge within MNO's. He feels that MNO's have missed opportunities of building application on their own networks: *"Well, I think that, broadly speaking, we as telecom companies haven't really been the best parties over the past years in demonstrating that we've built the applications on top of that well"*. He therefore also foresees that MNO's will have to reinvent their self to guarantee a strong position for the future. E.1 substantiates this vision. He states: *"Telecom operators did not excel in service innovation in the past. That was always very difficult and slow"*.

5.4 Generic Challenges for Cooperation

In this section, the identified main challenges from the interviews in implementing a cooperation between MNO's will be presented. In section 5.5, the identified opportunities will be discussed. Jointly, these sections aim to answer partial question B of Sub question 1: *What are the potential challenges and opportunities in implementing a multi-operator approach in the creation and operation of C-ITS ready 5G network(s) based on the interviewees, considering the specific characteristics of the Dutch telecom market?*

5.4.1 Getting the Institutional Environment Right

The current institutional environment is one of the main limiting factors for potential cooperation between MNO's. If cooperation between MNO's is desired for the sake of innovation, the institutional environment needs to be changed to allow for cooperation. All interviewees, including Dutch public regulatory bodies, state that regulation can't limit or force innovation and it can only steer the 'how'. Therefore, if cooperation is a desired solution for further network development, the ACM and Dutch regulatory bodies in general, should make changes to current regulation to enable this. A clear vision from the European Union or the Dutch government can facilitate the changes needed in regulation. Most of the interviewees currently point in the direction of the ACM to indicate the crucial factor that limits cooperation. As became clear from the interviews, the Dutch telecom market is a very consolidated market with just three MNO's left, following the merger between T-Mobile and Tele2 a few years ago. Further consolidation can lead to too many market power which can result in unfair pricing and reduced innovation. However, if the market becomes further consolidated depends on the form of cooperation. Therefore, changing the institutional the institutional environment right is challenging. If cooperation is desired, regulation can give a 'regulatory push' to MNO's to start cooperating by creating regulatory interdependencies. This was also done by creating transfer rules for consumers who switched between telecom providers. These regulations have forced telecom providers to cooperate and coordinate. For this purpose, the COIN partnership was established. This is a cooperation between dutch telecom providers. This case indicates that regulation can drive the 'how' question. For telecom providers, financial gains remained in sight despite the new regulations. As a result, regulation had the desired effect. The regulatory push can also be centralized around providing economic incentives that contribute to the creation of business cases to accelerate innovation. The challenging part about the institutional environment, is that regulation should strike a balance between pushing towards cooperation, while safeguarding consumers against undesired effects that arise from market too much market power.

5.4.2 Further Development of Use- and Business Cases

One of the main reasons that MNO's are not currently shifting their focus towards network development for purposes such as C-ITS, is that these use cases are still underdeveloped. The interviewed MNO's state that their focus currently lies on making existing use cases more profitable. They state that 'time, resources and money can only be spend once'. Therefore developing C-ITS ready networks is not on their current strategic agenda. In order for this to be changed, use cases need to be developed more. If these use cases are in the further stages of development, more will be known about what networks should be designed. From here, business cases can be developed. Currently, there is no outlook towards profitable business cases regarding C-ITS. Therefore, MNO's state that they are still in the 'what' instead of the 'how'. Realising and unlocking value is their main goal and the value associated with C-ITS ready networks is yet to be discovered. If cooperation is needed, will follow from the use cases. If business cases can't be made profitable individually, cooperation may become an option. For now, more development from the side of the use cases is needed according to the MNO's. MNO's do admit that this a 'chicken and the egg' problem. They feel that the network will develop when use cases are in place and not the other way around since they will not make investments that can't be earned back. 'Just making it' is not an option for MNO's. Moreover, all interviewees stated that regulation can't force innovation and it can only steer the 'how'. Regulation can't force MNO's to build unprofitable networks. Therefore, this vision needs to be dealt with by focusing on the use case side or through the creation of economic incentives that facilitate the creation of profitable business cases.

5.4.3 Designing Technical Solutions

Once use cases are getting more developed, technical solutions need to be designed in terms of creating supporting data infrastructures. Although MNO's look expectantly at connectivity developments from space, it is believed that mobile networks will play a crucial role in facilitating services such as C-ITS. Dealing with these new markets is a challenge on its own, but MNO's need to ensure that mobile networks provide better opportunities. Depending on how the MNO market will look like for intensive connectivity services such as C-ITS, technologies need to be developed and controlled by MNO's. From the interviews followed from a technology side, a lot is possible to create 5G networks for C-ITS. Network slices can already be prioritized and provided with higher quality of service. And in case of network sharing, handover technologies exist that can ensure ultra fast handovers milliseconds. But the real network development still needs to be performed. In order to assure ultra-low latency's a dramatic increasing number of cell sites needs to be obtained where cells can be build. On top of that, user planes need to be brought closer to the RAN which brings high costs. However, final network designs will follow from the use cases. The technology can act as a mean to reach the desired goal. Based on these design, strategies will be investigated. Among those strategies, cooperation will definitely prevail.

5.4.4 Getting a Shared Vision across all Stakeholders

The literature review indicated that obtaining a shared vision between MNO's is crucial to make cooperation successful. Although this statement is widely agreed on by all interviewees, it is also to short sighted. In the first interview already became apparent that gaining a shared vision across MNO's is difficult to their varying ownership structures. The vision of owners of MNO's therefore has to also be taken into consideration. KPN is a stock noted company with 10 major shareholders, Odido is owned by two private equity companies and Vodafone-Ziggo is partially owned by Liberty Global. All these owners have various goals considering their ownership. This makes aligning visions very difficult. On top of that comes that multiple interviewees stated if a cooperation would occur, all three Dutch MNO's would have to join the cooperation. If only two of the three would join efforts in a cooperation, the third MNO would we gradually pushed out of the Dutch market. This provides the remaining two MNO's with too many market power which can lead to market imperfections and too much market power. This makes the creation of shared vision across all three MNO's crucial. All MNO's need to enjoy the benefits in terms of synergy gains to make it feasible. If the owners of MNO's would be able to create a shared vision, the MNO's still need to create a shared vision as well. On of that comes that within MNO's discrepancies have been identified in visions across various departments of MNO's. There thus also lies a challenge in creating a shared vision within MNO's. Another troubling factor regarding shared visions is that public and private visions need to be aligned to get the institutional environment right. Aligned National and/or European vision can create the right institutional environment that can facilitate cooperation. Without a shared vision across public and private domain, the current institutional environment would not allow for a cooperation. This is indicated in the interviews where all interviewees point to the ACM as the main limiting factor that troubles potential cooperation.

5.4.5 Designing a Cooperative Agreement and Governance Mechanisms

From the interviews became clear that multiple interviewees have had bad experiences with cooperation between MNO's. There is a lack of trust among MNO's and this is fuelled by examples of opportunistic behaviour and conflicts. In order to facilitate trust and deal with undesired behaviour and conflicts, a clear cooperative agreement needs to be designed depending on the type of cooperation which is intended. The cooperative agreement must specify obligations and divide responsibilities and tasks. These tasks should contain deadlines on deliverables to limit possibilities for slowing down the process. Agreements need to be made on the quality standards that the cooperation should deliver to avoid risks of free riding. On top of that the cooperative agreement should limit potential opportunistic behaviour en must contain conflict resolving mechanisms through the creation of governance mechanisms. These governance mechanisms must ensure that the cooperation is viable in the long run and no problems emerge during the cooperation that may lead to a preliminary end.

5.5 Opportunities for Cooperation

The interview questions that are presented in Appendix B, were mainly prepared to identify barriers for cooperation from which the researcher could identify the main challenges. However, as a consequence of conducting semi-structured interviews, also opportunities for cooperation were proposed by the interviewees. These opportunities are thus less systematic substantiated than the challenges for cooperation. However, they do deliver valuable insights on how the various stakeholders foresee a potential cooperation among MNO's. Therefore, the obtained results regarding opportunities will be presented in this section.

5.5.1 Transsectoral sharing of data

Transsectoral sharing of data can be categorized as a form of knowledge sharing, as identified in the literature review in section 4.2. This potential form of cooperation is proposed by interviewee MNO.2. He foresees that sharing of data from various service layers across multiple sectors can assist in understanding and processing data more efficiently which can lead to more innovation. The proposition of MNO.2 states that data sharing should only occur on an infrastructure level, but also beyond that on an service and data level. This allows MNO's, service providers and data services to learn from each other and develop from there. According to MNO.2 This could lead to more innovation which can enable Dutch MNO's to develop networks more efficiently which can support the creation of business cases. Also it allows Dutch MNO's to catch up with, for example, American networks according to MNO.2. European vision can play a significant role in this by setting the institutional environment that forces this data sharing. MNO.2 refers to the intelligence act and digital market act, that are invoked by the European Union, as similar efforts for institutional arrangements. Also hyperscalers such as Amazon and Google need to comply to these acts which forces sharing of data across industry players and stakeholders. Such regulation can thus deliver valuable results.

5.5.2 Joint R&D

E.1, E.2, RB.2 and MNO.2 all see potential opportunities in joint R&D efforts for collaboration. A division can be made between joint R&D for two purposes; the development of use cases and the development of technology. The development of use cases is the most proposed of the two. This is understandable considering the underdevelopment of use cases. Further development of use cases is also identified as one of the main challenges that needs to be addressed. MNO.2 foresees more active consortiums of like-minded organisation. In these consortiums, the main activity will be looking at where use and business cases should go. E.1 shares this vision but states that research on use and business cases should occur on an European level in public private partnerships (PPPs). To realise this, European vision and urge is needed. RB.2 is also in favour of PPPs though be it on a national level. RB.2 sees a PPP with Dutch regulating bodies, Dutch universities, research institutes e.g. TNO, and MNO's. In this PPP, use cases and business can be developed and MNO's can learn to operate more cost efficient by investing more efficiently. Lastly, MNO.2 proposes an idea where MNO's establish a start-up as a joint venture solely for R&D purposes. In this startup, MNO's will jointly carry out activities on use and business case development. He acknowledges that establishing such a joint venture is very challenging. Firstly, a shared vision needs to be created which can already be troubling, but it is also challenging from a legal point of view considering the ownership structures of MNO's. He refers to the ownership of his own company and notes that establishing a joint venture within a joint venture is legally challenging.

The second form of joint R&D is focused on the technology development side. E.1 and MNO.2 both propose a joint R&D for the development of standards. Standardization bodies already carry out researches on an European level, but these tend to be slow. Therefore, E.1 and MNO.2 propose to carry out standardization efforts on top of what is already happening. MNO.2 states that the activities of such an R&D effort with like-minded organisations can be extended with the development of smart algorithms that support use cases. The R&D effort can also be concerned with researching how technology in general should be developed. RB.2 also sees the value of such joint R&D efforts since it can lead to more innovation. RB.2 sees that we are falling behind in the Netherlands, but also more generally in Europe. The Dutch government can create (financial) incentives to stimulate these kind of efforts according to RB.2.

E.2 is very critical about the potential of joint R&D efforts for use case-, business case- and technology development. He doesn't see it working at all because then you are going to give away competitive advantage as an MNO. He points to potential opportunistic behaviour such as free riding in these kind of collaborations. He do foresees a joint R&D effort where new market configurations are researched in PPPs along with the ACM. This can deliver insights into desired market images by determining what sections should be treated as a market and what not. This can lead to the development of network sharing propositions. Network sharing propositions are mentioned by all interviewees and will be discussed in the next section. E.2 proposes a PPP to research the willingness among MNO's towards these models. He do adds to this that demand from the MNO market is needed to realise this. Only than there is a chance of making such a PPP successful.

5.5.3 Passive Network Sharing

E.2 is very strict in the vision that he does not see three MNO's develop profitable business models for 5G for C-ITS while developing both passive and active network infrastructures. Although E.2 is the only one to make this statement, all interviewees have made statements that support this vision. All interviewees see a new market configuration in the future be it trough by dividing active and passive infrastructure components into separate markets. The concepts of passive and active network components are explained in section 4.2.3. In the current market, MNO's are tasked with building both active and passive network infrastructures. On the passive side, some sharing of cell sites occurs through Monet, but according to E.1, E.2, RB.1, RB.2, MNO.1 and MNO.2, this has to be intensified. Most of the interviewees propose that a new market should emerge on the passive infrastructure side with new players. MNO.2 also does not understand why there need to be three passive infrastructures and typifies it as undesired redundancy since it does not improve network quality. RB.2 already spotted a trend and sees that a market is emerging on the passive side of the infrastructures. Companies are buying cell sites and sub letting it to MNO's.

E.2, RB.1, RB.2, MNO.1 and MNO.2 propose that the provision of passive infrastructures can be arranged by issuing tenders. Passive infrastructure providers, including MNO's, can then apply for this tender and acquire the right to provide the passive infrastructure in a certain area. This avoids redundant investments from MNO's which frees up financial resources which can be spent on active network development or other service areas. According to MNO.2 this would allow MNO's to reinvent themselves. Regulation by the ACM dictates that the passive infrastructure should be opened to all MNO's at a certain price (E.2,RB.2, MNO.2). This allows for competition on the active network side since MNO's still need to compete with each other in providing the best network infrastructure in terms of performance. It is kind of like an MVNO construction as we know today state MNO.1 and E.2. Competition on the passive side can be induced by relatively short-term tenders states RB.2. This forces also innovation on the passive side. E.2 is a very strong advocate of such a model. He states that it allows for faster network development considering the lower expenditures for MNO's, and it also is desirable from a societal and environmental point of view. For society, the number of cell sites is reduced, and for the environment less fibers are rolled out. RB.1 also sees a broader basis than solely network development. Such a model can be applied when environmental and societal considerations come into play. RB.1 is critical about the duration of tenders, too long leads to less innovation and too short may not be feasible for passive infrastructure providers. A striking balance needs to be found here. E.2 and RB.2 don't see a roll laid out for a governmental body in laying out the passive infrastructure. They feel that this be be at the expense of innovation. They propose that private parties will take care of passive network provision. Tendering also keeps these parties on their toes which ensures they continue to innovate states E.2. E.2 does worry aloud about what will happen if you get too few offers on a tender. This can cause an even more expensive passive network infrastructure. RB.2 also fears what will happen in less profitable areas and whether bids will then come in at all on a tender. The upside to such a new market configuration is that redundancy in active network components stays in place. As stated by E.1, E.2 and RB.1, redundancy is a good thing when considering network failures or outside threats. In this model, redundancy stays intact.

5.5.4 RDI as Governance and Coordination Device

E.1, RB.1 and MNO.1 all foresee a different future laid out for the RDI, extending its activities beyond acting as a regulatory technical body. While this opportunity is not an option for cooperation on itself, it do provides an opportunity in realising successful collaborative efforts among MNO's. MNO.1 states that 'a referee' is needed from the public domain when engaging in collaborative efforts. E.1 also foresees a crucial role for the public domain in making collaborative efforts successful by acting as a coordinating and governing body that enforces agreements. E.1 does note, however, that a clear vision from the public domain is needed to realise this. This vision is supported by MNO.1: a clear vision from the ministry is needed. E.1 feels that an external governing and coordinating body can increase chances of successful collaboration, but is critical about recruiting an external consultancy company since these tend to be expensive and deliver low results. MNO.1 also feels that this effort from the public domain has to be carried out by a public body and not a consultancy company. He notes that the RDI should take a leap forward in both knowledge and vision to make this viable. RB.1 also foresees such a role for itself laid out in the future. RB.1 says that they can do it considering that they 'have demonstrated an independent and unbiased view and have a good track record'. MNO.1 states that the RDI already can take a coordinating role in the establishment of networks in the current market. An example of this coordination can be agreeing on fiber roll out with all three MNO's. This already lowers costs for MNO's for laying out these fiber networks. From here the role of the RDI can only intensify. MNO.1 states that within operators, there are people with ambitious visions, but 'a spark' is missing. He foresees that the RDI can play a role in bringing these people across MNO's together. To conclude, according to E.1, RB.1 and MNO.1 the role of the RDI should encompass more activities. Already it can coordinate activities across MNO's, but it can also acts as governance and coordination device in a potential collaboration.

6
Reflection on Results

In this chapter, the researcher will reflect on the obtained results from the interviews that are presented in 5. First, the researcher will identify and substantiate the inconsistencies in the interview results. Than the main insights from the interviews will be identified. These insights will be compared to the conceptual model that was presented in section 4.4.2. Than the resulting model of the research will be constructed.

6.1 Insights from Interviews

In this section, the main insights from the interviews will be discussed from which an answer will be provided to sub question 2: *What insights can be gained from interviews with stakeholders and experts regarding their perspectives on collaboration in the 5G for C-ITS context, and how can these insights contribute to the overall understanding of effective collaboration strategies?* In general, leaving aside the reason for cooperation, it became clear that cooperation among Dutch MNO's is difficult considering the configuration of the Dutch telecom market. All interviewees questioned, for various reasons, whether cooperation is desirable and if it is achievable. Factors that will limit a collaboration will be discussed first, than the insights regarding potential forms of cooperation will be discussed. This section will be finalized with explaining how these factors and forms of cooperation contribute to the overall understanding of effective collaboration strategies.

6.1.1 Development of C-ITS

The development of C-ITS was one of the major topics in the interviews. According to all of the interviewees, this use case is still underdeveloped. This makes that the demand for C-ITS networks is not yet there. This can come from the fact that a lack of networks limits further innovation now. However, the MNO's were clear in stating that no networks will be build without demand from the market. It can thus be that a deadlock is identified here. The interviewed MNO's referred to this situation as the 'chicken and the egg' problem. This refers to the question of 'what comes first'? Whether there truly is a deadlock and how this deadlock can be broken, are questions that needs to be addressed in further researches. This will therefore be discussed in section 8.2.

6.1.2 Insights in Factors that influence Collaboration

In this section, the insights in the identified set of factors, that influence collaboration between MNO's, from the interviews will be explained.

Lookout for Unattainable Potential Profits

Network operators are in business to generate profits. That is their main goal. As stated in the interviews, there are considerations regarding what is socially desirable, but the main focus always lies on generating profits and growing the business. Therefore, collaboration will be only be an option if there is realm of unattainable potential profits. Profits that can only be realized through a collaboration. In other words, the joint business model needs to be better than the individual business model, creating economic interdependencies. This will push MNO's to new propositions from which they can learn and innovate in other fields of businesses. The institutional environment can push towards cooperation through the creation of incentives, but if there is not outlook on unattainable potential profits, MNO's will be reluctant to a cooperation.

Shared Vision in Network Operator Domain

In order to enable potential collaboration, the creation of shared vision in the network operator domain is crucial. This shared vision has to be created across three levels in the domain. The starting point is the creation of shared vision across MNO's. On this level, the strategic decisions are made for the coming years. If this shared vision is created, MNO's need to present and convince their owners/ shareholders of their plans and create a shared vision between owners of MNO's. If a shared vision among MNO owners is created, the MNO's need to create a shared vision within their organisations. From the interviews followed that disparities in vision are present between various divisions. According to the interviewees, technical divisions are most likely to be willing to cooperate. Also strategic and innovative divisions need to be brought on board to make collaboration successful. It is important that a shared vision in the network operator domain is created across all three MNO's; KPN, Odido and Vodafone-Ziggo. If only two of the three are willing to collaborate, the third one would be gradually pushed out of the market due to economies of scale. Therefore, all three need to join the collaborative effort to maintain competition in the long term. If this is not achieved, the Dutch market oversight regulatory body, the ACM, won't agree with a collaboration which causes that the institutional environment would not allow for collaboration. It is thus important to create a shared vision between private and public domain.

Shared Vision across Network Operator- and Public Domain

Gaining a shared vision across the network operator- and public domain can contribute to realising cooperation. If the current institutional environment does not allow for collaboration, having a shared vision can contribute to getting it right. A shared vision can also contribute to the creation of profitable business cases, since the public domain can design economic incentives. On top comes that a shared vision across both domains, can deliver opportunities in terms of governance mechanisms. This will be discussed in further sections.

Institutional Environment

The institutional environment sets the context in which collaboration needs to occur. This strongly influences the possibilities and willingness to collaborate. From the interviews can be concluded that legislation can't force economic actors to invest in networks that are unprofitable. Legislation can act as a steering- or limiting device, but it cannot dictate to network operators that they must build an unprofitable network. If collaboration is undesired for the sake of competition, legislation can limit MNO's from collaborating through competition law. The ACM enforces this competition law. The RDI enforces technical regulations surrounding the operation of mobile networks and ensures that MNO's comply with the set standards. On top of that come financial regulations such as incentives or regulations regarding net neutrality. These financial regulations have an influence on the lookout for potential profits. These are all examples of regulations that MNO's need to comply with. Here, regulation acts as a device that limits MNO's from reduced innovation or abusing market power, but also can stimulate towards certain goals. Legislation can also set the environment to encourage MNO's to collaborate through the creation of regulatory or economic interdependencies. This can push MNO's towards collaboration. However, this will only have the desired effect if there are unrealized profits looming for MNO's

Interdependencies

Interdependencies are an important aspect of realising collaboration. Interdependencies create a 'need for each other'. Therefore, these interdependencies need to be stable to maintain this need for each other. Shifting interdependencies can cause a collaboration to collapse, according to experiences of one of the interviewees. A distinction can be made between two types of interdependencies: economic interdependencies and regulatory interdependencies. Economic interdependencies emerge when MNO's can only unlock value through a collaboration by bundling financial resources. This can occur when massive investments need to be made, which can't be carried individually. Regulatory interdependencies emerge when regulation pushes towards a collaboration. These can be created on a national or European level. If the Dutch government or the EU wants MNO's to collaborate, regulation can push them towards this. Technological interdependencies were not mentioned in the interviews. Since technology is available in the market, it is a matter of controlling this technology followed from the interviews. Controlling technologies can be achieved by attracting human capital and is therefore more a matter of economic interdependencies. Interdependencies can also be created through the establishment of enforcing governance mechanisms. The chosen form of collaboration, can create interdependencies as well.

Risk of Opportunistic Behaviour and Conflicts

Opportunistic behaviour and conflicts have been named several times as potential problems in examples of collaboration between MNO's and therefore should be taken into consideration. Interviewees indicated that experiences in realizing collaborative efforts often resulted in conflicts and opportunistic behaviour. Conflicts could already emerge at the negotiating table. Therefore, coordination is needed in the earlier phases of the negotiations to create a shared visions which will limit potential conflicts and opportunistic behaviour. On top of that, governance needs to protect the collaboration against potential behaviour such as free riding. The risk of potential opportunistic behaviour and conflicts strongly determines the willingness to collaborate. If the risk is high, no knowledge will be shared to safeguard competitive advantages. Therefore, minimizing these risks is crucial to be able to unlock value through a collaboration.

Trust

From the interviews became evident that a great sense of distrust and competitiveness is present among MNO's. This is mainly noticeable in the strategic and innovative divisions of MNO's which also complicates creating a shared vision. On top of that, statements from interviewees have indicated that this sense of distrust is sometimes induced by negative experiences and examples of similar efforts where conflicts and opportunistic behaviour arose. Therefore, trust needs to be created in a process of collaboration. Gaining a shared vision and good governance mechanisms can induce a feeling of trust. Creating trust is crucial in making a potential collaboration successful. Without trust, MNO's will be wary of sharing knowledge and resources, which can cause a collaboration to result in little value creation which may lead to a collapsing effort.

Governance and Coordination

Governance mechanisms need to be created to facilitate a feeling of trust and limit potential opportunistic behaviour and trust. On top of that can governance mechanisms must specify goals, responsibilities and obligations. From the interviews became clear that governance mechanisms in the form of hybrid governance should be applied when governing a collaboration between MNO's. There is need for an independent 'referee' that enforces the agreed on responsibilities and obligations in market governance mechanisms such as contracts and agreements, and assures that agreed on goals are achieved. From 5.5 followed that the RDI can act as such a governance device. In an independent role, the RDI can ensure that a collaboration follows the intended pathway. A shared vision between the public and private domain is needed to realize this. Therefore, the RDI can take this governing role in the earlier phases of establishing a cooperation by coordinating the process of negotiations. This contributes to the creation of a shared vision across all parties and facilitate a feeling of trust. Also the form of collaboration determines the what governance mechanisms are needed.

Technological Challenges

Technical challenges influence the willingness to collaborate. From the interviews followed that technology exists in the market that enables all forms of collaboration along with the associated business cases. One top of that, most of the technology that facilitates C-ITS ready 5G networks, is emerging in the market. 'It is a matter of controlling the technology' stated one of the interviewees. The degree of controllability determines the amount of financial resources need to be spend to achieve full control. This influences the lookout on potential profits which in turn creates economic interdependencies. Once control is achieved, the desired network solutions, that facilitate the proposed business model, can be designed. On top of that comes the cost of technology itself, if the technology is very expensive this also creates economic interdependencies. Than, there is the question regarding redundancy, redundancy makes that critical services always have a backup infrastructure. If technology becomes perfectly reliable, safe and secure, redundancy can be eliminated. This is not the case for now, which limits the potential forms of collaboration. The degree of intensity of collaboration also influences the technological challenges, when a more intensive form of collaboration will be selected, technological challenges can reduced through the usage of combined knowledge and resources.

6.1.3 Insights in Potential Forms of Collaboration

From the interviews became clear that knowledge sharing, joint R&D and passive network sharing are potential forms of collaboration. The insights into each of these forms will be discussed individually. Than the eliminated forms of collaboration will be discussed and substantiated.

Knowledge Sharing

As identified in section 5.5, one of the interviewees proposes that European legislation should force transsectoral sharing of data across industries that show resemblance to the network operating industry. Such knowledge sharing regulations will provide companies, that fall under such an European act, a platform to learn from other industries and process data more effectively. This enables innovation on a wide scale, but also allows the European Union to monitor developments in the market. MNO's in this case, can use the data from other industries to tailor network solutions more effectively and efficiently. All interviewees were asked about knowledge sharing somewhere in the interviews and only one interviewee responded with this proposal. The remaining interviewees were reluctant about knowledge sharing since this form of collaboration brings risks in term of giving away competitive advantage to competitors. What is crucial to understand is to why the interviewee provided this particular solution regarding knowledge sharing. The answer lies is legislation that forces the sharing of data and creates steady interdependencies. When legislation forces sharing of data, countermeasures will be applied when organisations, falling under the legislation, won't comply. These countermeasures can take many forms, depending on the severity of the breach of rules. This provides a feeling of trust in both the process of sharing information and the authenticity of information.

Without legislation that (en)forces this sharing of data, knowledge sharing would probably not be an option. Knowledge sharing agreements sealed with market governance mechanisms probably have a too 'free' nature. Without legislation, the sharing of knowledge would be purely based on a contractual agreement which can be potentially abused by the members of the agreement. It is very difficult to check whether the shared information is authentic and if all the available information on the topic is shared. This also creates a feeling of distrust and makes that MNO's will always be wary. On top of that comes that, in such a market agreement, the creation of a truly shared vision across the entire network operator domain would be very difficult considering they will operate individually and not as a collective. There is no feeling off working towards a common goal and thus conflicts can arise more easily. Chances are that members of a collaboration would be entering the collaboration for the sole reason to learn from direct competitors to overcome competitive disadvantages. This makes that knowledge sharing is more likely to have successful results when its (en)forced by regulation. To completely seal everything in a knowledge sharing agreement in terms of risk, will take so much effort that the collaborative effort is likely to collapse. This is also indicated by the experiences of the interviewees. Regulation on itself can act as an agreement and as a protection against opportunistic behaviour such as free riding.

Joint R&D

As highlighted in section 5.5, the interviews revealed two potential opportunities for joint R&D efforts; for the development of technology and for the (further) development of use cases. While joint R&D efforts can have varying goals including those proposed, establishing a shared vision regarding the end objectives of the collaboration is crucial for its success. Without such a strong agreement, the collaborative effort is more at risk of failure. Once a shared vision is established, the further characteristics of the collaboration can be agreed upon. Agreements should be made in terms of responsibilities, obligations and goals. Governance mechanisms need to be designed to ensure that everybody complies with these agreements and the set objectives.

An independent body can ensure that the collaborative agreement is uphold. As stated in the interviews, the private domain desires an independent referee to manage such a collaboration. This referee can be the RDI, as widely suggested in the interviews. If public bodies become involved, the joint R&D effort can get characteristics of a private public partnership, depending on the degree of involvement of the public bodies. If the public body has a say in the goals, it can be considered a PPP. Public and private domain than work together on a common goal. The goal itself can create interdependencies, if the goal can't be reached individually. A weakness of a joint R&D, is that members of the cooperation can walk away when that need for each other disappears. The governance arrangement can possibly curb this, however, deserted members can than deliberately slow things down for the sake of their competitive advantage. One of the interviewees proposed the creation of a joint venture for the sole purpose of joint R&D. This can create stronger interdependencies because the fate of that company concerns everyone.

In summary, the success of a joint effort heavily relies on the creation of a shared vision, clear agreements, robust governance mechanisms, and potentially the involvement of an independent body that acts as a referee. This will protect members of the collaboration against potential opportunistic behaviour. Interdependencies need to be steadily present to realise and maintain a successful collaboration. The selection of a more integrated form of joint R&D such as a joint venture, can foster interdependencies, offering protection against early withdrawals.

Passive Network Sharing

As explained, sharing of acting network components is not an option according to the interviewees due to the loss of redundancy and competition. What is an option is the sharing of passive network components such as fibers and cell sites. This passive network sharing will be an extension of what is already being done in the Netherlands in terms of cite sharing. An important advantage of passive network sharing is that it simultaneously deals with two prevailing challenges in the network operator domain; a growing resistance against a growing number of cells, and operating more environmentally efficient.

Broadly defined, there are two potential forms of passive network sharing. The first option is government ownership. The Dutch government can build the passive network infrastructure and from there, lease capacity of this infrastructures to the MNO's. It can be compared to the model that is applied in the Dutch railway sector. A caveat of state ownership is that innovation will fall behind in the long run. Therefore there is a second option, splitting the passive and active infrastructure markets. In most area's, passive and active infrastructures are built and owned by MNO's. By splitting these markets, CapEx for MNO's can be lowered through induced competition in the new market. In this proposition, competition maintains in both sections of the market which can contribute to innovation.

The challenges lay in creating this form of passive network sharing and getting MNO's willing to do this. The government can't expropriate properties from MNO's without huge resistance. Therefore, a solution needs to be found that is carried across the entire network operator domain. Through regulation, the Dutch government can steer towards a passive network sharing agreement. Regulation will thus create interdependencies in this case among the MNO's. However, the government must ensure a sufficing institutional environment to safeguard MNO's against opportunistic behaviour from either the government itself, or the newly entered private companies that will facilitate the passive network infrastructure. Trust is than partially created through regulation. Governance mechanisms such as contracts have to be created across the passive- and active network infrastructure domain regarding the lease of passive infrastructures. Again, a public body such as the RDI, can enforce and maintain these collaborative agreements.

The Eliminated Forms of Collaboration

Active network sharing, a joint venture and a merger for the creation of C-ITS ready 5G networks are not feasible forms of collaboration. Multiple causes can be pointed out. First redundancy, redundancy makes that Dutch critical services are more resilient against outside threats or network errors. In the case that only one network will be created for C-ITS, this brings in risks for when network connection is lost since devices can't switch to another network. Therefore, redundancy can only be eliminated when network stability and network safety & security can be perfectly guaranteed. This is very difficult to achieve and probably won't happen in the (near) future. Risks for loss of network will always be there and have to be taken into consideration when designing networks for critical services. The second reason is competition. Competition is not only there to realise good prices for consumers, it also pushes network operators to innovation. Eliminating competition can result in high market power which may lead to unfair pricing and reduced innovation in the long run. Therefore, the aim is to always maintain competition where possible. In the current state of the market, to little is known about the final network requirements due to underdeveloped use- and business cases. It can be that MNO's can't individually create profitable business cases around these services. In that case, a trade-off will have to be made. Redundancy will have to be let go, collaboration needs to be supported, or the Dutch government has to support the creation of profitable business cases through financial incentives. To conclude, forms of cooperation where only one network will be operated, won't be an option for the future. With that, mergers and joint ventures for the purpose of creating and operating a network will be ruled out. On top of that, network sharing can only occur on the passive side of the infrastructures. If active components are shared, this will result in one network. Therefore, active network sharing purposes are also not considered as a feasible collaborative approach for the future.

6.1.4 Implications for Overall Understanding of Collaboration

Most of the factors that were identified in the literature review were confirmed in the interviews. However, some findings of the literature review were too general for application to this particular case of potential collaboration. Thus, a strong contribution of this research is to make the identified factors from literature more case-specific and concrete. The definition of shared vision between parties entering a collaboration is heavily influenced by the ownership structures of the companies. Shareholders or owners also need to have the same vision as the MNO's in this case to make collaboration successful. This is a contribution to the overall understanding of collaboration. On top of that comes that shared visions within companies can also be a troubling factor. Visions need align across the entire vertical chain from owners to the board of MNO's to the employees carrying out the agreed on policy.

Another contribution to the overall understanding of collaboration is that market configuration and institutional context play a big role in the potential outcomes. There is no one-size-fits-all solution, desired market outputs and institutional context vary per sector considering the design of the industry. Desired market outputs and institutional context influence regulatory factors and therefore are important determinants of potential forms of collaboration.

6.2 Resulting Model of the Research

The starting point of constructing the resulting model of the research will be the conceptual model from section 4.4.2. The conceptual will be compared to the findings from the interviews. From there the resulting model of the research will be constructed.

Most of the factors that were identified in the literature review were confirmed in the interviews. However, interviews have shed new light on some factors, which have been specified more in the interviews. This has been incorporated in the resulting model of the research which is presented in figure 6.1. Shared vision is subdivided in two factors; shared vision across mobile network domain and shared vision across. Availability of technology has been changed to technological challenges. According to the interviewees, most of the technology is available in the market and challenges lay in the cost of technology and controlling the technology. Interdependencies have been specified more with the identification of regulatory and economic interdependencies. Benefits for MNO's is changed to lookout for potential unattainable profits. MNO's were clear that they will only engage in a collaboration when there are new profits looming that are unattainable individually. Also the relationships between governance and coordination and shared vision have been mapped. The presence of an independent body that will coordinate and govern a potential collaboration can contribute to the creation of shared vision. An independent 'referee' is needed. Lastly, joint venture and mergers have been crossed out in the potential forms of collaboration. Considering the need for competition and redundancy, these forms of collaboration won't be possible from an institutional point of view.

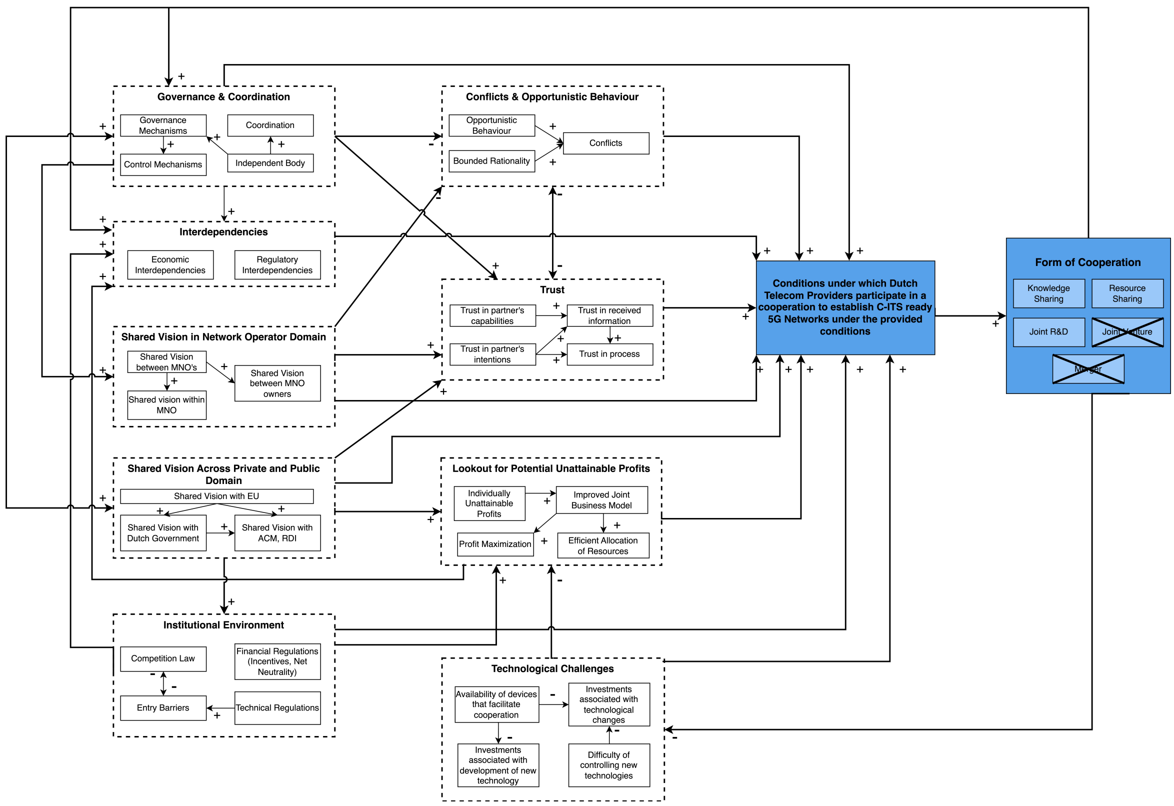


Figure 6.1: Resulting Model of the Research

6.3 Variances in Interview Outcomes

From the results of the interviews, some variances can be identified. In this section the researcher will reflect on these variances. A first reason for this follows from the set of interview questions presented in Appendix B, is a broad set of questions. Per interviewee, a selection was made out of this set of questions since asking all questions would not fit within the time frame of the interview. On top of that, inconsistencies in results can be the consequence of conducting semi-structured interviews (Barriball & While, 1994). Although a set of interview questions was prepared for the interviews, posing spontaneous questions can trigger differences of results. Also, the interviewees were heterogeneous stakeholders who all operated in a different function and thus have different responses to the imposed questions. This can come from subjectivity or differences in interpretation, but also differences in knowledge, expertise and motivations of the interviewees.

When considering tables 5.2, 5.3, 5.4 and 5.5, a few variances can be identified. Across all researched topics, RB.2's shares little overlap with the responses of the other interviewees. This comes from the fact that RB.2, works for a regulatory body that is concerned with maintaining competitions in all sort of markets. Although, RB.2 is also concerned with the telecom market, he merely focuses on the outputs that the market produces. Therefore his knowledge about, amongst others, business models or technology in this market is limited. On top of that comes that RB.2 answered most questions from a regulating body point of view with regard to market conditions. This delivers other results. RB.2 also multiple times stated that he was not the right person for the question and that he had no knowledge about that particular topic. The latter also happened in the interview with E.1. E.1 made it very clear that he had no technological knowledge regarding network operation and that he did not know which technologies exist or are being developed in this market. This is indicated by the low amount of responses of E.1 in table 5.5. Lastly, some statements from RB.1. RB.1 is a regulating body that is mainly concerned with monitoring and enforcing technical quality requirements from a public domain point of view. This explains some economic themed statements of RB.1 that don't match with the statements of other interviewees. According to some other interviewees, knowledge within the RDI is limited to the technical knowledge which makes that they do not have an accurate vision on some market developments.

7 Conclusion

Dutch mobile network operators are still facing problems in making 5G current networks profitable. With the arrival of C-ITS, an even more challenging time is arriving for MNO's. Collaboration between MNO's could potentially mitigate economic, technological, environmental and societal challenges in the future. Therefore, this research aimed to answer the following research question:

Under which conditions and in what forms can Dutch mobile network operators collaborate to establish C-ITS-ready 5G networks in the Netherlands?

The literature review and the interviews provided gradually provided an answer to this research question. It became clear that trust, technological challenges, the institutional environment, governance & coordination mechanisms, interdependencies, risk of opportunistic behaviour and conflicts, a lookout for potential unattainable profits, a shared vision across the entire network operator domain and a shared vision across private and public domain, all influence the willingness for collaboration. On top of that it became evident that potential forms of collaboration are limited. The public domain insists on maintaining competition and redundancy. A loss in competition can lead to low innovation in the long run and eliminating redundancy makes the Netherlands as a whole vulnerable to outside threats and network errors. Therefore, three potential forms of collaboration were identified; knowledge sharing, joint R&D and passive network sharing.

To make any of the indicated forms of collaborative efforts successful, a number of conditions need to be met. Further development of use cases is needed to to establish if C-ITS will ever become a use case. Than, business cases need to be developed. If needed, the Dutch government needs to create financial incentives to facilitate the creation of (joint) business cases. From these business cases, it can be determined if collaboration is desired, and, if so, in what generic form. A stable sense of needing each other to realise unattainable profits needs to emerge to facilitate collaboration. Economic developments or changes in regulations can create these interdependencies. Interdependencies can facilitate the creation of a shared vision across the entire network operator domain. Both public and private domain need to be onboard to get the institutional environment right for collaboration. This could also deliver opportunities in terms of a governing and coordinating 'referee'. The cooperative agreement needs to be designed based on the shared vision. This agreement should specify goals, responsibilities and obligations across the members of the collaboration. On top of that, governance mechanisms need to be designed to protect the collaboration against opportunistic behaviour and conflicts. This will limit chances of collapsing efforts. An independent referee such as the RDI can play a crucial role in coordinating the negotiations and governing the collaborative in the process of cooperation.

From the interviews a potential form of collaboration was identified that was widely carried across all interviewees. The interviewees collectively proposed a split in the active and passive network infrastructure markets. Government ownership or the establishment of a new market, could relieve MNO's from high CapEx. A similar model to the MVNO structure can than be applied, where MNO's lease capacity of passive network infrastructure. Further research should point out how this can be further specified and if is a potential collaborative solution for the future.

While this research has delved into the specific conditions and forms under which Dutch mobile network operators (MNOs) could collaborate to establish C-ITS-ready 5G networks, it is very important to step back and consider feasibility and implications of potential collaboration in this context in a broader perspective.

Collaboration among MNO's offers great potential in addressing challenges that emerge by technologies like C-ITS and the continuing search for profitable 5G business models. By pooling resources, expertise, and infrastructure components, MNO's can unlock synergy gains that benefit not only their individual business models but also contribute to the broader societal and economic challenges. However, the path to collaboration is not without obstacles. Creating a collaborative mindset among MNOs requires a fundamental shift in vision, forfeiting the current competitive vision that is deeply embedded within the organisations of MNO's. It necessitates viewing competitors as potential partners, recognizing that collective efforts can outweigh the individual goals. This change of vision needs to happen across all three MNO's in order to make collaboration feasible which makes matters even more challenging. On top of that comes that the institutional environment that is currently focused on stimulating and maintaining competition, needs to change to facilitate collaboration. This means that also here, a fundamental shift is needed in the vision behind regulation on both an European and national level. Once these changes in vision and institutions are realised, establishing trust and aligning interests among diverse stakeholders both within the private sector and in collaboration with governmental bodies will be difficult, but is also crucial for sustainable collaboration. The creation of governance mechanism that curb potential conflicts will also take time to establish and need to be approved by all members of the collaboration. Getting these MNO's on the same page is here once again crucial to make collaborative efforts feasible.

In conclusion, while the road ahead may be full of challenges, the potential benefits of collaboration among Dutch MNOs in the realm of C-ITS-ready 5G networks can become too significant to ignore. By embracing collaboration as a strategic option, MNOs can not only deal with the challenges of 5G infrastructures more effectively but also unlock new opportunities for innovation, growth, and societal impact. However, considering the current state of the mobile network operator domain, where competitiveness very high which results in distrust, and the associated institutional environment that aims to maintain this competition, collaboration will be very difficult to realise in the near future. A deeper urge for collaboration needs to emerge to push both the private and public domains towards realising collaboration, resulting in a fundamental shift in perspective(s) that is needed to adress the challenges that lie ahead.

8 Discussion

This chapter marks the final chapter of this thesis; the discussion. In the discussion, first the limitations of the research will be identified. Than, recommendations for future research will be provided.

8.1 Limitations of the Research

Limitations of the research are centralized around two themes; the selection of the interviewees and the timing of the research. Both will be discussed in this section.

8.1.1 Selection of Interviewees

Time constraints were one of the limiting factors in this research. Therefore, a selection of interviewees needed to be made. This selection was carefully made to pursue completeness in the yield of results. This was achieved as saturation in results was reached which is indicated in section 5.2. Therefore, additional interviews would mainly contribute to the richness and depth of the already identified data. However, new interviews with other stakeholders can always result in new insights considering the varying knowledge and expertise of stakeholders. It is not expected that these findings would be at odds with the obtained results of this research.

Ministry of Economic Affairs and Climate Policy

The Ministry of Economic Affairs and Climate Policy is the main regulating body that determines the institutional and market context for the mobile network (operating) domain. Its policy trickles down to the ACM and RDI, who act as regulation enforcing bodies. Interviews with people from the ministry could deliver insights in their long term vision. This long term vision could be lacking in the RDI and ACM. The question remains whether the ministry will want to share their long-term plans with a researcher. Interviews with the ministry could also deliver insights in how they look at at a potential collaboration and if they would make changes to the institutions or incentives for collaboration.

European Union

The same argument goes for the European Union as for the ministry. The European Union also determines the institutional and market environment for the mobile network network (operating) domain. Interviews with people form the European Union could deliver insights in long term plans with the sector. On top of that, the visions and considerations of the EU could be mapped which may lead to new results.

Owners of MNO's

The creation of a shared visions in the network operator domain is crucial to make collaborative efforts succeed and create value. An important determinant is the creation of shared vision between the MNO's. However, the interviews indicated that the vision of owners of MNO's also play a big roll in realising this shared vision between MNO's. MNO owners have varying objectives and goals and thus can have differing visions on a potential collaboration. The varying ownership structures makes mapping the visions of owners very difficult.

Interviewees from various departments within MNO's

Multiple interviewees stated that the vision within MNO's may vary on a department level. Conducting interviews with the various divisions within MNO's could sketch a view on how these variations in vision are prevailing. However, multiple interviewees already indicated that this is mismatch in vision the case so this is already identified in the research. Interviewing people from various departments would therefore merely confirm or contradict these discrepancies in vision.

Hardware & Software Vendors

Interviews with hardware and software vendors could deliver new insights on the technology side of the matter. However, it became apparent that technology is not the main troubling factor for collaboration. On top of that, most interviewees, with technological knowledge, indicated that a lot of technology exists that enables joint business models and the creation of C-ITS ready 5G networks. It is mainly a matter of mastering the technology, followed from the interviews.

8.1.2 Timing of the Research

From the interviews became clear that currently to little is known about how C-ITS will develop and if it ever will become a use case in the future. This makes that market demand for C-ITS ready 5G networks is currently low. Final network configurations are thus far from designed which complicates the creation of business cases. With that, MNO's often insisted on the potential profits that can be realised by providing 5G networks for C-ITS. MNO's are still in the 'what' question and not in the 'how'. Therefore, it could be that the same research, carried out years later, would deliver new results. This does not imply that the findings of this research are not accurate. The contrary is the case. The results provide a clear picture on what factors are currently influencing potential collaboration and what forms of collaboration are currently achievable, given the current market, technological, economic and institutional context.

8.2 Recommendations for Future Research

This section aims to provide future researchers with recommendations for further research. Based on the obtained results from this study, potential research topics were identified. These topics will be presented.

8.2.1 Identified Forms of Collaboration

This research identified three potential forms of collaborations and has indicated some opportunities for collaboration in section 5.5. It is too early to state that these provided opportunities are widely carried and are ready to make concrete. Further research into these generic forms of collaboration should identify how such a form of collaboration would be potentially successful, and under which terms this collaboration can occur. The provided opportunities in section 5.5, can act as a starting point for these researchers, but an also more general approach is advisable. The following three potential forms of collaboration are identified in this research:

- Knowledge Sharing
- Joint R&D
- Passive Network Sharing

In the current institutional and market context, these three potential forms of collaboration require further research. For each form, the willingness to participate need to be mapped across the entire network operator and public domain. From there, the responsibilities, obligations and goals associated with each form need to be mapped. Based on this, governance mechanisms need to be designed that align with the visions of all stakeholders. These governance mechanisms need to capture the specified responsibilities, obligations and goals to safeguard the collaborative effort against potential opportunistic behaviour. Also, the institutions of the public domain need to be mapped regarding more specified versions of these forms of collaboration. From there, (desired) changes in regulation can be presented to the public domain.

8.2.2 C-ITS Development

Multiple interviewees referred to the proverb of the ’chicken and the egg’ problem. What comes first? A network? or the service that will utilize the network? MNO’s clearly stated that they won’t will build a network without the lookout on profitable business cases. With that, a possible deadlock in innovation has been identified here. Further research in C-ITS development on the service side, could indicate if this deadlock is really present. Interviews with C-ITS developers could deliver insights in if the absence of a network is limiting them from further development. From there, future research can than focus on how to break this deadlock. On top of that, can interviews with C-ITS providers map what is needed from networks to work towards final network designs. This can clarify issues in the current underdeveloped business models.

8.2.3 Collaboration with other Connectivity Providers

In excess of mobile communication networks, new connectivity networks are developing rapidly. MNO’s look with anxiety to these developments and fear that they may become excessive in the future. However, these new communication technologies may also provide opportunities. Telecom providers in general have large customer bases. On top of that comes that MNO’s with their experience and track record know a great deal about demands from the market and how to serve these needs. These are valuable assets that these new connectivity providers don’t have to that extend. With that they have a lot to offer in a potential collaboration.

From the interviews followed that it is difficult to make some coverage areas profitable for MNO’s. Further research can address how and if these gaps in the business models can be filled through collaborating with other connectivity providers. One of the new technologies are so-called Low Earth Orbit (LEO) satellites. Through these satellites, connectivity can be provided from space. It can be researched whether these LEO satellites can support MNO business models by providing connectivity in rural areas. This is already happening in France and Germany according to one of the interviewees. Another option is the Lorawan network. Lorawan operates in an unlicensed and thus 'free' spectrum. This brings benefits in terms of lower CapEx than the mobile networks. It can be researched if Lorawan can be a solution for providing a network infrastructure for services such as C-ITS or if a combination of the two can be a possibility.

8.2.4 Freeing up High Spectrum Bands

One of the interviewees suggested that freeing up high spectral bands may boost innovation. However, this interviewee also discussed the difficult trade-off that this proposal brings. As the auctioning of spectrum bands brings a lot of money into the Dutch treasury, the Dutch government may be reluctant to this proposal. Freeing up spectral bands results in lower CapEx for MNO's. This frees up financial resources which can be spend elsewhere such as on innovative services. Further research could identify if the Dutch government is willing to free up these spectral bands for MNO's and under which terms this may occur. It is a possibility that if the money that is saved up by MNO's, by freeing up spectral bands, is spent on innovative services that are in the interest of the Dutch government, the Dutch government would be willing to do it. However, this is to future researches to study.

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A

Appendix A: Evolution of Mobile Wireless Communication

In the early 80's of the past century, the first generation of mobile wireless communication was established. This first generation of mobile wireless communication, 1G, focused on realizing voice communications in an analog form without the transmission of any data (Sharma, 2013). Since 1G, mobile wireless communication has taken a huge flight as illustrated in figure A.1 As stated by Kabalci (2019) and Thompson et al. (2014), this evolution of mobile wireless communication has been fueled by the desire to eliminate shortcomings of previous generations, create more robust systems and expanding demand for data services over the internet.

It took until the early 90's to implement the next generation of mobile wireless communication, 2G. 2G was the first iteration of wireless communication services that allowed for actual transmission of data through a digital system in the 850-1900 MHz spectrum (Hossain, 2013). Global Systems for Mobile Communications (GSM) was the first standard of the second generation through which digital data was transmitted. Radio signals from the 2G network consumed a low amount of power which made that device batteries could last longer. Through the initial 2G networks, users could only make phone calls or send messages to other users. Later in the 2G era, the so-called 2.5G and 2.75 era begun. Here general packet radio services (GPRS) technology updated the existing 2G GSM network. This allowed data to be packaged which was needed because of the rise in demand for data transfer in mobile services. Users were now able to enjoy a small data rate of up to 144 kbps to access the internet and send emails (Gupta & Jha, 2015). The main improvements realized by the 2G network are higher spectral efficiency, better data services and more advanced roaming possibilities (Sharma, 2013).

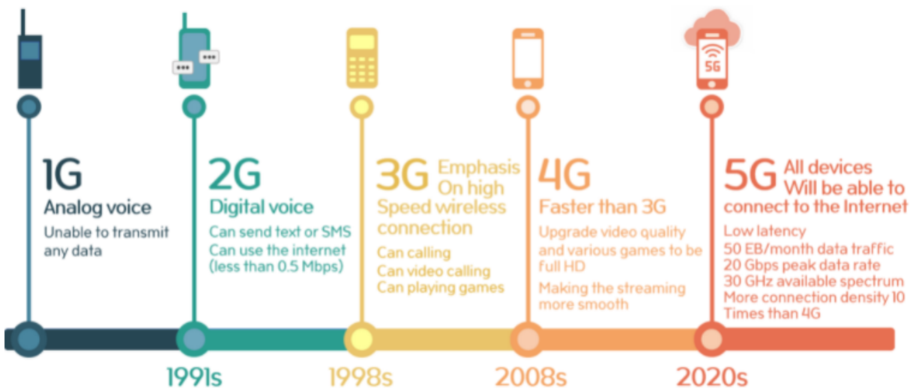

Figure A.1: Evolution of Mobile Wireless Communication

Between 1998 and 2000, the third generation of mobile wireless communication, 3G, arrived which operated in the 1.8 - 2.5 GHz spectrum (Hossain, 2013). The 3rd Generation Partnership Project (3GPP), a worldwide partnership with Europe, China, Japan, the US and South Korea, developed the Universal Mobile Telecommunications Systems (UMTS) standard as the successor of GPRS. In the 2G era, network standards varied over the different parts of the world. That is why the decision was made to develop a network with equal design standards regardless of the technology platform it runs on. This marked the beginning of the 3G era which was outstanding for it's degree of standardization through a family of standards that are inter operable (Sharma, 2013). Through standards such as UMTS, Wideband Code Division Multiple Access (WCDMA) and Code Division Multiple Access (CDMA) 2000, faster exchange of data up to 2 Mbps was realized over the Internet Protocol (IP) together with higher quality of service levels (Gupta & Jha, 2015; Hossain, 2013; Kabalci, 2019). For the first time, global roaming and video streaming were possible and 3G also significantly improved voice quality. One of the setbacks of 3G was the amount of power that was needed from devices (Gupta & Jha, 2015). For network operators, 3G network plans were much more expensive than the conventional 2G network plans. However, network operators achieved higher network capacity through significant improvements in spectral efficiency. This also allowed network operators to offer novel more advanced services to their users (Sharma, 2013). Later in the 3G era, new technologies such as High Speed Uplink/Downlink Packet Access (HSUPA/HSDPA) and Evolution-Data Optimized (EVDO) significantly improved data rates towards 5-30 Mbps (Gupta & Jha, 2015). This is referred to as the 3.5G era. The 3GPP also developed a new set of standards in the form of Long Term Evolution (LTE). This paved the way for the upcoming 4G network.

In 2005, the first successful trials of 4G were a fact and the 4G era began. It was until approximately 2008 till the International Telecommunication Union (ITU) set the requirements that 4G systems must achieve a data exchange rate of at least 100 Mbps (Kabalci, 2019). There were two technologies through which these high data exchange speeds were realized. Firstly, LTE Advanced as developed by the 3GPP, and secondly Worldwide Interoperability for Microwave Access (WiMAX) developed by the Institute of Electrical and Electronics Engineers (IEEE) (Kabalci, 2019). Through a new version of IP, IPv6, changing IP addresses were assigned to devices based on the selected network which proved a complete and reliable solution in terms of secure data exchange (Gupta & Jha, 2015). Through the 4G network, users could now benefit Multimedia Messaging Services (MMS), Digital Video Broadcasting (DVB) and mobile TV (Gupta & Jha, 2015).

B
Appendix B: Interview Questions

Introduction

1. Can you tell me about your role within X? What are your daily responsibilities, and can you highlight any telecom-related research you've been involved in?

Future of the Telecom Market

2. Considering the steadily increasing demand for more connectivity, speed, and reliability, how do you see the future of the telecom sector in terms of new services? Can the current telecom structure meet the demands of new industries/service areas? What role does net neutrality play, and can profitable business models be established despite high investments?
3. Collaboration between telecom providers can improve network capacity, availability, and quality, thereby accelerating the implementation of new services through shared investments. What is your vision on this?

Cooperation

4. Given the composition of the telecom market, what forms of collaboration do you think offer the best opportunities to bring telecom providers together in a secure way for consumers that align with the ACM's vision?
5. Why are certain collaboration forms excluded? What are the reasons for that decision? How do you view more intensive network sharing or joint ventures, such as creating a network for C-ITS?
6. To what extent could collaboration lead to excessive market concentration? What potential solutions could the ACM offer to address this concern?

Benefits for MNO's

7. Do you see advantages that telecom companies can gain from collaboration, especially in terms of strategy and innovation that can only be achieved through collaboration? Do these advantages extend to consumers?
8. Do you believe that the benefits of collaboration can outweigh the drawbacks for telecom companies? If so, what contributes to this, and in which collaboration forms do you see opportunities?

Crucial Factors

9. What do you identify as the main causes of potential problems related to collaboration?
10. Do you have ideas on how these negative factors can be minimized in this case?
11. To what extent does existing law and regulations limit collaboration possibilities? Is this currently the most restricting factor?
12. How much does the ownership's vision influence telecom owners in entering collaborations? Do mobile network operators have full autonomy, or are strategic decisions made at a higher level?

Shared Vision

13. From your position, do you observe telecom providers sharing a similar future vision and encountering similar challenges? Could this similarity create opportunities for collaboration?
14. To what extent do you believe a shared vision from both the public and private sectors can facilitate collaboration?
15. How feasible is it to establish a shared vision/strategy in collaboration? What elements do you think are necessary for this?

Trust, Conflicts and Governance

16. Do you believe there is enough trust between telecom providers to facilitate collaboration? Is knowledge-sharing or joint R&D currently possible? Is there a significant risk of opportunistic behavior, and can RDI play a role?
17. Does the ACM have confidence in the successful collaboration between telecom providers? Do you trust that telecom providers won't abuse their power?
18. How could governance arrangements be structured to enable collaboration? Is assistance from public entities necessary, and are the appropriate tools currently available?
19. To what extent does a lack of dependencies pose problems for potential collaboration? What causes these problems, and how can they be managed?

Technology

20. From a technical standpoint, do you think a shared network is possible for specific services with high cell density?
21. In the case of network sharing, is it possible to establish a joint business model between telecom providers? What is required for this, and are there technologies available that facilitate a joint business model?
22. Do you see any other points from a technical perspective where collaboration could offer opportunities?

Regulation

23. Considering the already concentrated telecom market with a limited number of mobile network operators, do you think collaboration can be facilitated from the public domain? Why or why not?
24. What regulatory measures are needed from the public domain to enable collaboration? Are there currently enough guidelines in place?

Round-up

25. Are there any questions you feel were missed in this interview? Any factors left unexplored?
26. Do you have any other insights or findings that should be considered in this research?

C

Appendix C: Interview Results - E.1

Considerations	Findings
Economic	• Still a lack of use cases which limits the development of business cases • Without business cases, investments can't be earned back • Knowledge sharing or Joint R&D can facilitate the development of use cases • Sharing investments can deliver faster go-to-market which, in turn, can allow for the creation of revenues • MNO's will always consider their own competitive (dis)advantage • Net neutrality limits business opportunities for MNO's
Institutional	• Competition in the market is already low • More market consolidation can be undesirable since competition will be lowered. • ACM will have its own considerations regarding market performance, competition, and consumer protection. This will limit opportunities for cooperation severely. • Regulation from the Ministry can steer MNO's towards cooperation by creating interdependencies • European competition co-determines possibilities for cooperation
Organizational	• Shared Vision between MNO's is very important • Shared Vision within MNO's is differing • Gaining a shared vision between owners of MNO's is even more difficult considering their ownership models • Discrepancies within MNO's about willingness to share knowledge • Interdependencies need to be present to create willingness for cooperation; without them, MNO's will feel like they can do it on their own • When interdependencies start to shift, cooperative efforts can collapse • An independent body is needed to maintain and enforce a cooperation (RDI or consultancy) • MNO's are not used to cooperating with each other. This limits trust. • Governance mechanisms can be developed and maintained by public parties to allow for cooperation
Technical	• More intensive sharing of network components can lower investments • Redundancy is also desirable in case of loss of coverage because of, for example, cyber attacks • Therefore, one network operated jointly by the MNO's can be undesirable • Cooperation can result in lower innovation. • Over the past, MNO's have shown not to be the best in service development

Table C.1: Categorized Interview Statements of E.1

D

Appendix D: Interview Results - E.2

Considerations	Findings
Economic	• Telecom market in its current form can't develop profitable business cases for all three MNO's • Little known about how use cases can be turned into profitable business cases. This is an issue that concerns all three MNO's. • Without business cases, investments can't be earned back • In case of network sharing, distribution of profits and costs is problematic • More sharing of network components can divide investment burden and allow for better ROI • MNO's need to be able to charge more for data usage for services like C-ITS • Dutch government needs to create financial incentives that push the development of networks
Institutional	• European vision is needed to create legislation that pushes cooperation • EU needs to allow MNO's to charge more for C-ITS services to facilitate the creation of business models • ACM needs to be flexible to allow for cooperation, but probably won't accept cooperation in this consolidated market • This needs to be enabled by European and National regulation
Organizational	• Gaining a shared vision between MNO's is very difficult • Opportunistic behavior has been observed in similar efforts of cooperation • Vision within MNO's is inconsistent, technical division more likely to be open to cooperation • Shared vision of MNO owners makes cooperation difficult • Shared vision between private and public domain is important • Great sense of distrust and competitiveness among MNO's • MNO's don't trust each other's capabilities, therefore similar quality is not guaranteed • All three MNO's must join the cooperation, but can't be forced through legislation • Lack of knowledge about business cases creates that there are no interdependencies currently • Very difficult to design governance arrangements that facilitate trust and limit opportunistic behavior. Never worked in experiences of experts
Technical	• Three redundant infrastructures undesirable in terms of societal resistance. Not environmentally friendly and resistance against growing number of cells in the social space • Redundancy is desired in case of loss of coverage • RDI and Ministries lack the knowledge and competences to build and operate such networks. Therefore, MNO's are needed. RDI maintains as an oversight body to enforce technicalities • Cooperation can result in lower innovation in the future due to less competition in the market. • Technology exists to combine slices of different networks and build business cases around this method • Prioritization of data streams can be achieved on networks.

Table D.1: Categorized Interview Statements of E.2

E

Appendix E: Interview Results - RB.1

Considerations	Findings
Economic	• MNO's can easily carry investments and build profitable business cases • High-quality standards from RDI already make it difficult to generate profits in some areas currently • Cooperation can deliver better ROI and is crucial for the existence of Dutch MNO's in the future. • Joint business model needs to be better than individual business models, creating interdependencies for revenues • Without a business case, no MNO will be willing to build a network • Government needs to create financial incentives for the sake of innovation to support the creation of business cases • Sharing investments can speed up innovation
Institutional	• Main limiting factor is the reluctance of ACM regarding cooperation between telecom providers • National regulation can provide municipalities with tools to force cite sharing to reduce societal resistance • Regulation must not limit innovation, but can't force innovation either. Regulation only can steer the 'how'
Organizational	• Creating a shared vision between MNO's is very difficult • Owners behind MNO's have differing interests regarding strategy and profit generation • Gaining a completely shared vision is impossible, some elements can be aligned but objectives and motivations will always be different • Trust between MNO's is mainly on the technology side, more problematic in strategy departments • Interdependencies must emerge to push cooperation. Can emerge due to shifts in technology, potential revenues, and regulation. Now there are no interdependencies. • Can play a role as coordinating body in case of cooperation. RDI has experiences in talking with all three MNO's and has a good track record acting as an independent body between the MNO's • Independent public body can enforce cooperative agreement to create trust. RDI can play a role in this because of their current unbiased position towards MNO's
Technical	• Dutch 5G networks already lacking compared to other countries • Network sharing or a joint network can be undesired due to a loss of redundancy. Makes Dutch network infrastructure less resilient • Cooperation can boost network quality and applications on the short term, but may be undesirable in the future • From a technology point of view, there are many possibilities for cooperation. A lot of technology is already available in the market. • Hardware & software vendors have the tools and equipment to allow for knowledge sharing purposes that facilitate a joint business model

Table E.1: Categorized Interview Statements of RB.1

Appendix F: Interview Results - RB.2

Considerations	Findings
Economic	• There are no profitable use and business cases now and thus no ROI • Use cases will develop over time when networks are in place. • Freeing up high spectral bands lowers costs for MNO's but reduces income for the Dutch government due to the loss of auction revenues. • Competitiveness in markets is a must for the ACM, exceptions can be made if public urge is present, but development needs to be ensured. • MNO's will always look after their own interests and pursue what is best for them
Institutional	• Crucial factor that limits cooperation are the rules and legislations that need to protect consumers. Cooperation may bring too much market power to the MNO's which may result in unfair pricing and reduced quality. • Institution must not block innovation. • Maintaining competition forces innovation of MNO's. • Trade-off between consumer benefits and competitive markets. • Cooperation is an option when the market stays competitive.
Organizational	• Initiative does not lie with the ACM; ACM is an oversight body that acts reactive on efforts coming out of competitive markets. • ACM and governmental bodies must research what needs to remain as a market, and what parts can be loosened from strict regulation. • A shared vision between private and public domain needs to be created • Interdependencies between government and MNO's can facilitate cooperation. • Current lack of interdependencies come from the fact that business cases are low • Emerging interdependencies can fuel changes in regulation strategy, allowing for cooperation efforts.
Technical	• Mobile networks will be the main networks that will provide massive connectivity to services like C-ITS. • Can the desired reliability ever be achieved with mobile networks? • Public bodies and the ministries lack the technical knowledge to build and maintain networks for such purposes. • Free allocation of high spectrum. Force cooperation and coordination within this spectrum.

Table F.1: Categorized Interview Statements of RB.2

G Appendix G: Interview Results - MNO.1

Considerations	Findings
Economic	• Turning these massive investments into profitable business cases is the main challenge. Without business cases, no MNO is willing to invest in these networks. • Priorities of MNO's lie in other fields of service where profitable business cases are already achievable • How to divide costs and profits? Can be problematic. • Why build a network when no money can be earned? There are no incentives and no business cases • Tendency of lower forced tariffs which makes profitability of existing networks already challenging, but there are small opportunities to charge additional costs for different purposes. • Chicken and egg problem: first a network? Or first use cases that are profitable?
Institutional	• Regulation can steer towards cooperation when there are benefits for the MNO's. • Regulation can't force MNO's to build a network that is not profitable. • ACM will not be fond of cooperation between MNO's. An even more consolidated market with fewer competitions can be bad for consumers in the long run • Cooperation will only be allowed if it delivers sufficient benefits for Dutch society, in the short and long run. • European vision and strategy need to be rolled out to push towards cooperation
Organizational	• Experiences with free riding and opportunistic behavior in cooperation between telecom providers. Also, no trust in each other's capabilities and intentions • Difficult to obtain a shared vision between all three MNO's. Getting all three on board is crucial, since cooperation of two MNO's pushes out the third. • Within MNO probably differing visions on if cooperation is desired • Cooperation is quite vulnerable to bickering and political games • MNO's are private companies, getting shareholder on board is difficult • A shared vision must be created between the private and public domain • Currently no interdependencies among MNO's, can build these types of networks when business cases arrive • Coordination by RDI can help in coordination when networks are constructed • Dutch regulating body must uphold potential cooperative agreements when needed
Technical	• Dutch 5G networks are among the most advanced in the world • Data transmission and coverage can be prioritized on networks • User planes need to be brought to the RAN. This is very expensive to realize and to make profitable • Most of the technology exists to build networks with massive connectivity, but the technology is yet to be controlled • Discrepancies in technical knowledge between the private and public domain. Public bodies don't know how networks and business work. • Technology exists that allow for creating business models in network sharing. • Technology is there to combine various slices

Table G.1: Categorized Interview Statements of MNO.1

Appendix H: Interview Results - MNO.2

Considerations	Findings
Economic	• Without developed use cases, business cases can't be developed which makes making big investments very difficult • Crucial factor that limits cooperation is the fact that ROI is very poor at this moment • MNO's need to reinvent themselves to develop new revenue streams to make investments feasible. • Who is going to pay for the networks, without the possibility to earn investments back? • Chicken and Egg problem: what comes first, the network or the use case? • There are considerations from a societal and environmental point of view, but economic considerations remain the most dominant. • Not the ambition to have the world's most advanced network • Priorities of MNO's lie in other fields of service where profitable business cases are already achievable, money can be spent only once. • MNO's have missed a lot of business propositions over the last years, need to invest in building applications on top of their network
Institutional	• MNO's operate and develop in accordance with legislation, but legislation can't force them to build and pay for a network. • Ownership structures of MNO's make creating a new joint business unit very difficult • Regulation must not obstruct innovation. If cooperation is truly necessary and needed, regulatory bodies such as the ACM and RDI need to loosen up regulation.
Organizational	• Knowledge sharing like data sharing is very promising since MNO's can cooperate with each other and other service areas to further develop use cases. From the what to the how. • Shared vision between MNO's is very difficult • The vision of the owners behind MNO's also limits the creation of a shared vision. • If the public domain wants cooperation, a shared vision between private and public is needed • Aligning vision within an MNO is already very difficult. Technicians willing to share information, but strategists not • Sense of distrust in each other capabilities and intentions. • No interdependencies present among MNO's. If they want to, they can build and operate a network for C-ITS buy themselves.
Technical	• Technology is there or can be developed to build a network. • Sharing technology that allows for joint business models exists • MNO's need to learn to build 'over the top' applications

Table H.1: Categorized Interview Statements of MNO.2