6G for Connected Sky
“6G-SKY”

Work Package 1: Holistic Adaptive Combined Airspace and NTN Architecture for 6G

Task 1.2: Business Modelling

Deliverable 1.6: **Business modelling**

6G-SKY Project
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for full publication

Abstract

This deliverable identifies value chains/networks for combined airspace and NTN integrated with TN, further provides Business model canvas analysis for certain value chains and actors, and highlights business simulations of certain use cases.

6G Sky context:

6G-SKY, Work Package 1: Holistic Adaptive Combined Airspace and NTN networks Architecture for 6G

Task 1.2: Business Modelling

D1.6 Business modelling

Editor: Anders Nordlöw, Ericsson
Reviewer: Cicek Cavdar, KTH
Contributors: see list of participants

Project coordinator: Dominic Schupke, Airbus

Technical Project Coordinator: Cicek Cavdar, KTH

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Ericsson AB	Airbus
Deutsche Telekom	SAS
KTH	Fraunhofer IIS
Lakeside labs	

List of Authors

Name	Affiliation
Anders Nordlöw	Ericsson
Christian Raffelsberger	Lakeside Labs
Aunas Manzoor	KTH
Mustafa Ozger	KTH
Cicek Cavdar	KTH
Veli-matti Riepula	DT
Holiš Jaroslav	DT
Dominic Schupke	Airbus

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Executive Summary

The 6G-SKY project has the overall purpose to evolve business modelling, architecture and technical solutions for combined airspace and non-terrestrial network (ASN) to support 6G introduction.

This document, D1.6 covers the following main parts:

- Theory introduction to value chains, value networks, business model canvas and revenue models
- Introduction to major initiatives influencing combined Airspace & NTN in Europe and US.
- 6G use case framework for combined Airspace and NTN
- Highlighted value chains for combined Airspace and NTN
- Business model canvas analysis
- Techno economic analysis of cellular networks for aircraft operational connectivity
- HAPS seasonal coverage and whitespot coverage
- Digital airspace and NTN impact on sustainability

The study of value chains/networks has been done to identify major actors in providing value, what value that is transferred between actors and money flows.

This analysis has been complemented with business model canvas analysis for a certain actor in a specific value chain/network.

An hierarchical approach has been used to break down the holistic combined Airspace and NTN integrated with TN into a set of use case segments with connected use cases and specific value chains. In the next steps business model analysis has been done based on these findings.

The evolution of value chains/networks is affected by many factors. One notable factor is the influence of major industry initiatives for combined Airspace and NTN in Europe and US, such as SESAR, SES and Advanced Air Mobility. Other factors are e.g. changes in customer needs and innovation in technology.

Furthermore, some specific deep dives in analysis have been made for Techno economic analysis of cellular networks for aircraft operational connectivity and for HAPS seasonal coverage and whitespot coverage.

Currently, there is a high pace of concurrent changes and potential disruption within technology, use of networks, sustainability, society and for value networks.

Business modelling studies can greatly impact choice of business targeting, offers, regulatory impacts and governmental policies and serve as input for further societal, industry and academic studies.

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Glossary

List of acronyms with alphabetical order.

AAM	Advanced Air Mobility
A2G	Air to Ground
ACARS	Aircraft Communications Addressing and Reporting System
ACAS	Airborne Collision Avoidance System
ADS-B	Automatic Dependent Surveillance-Broadcast
ANSP	Air Navigation Service Provider
ASN	Airspace and NTN
ATC	Air Traffic Control
ATM	Air Traffic Management
BSS	Broadcasting-satellite service
BVLOS	Beyond visual line-of-sight
CEPT	European Conference of Postal and Telecommunications Administrations
CIS	Common Information Service
CISP	CISP: Common Information Service Provider
CNS	Communication, Navigation and Surveillance
Combined ASN networks	Combined Airspace & NTN networks
D2C	Direct to Cell
D2D	Direct to Device
D2H	Direct to Handset
DME	Distance measuring equipment
EASA	European Union Aviation Safety Agency
ECO	European Communications Office
eVTOL	Electrical Vertical Take-Off and Landing
FAI	Fédération Aéronautique Internationale
FBW	Fly-by-wire
FCC	Federal Communications Commission
FCS	Flight Control System

FSO	Free Space Optics
FSS	Fixed-satellite service
FW	Fixed Wing
FWA	Fixed Wireless Access
GEO	Geostationary Orbit
HIBS	High Altitude IMT Base Stations (HIBS)
HAO	Higher Airspace Operations
HAPS	High Altitude Platform Station
IAM	Innovative Air Mobility
IATA	International Air Transportation Association
ICAO	International Civil Aviation Organization
ICNS	Integrated Communication, Navigation and Surveillance
IODT	IODT: Interoperability Development Testing
ITU	International Telecommunication Union
IMT	International Mobile Telecommunications
IoT	Internet of Things
KPI	KPI: Key Performance Indicator
LAPS	Low Altitude Platform System
LEO	Low Earth Orbit
LOS	Line of sight
LTA	Lighter Than Air
LTE	Long term evolution
MBB	Mobile Broadband
MEO	Medium Earth Orbit
MNO	MNO: Mobile Network Operator
MSS	Mobile-satellite service
MVNO	MVNO: Mobile Virtual Network Operator
NGSO	Non-Geostationary Orbit
NOC	Network operation centre
NRA	National regulatory authorities
NTN	Non Terrestrial Networks

OOK	On-Off Keying modulation
OSS/BSS	OSS/BSS: Operations/Business Support System
RAN	RAN: Radio Access Network
RPAS	Remotely Piloted Aircraft System
SATCOM	Satellite Communication Systems
SES	Single European Sky
SERA	Standardised European Rules of the Air
SESAR	Single European Sky ATM Research
SLA	SLA: Service-Level Agreement
Smart city	A smart city is an "innovative city that uses information communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects"
SORA	Specific operations risk analysis
STM	Space Traffic Management
TN	Terrestrial Networks
UAM	Urban air mobility
UAS	Unmanned Aircraft Systems
UAV	Unmanned Aerial Vehicle
USSP	USSP: U-Space Service Provider
UTM	Unmanned Traffic Management
WRC	World Radio Conference
3GPP	3rd Generation Partnership Project
VRIS	Valuable, Rare, Imperfectly Imitable, and Non-Substitutable

1 Introduction

1.1 Objective of the document

This document acts as the deliverable D1.6, addressing Task 1.2 topics:

- Value chains for combined Airspace and NTN
- Business Canvases for combined Airspace and NTN
- Business simulations for combined Airspace and NTN

1.2 Theory: introduction to value chains, value networks, business model canvas and revenue models

The theoretical frameworks that have been used for this report mainly consist of value networks, business model canvas, and revenue models.

While the concept of value chains has been widely used and subsequently developed, several authors [1 2, 3] note that there has been a shift from the concept of value chains to that of value networks.

The concept of value networks captures inter-organizational exchanges in an attempt to provide a better model for today's complex and dynamic business environment [1 [4efines value networks as a set of roles and interactions where people exchange both tangible and intangible goods to achieve social or economic good.

In contrast to the concept of value chains, where activities follow a linear sequence to transform inputs into products, activities within the value network are performed simultaneously, requiring continuous coordinated adjustments between different actors [5.

In today's landscape, competition is mainly waged between networks of interconnected organisations, rather than between individual firms [2 This makes the concept of value networks appropriate for analysing many modern industries, including the telecommunications industry.

The value network modelling framework proposed by [1 will be used for this deliverable. This model employs a simple terminology and allows for both descriptive and prescriptive strategic analysis.

It involves the mapping of economic entities, which can be viewed as either an actor, a set of capabilities, or assets. The economic entities of a network collaborate to deliver value to the end customer. Economic entities are linked by their offerings, which can take five different forms: product, service, brand, information, and coordination.

A product is simply defined as a transferable, for which ownership is passed on to the recipient.

A service is an offering in which the state of something that is supplied by the recipient is transformed.

A brand is a form of prior awareness among customers that indicates that the potential value generated by the economic entity is high.

A coordination offering is something that is present in the network-based perspective and involves the management of network actors and their offerings. These offerings are visually distinguished through the use of arrows in different colours.

Despite its prevalence as a business term, there have been differing understandings in academic literature of what exactly a business model is. In this study, the business model canvas of [6will be used to describe the various aspects of a company's business model, including what value it offers to customers as well as what resources, activities, and partnerships it employs in order to achieve this.

Revenue models are core components of business models, as they describe how a company generates income from its customers through pricing structures 7.

This deliverable refers to the revenue models one-time fee, recurring fee, pay-per-use, and service level agreement to describe how actors extract value from being a part of the respective value networks.

2 Major initiatives Innovating Combined Airspace and NTN in Europe and US

2.1 SESAR and SES

Since the Chicago Convention in 1944, the regulatory framework in aviation has primarily been shaped on an international basis through the UN agency International Civil Aviation Organization (ICAO) [1 has since the introduction of the single European Sky in 2004 been the regulatory authority and in Sweden, the Swedish Transport Agency is completely subordinate to the EU regulatory authority EASA [2

The air traffic service is to a large degree still dependent on traditional communication solutions, i.e., in the form of VHF radio which is the main communication mode between pilot and air traffic controller, although simpler data link solutions are also used. To modernize Air Traffic Management within Europe the Commission launched the first SESAR (Single European Sky ATM Research) project in 2004 and development work has been ongoing since then [8

The current project is SESAR 3 joint undertaking, which aims to modernize Europe's air and ground ATM infrastructure and operational procedures, thus contributing to a smarter, more sustainable, better connected and accessible air transport system. EU has the intention to create the Digital European Airspace by 2040. The background is an analysis that aerial platforms will grow in types and use. The growth of aerial platforms will require automation of the airspace, which in turn will drive digitalization of the European airspace. The vision is described in the European ATM master plan as follows:

"By 2040, increasing numbers of aerial vehicles (conventional aircraft and unmanned aircraft, such as drones) will be taking to Europe's skies, operating seamlessly and safely in all environments and classes of airspace. Trajectory based free-route operations will enable airspace users (civil and military) to better plan and execute their business and mission trajectories within an optimised airspace configuration that meets safety, security and environmental performance targets and stakeholder needs. The system infrastructure will progressively evolve with the adoption of advanced digital technologies, allowing civil and military ANSPs and the Network Manager to provide their services in a cost-efficient and effective way irrespective of national borders, supported by secure information services. Airports and other operational sites (e.g. landing sites for rotor craft and drones) will be fully integrated at the network level, which will facilitate and optimise airspace user operations in all weather conditions. ATM will progressively evolve into a data ecosystem supported by a service-oriented architecture enabling the virtual defragmentation of European skies. Innovative technologies and operational concepts will support a reduction in fuel and emissions while also mitigating noise impact, in support of the EU's policy of transforming aviation into a climate-neutral industry. Performance based operations will be fully implemented across Europe, allowing service providers to collaborate and operate as if they were one organization with both airspace and service provision optimized according to traffic patterns. Mobility as a service will take intermodality to the next level, connecting many modes of transport, for people and goods, in seamless door-to-door services".

The EU aviation strategy [9 acknowledges SES and SESAR as key drivers of sustainable growth and innovation in air transport:

- The Single European Sky (SES) is an ambitious initiative launched by the European Commission in 2004 to reform the architecture of European ATM. It proposes a legislative approach to meet future capacity and safety needs at a European rather than local level.

- Single European Sky ATM Research (SESAR) is an EU research program to drive the evolution towards a digital European sky by 2040.

SESAR proposes a holistic target architecture and suggests a four phased approach for improvements:

A. Address known critical network performance deficiencies.
B. Efficient services and infrastructure delivery.
C. Defragmentation of European skies through virtualization.
D. Digital European sky.

SESAR proposes a tightly integrated architecture, which means that the infrastructure must support all layers and functions of the target architecture:

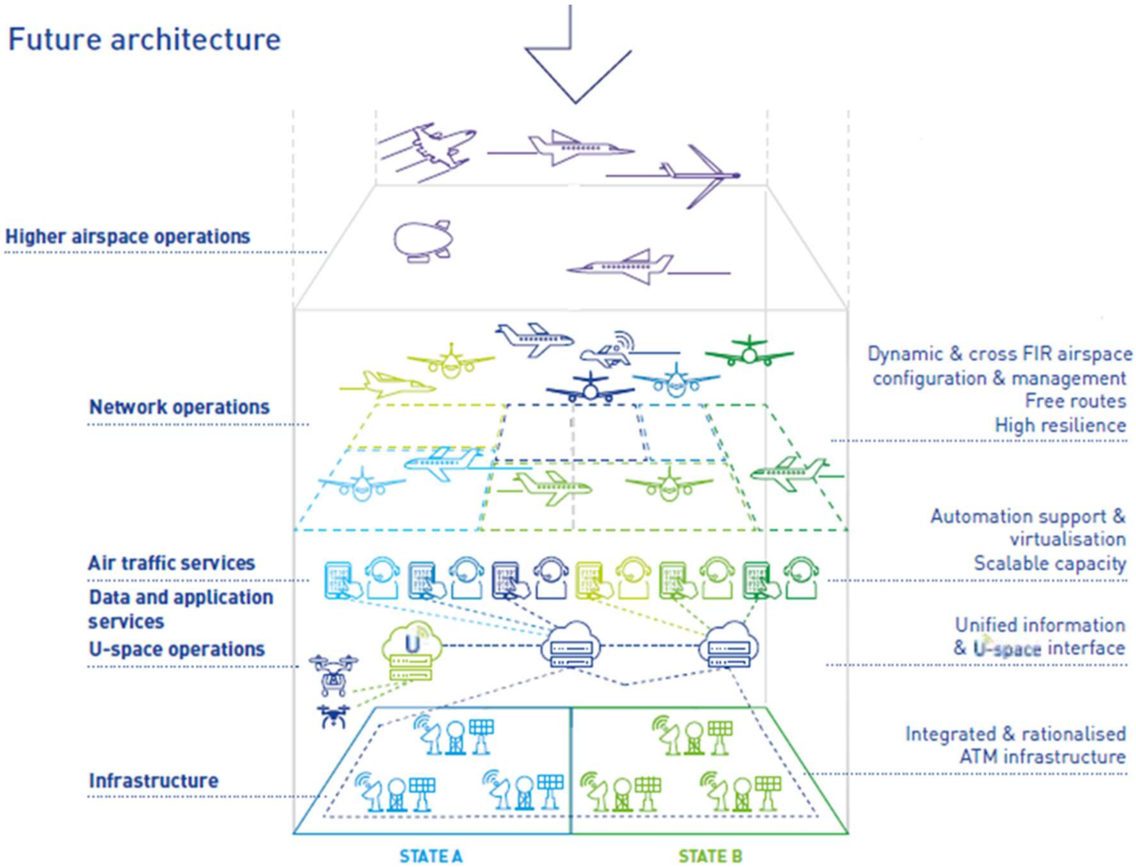

Figure [1: SESAR Target architecture.

2.2 Advanced Air Mobility

Advanced Air Mobility (AAM) is a vision driven by NASA to materialize an air transportation system to enable mobility of people and cargo mobility in areas where the current aviation cannot serve [3AAM covers local, regional, inter-regional and urban areas through new aircraft such as electric Vertical Take-Off and Landing (eVTOL) and UAVs. This vision aims to support the aviation market and provide benefits to the public. This vision is started by the Aeronautics Research Mission Directorate (ARMD) to elevate cooperation among different players such as industry and state government and other government agencies such as FAA via ARMD projects.

AAM ecosystem is being realized through working groups (WGs) consisting of different elements such as aircraft, airspace, community integration, and crosscutting. Aircraft WG focuses on aircraft design, operations management, flight automation, and manufacturing. Airspace WG deals with the design of airspace, flight procedures, UTM UAS services, and operations.

Community Integration WG consists of government bodies (federal, state, and local municipalities), community and industry-based groups and operators. Crosscutting WG includes standards and requirements for the concept of operations and national campaign [3

These WGs contribute to the Organizational Framework, which is divided into five main pillars. These pillars can be listed as follows [3:

1. Vehicle development and production - design, manufacture, and system readiness of AAM vehicles.
2. Individual vehicle management and operations - operations and maintenance of AAM vehicles, sharing of the airspace.
3. Airspace system design and implementation - design, development and implementation of infrastructure.
4. Airspace and fleet operations management - multiple vehicles in AAM sharing the airspace.
5. Community integration - societal integration and acceptance of AAM operations.

3 6G Sky Use case framework for combined airspace and NTN

6G-SKY has defined the following use case framework for digital airspace, see Figure 2 below:

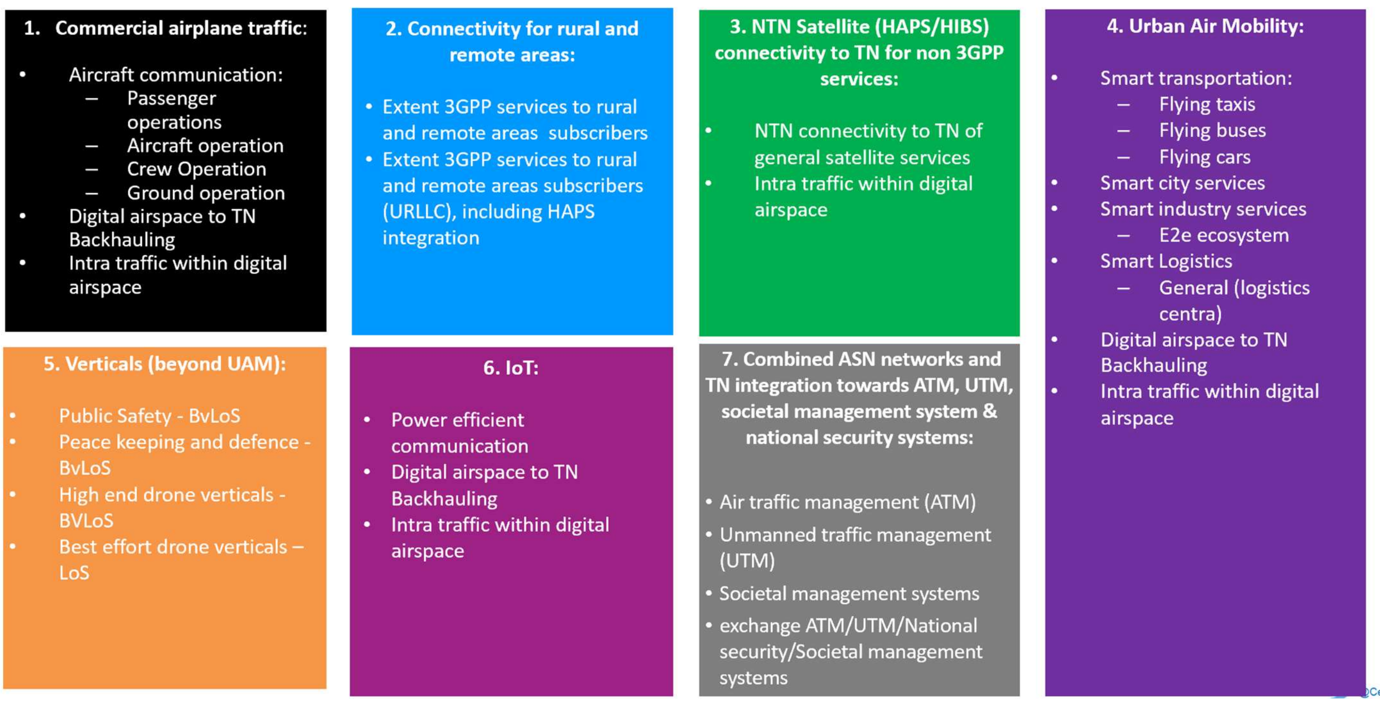

Figure [2]: Use case segments for combined ASN networks.

The use cases are defined from a commercial perspective and are all supported by digital airspace. In this report, the following 7 use case segments will be further analyzed and described:

1 Commercial airplane traffic - The vision for communication towards the use case segment for commercial traffic is that you should be able to gain the same experience on an airplane as if you were using the UE on ground level. This also means that basically all 6G innovation areas will be valid.

2 Connectivity for rural and remote areas - This use case segment is not considered to be served with same level of performance compared to areas with a higher density of wireless traffic. Here, satellite and HAPS systems can complement 3GPP connectivity.

3 NTN Satellite (HAPS/HIBS) connectivity to TN (for non 3GPP services) - A use case segment that employs the wireless network as a connection point and transport of satellite related data traffic.

4 Urban Air Mobility (UAM) - This use case segment is expected to be impacted largely by 6G innovation. One reason for this is that a large portion of the population is already in cities and urbanization will increase. Smart cities will trigger many other smart solutions and the use case segment will benefit of a tight TN and combined ASN networks integration forming a digital society.

5 Verticals (beyond UAM) - Addresses the use of aerial platforms for different industries beyond those served by Urban Air mobility. As part of the ongoing value chain re-engineering, industries are looking into how to use aerial platforms to enhance and innovate value chains. One example is electricity infrastructure owners that want to inspect the electricity infrastructure by using drones.

6 IoT is a special use case segment with special requirements on both devices and the network.

7 Combined ASN networks and TN integration towards ATM, UTM, societal management system & national security systems - A use case segment that will interact with all aerial platforms but also towards different types of management systems.

3.1.1 Commercial airplane traffic

Commercial airplane traffic has basically two types of traffic types: links to and from the airplane, as well as communications related to the internal body of the aircraft.

Broadband in-flight connectivity services for commercial airplanes can be provided using satellites or direct air-to-ground (A2G) communications.

Satellite-based in-flight connectivity is already offered to airplane passengers today. Satellites have the advantage of offering global coverage that can span over both land and sea, which make them suitable for intercontinental flights.

However, satellite-based in-flight connectivity services suffer from a limited system capacity and long latency [4]. The alternative or complementary approach is based on A2G communications using cellular technology to establish direct connectivity between terrestrial base-stations and aircraft. A2G networks offer a larger system capacity and shorter latencies than satellites but their coverage is limited to over land or along the coasts. If both systems are supported in an airplane they can co-exist; either supporting stand alone communication or jointly depending on network design and communication needs.

In the ICARO project, four service operation areas were defined for in cabin communication, i.e services for:

- Passenger operation
- Aircraft operation
- Crew operation
- Ground operation

Each service operation area has a set of services attached to it. Each of the services can be further innovated with 6G. Below follows a figure showing an overview of services attached to the service operation areas:

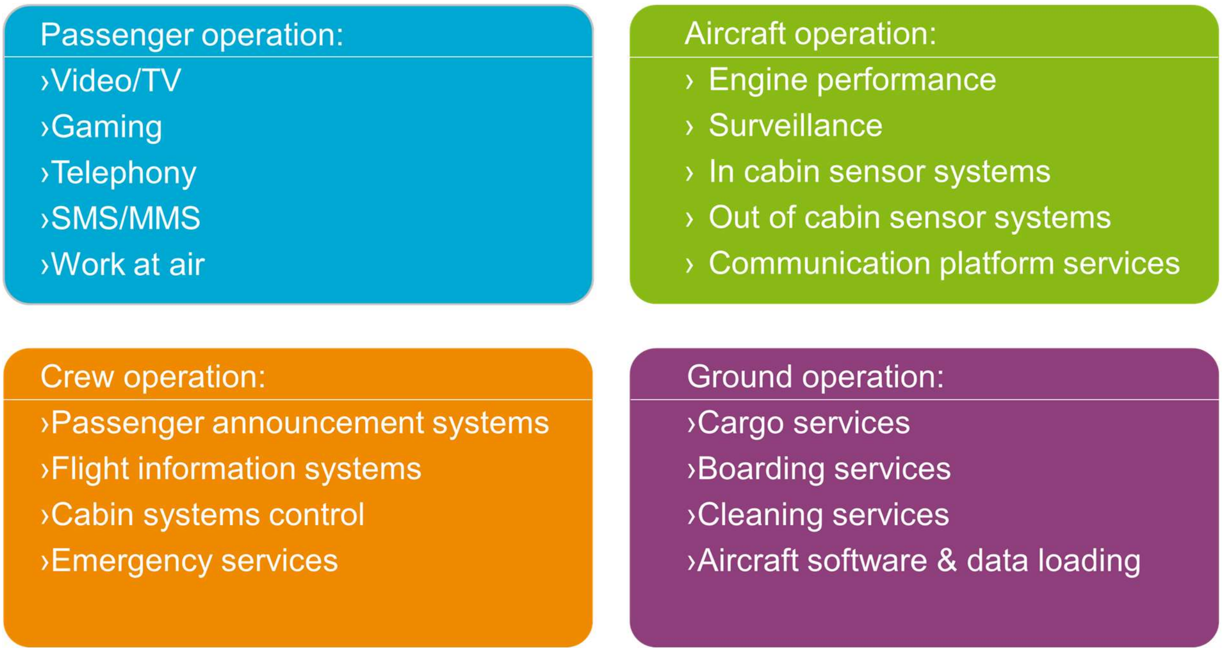

Figure [3 Services attached to service operation areas

3.1.1.1 Passenger operation

In-Flight Entertainment and Connectivity (IFEC) is a growing market and wireless connectivity (nowadays WiFi) is important to a majority of passengers. Passengers may also expect free services on short-haul routes and rebook with an airline that offered quality inflight connectivity. IFEC primarily addresses passengers and includes Internet access as well as on-board services, e.g., entertainment videos provided by the airline. Beyond 6G passenger (or crew) devices, 6G may play a significant role in the overall IFEC infrastructure.

3.1.1.2 Aircraft operation

Communications for Operations and Maintenance embraces manifold communication activities during flight and ground operations, as well as (regulated) maintenance actions for aircraft. At an airport, for instance, multiple interactions appear between the aircraft, airline, and the airport ground services. For example, recorded sensor data can be downloaded from the aircraft for predictive maintenance. As 6G becomes a worldwide standard and with a rich ecosystem, it can facilitate these communication and sensing activities on a broad scale.

Safety-Critical Communications, e.g., between ATC and pilot, is currently supported by legacy systems such as VHF or L-band satellite systems operating in dedicated and protected spectrum bands. Activities are undergone to consider public non-safety commercial communication systems as a component of aircraft safety communications, e.g., in the hyper-connected ATM ambitions. 6G emerges in the right time to support such safety-critical communications.

3.1.1.3 Crew operation

Communication systems that can enhance crew operation can both be enhanced and innovated with 6G. Today, passenger announcement systems still use wired solutions for announcing information to passengers. These could e.g., be innovated with wireless headsets and microphones.

Flight information systems can be real-time updated and also tied to individual passengers needs.

3.1.1.4 Ground operation

When an aircraft is on the ground there are many interactions ongoing. All of these interactions can be digitalized and innovated with wireless services.

3.1.2 Connectivity for rural and remote areas

HAPS and satellites can be used to extend connectivity to rural and remote areas and by this work as a complement to wireless networks. Different parts of world have different needs of providing connectivity to rural and remote areas. Digitalization in Europe faces the challenge of requiring network connectivity everywhere and always. Even if most of the world’s population is estimated to live in the urban areas, rural areas need to be supported to stay attractive for the people e.g., to be able to produce the food (and other agricultural products such as bioenergy) efficiently and sustainably using smart farming technologies.

Bridging the so-called digital divide is one of the key obligations across Europe. Employing NTN based connectivity services into those areas may be an attractive solution as long as the terrestrial networks do not have a complete coverage.

Another aspect is the world-wide export of products and services, which can greatly benefit from a satellite backbone and service platform. Satellites provide services for maritime users on oceans, islands, mountain districts and sparsely populated areas where it can be an attractive alternative for sparsely populated and remote areas.

HIBS (High-altitude platform stations as IMT base stations) do not replace terrestrial systems but can be seen as a complement. With flying base stations, moving at an altitude of 20-50 km, it is possible to create large macro cells, which can provide a significant addition to coverage, primarily outdoor. HAPS could support a variety of use cases for both developed and developing markets. It could for instance provide enhanced and temporary connectivity over regional areas where the ground infrastructure is broken (or simply over saturated) to provide additional connectivity.

3.1.3 NTN Satellite (HAPS/HIBS) connectivity to TN for non 3GPP services

Satellite and HAPS can also be used for non-3GPP services. Examples include earth observation, disaster management, and critical infrastructure monitoring that are provided by satellites and HAPS.

Particularly, the use case of 6G for future Earth Observation (EO) tasks can be highlighted, where EO entities on platforms (e.g., satellites, HAPS and drones) can profit from high-capacity 6G networking combined with AI-processing (e.g., edge computing) on the platforms and the 6G infrastructure.

6G enables (i) a standard interface to these platforms and (ii) high data rates, which are often needed in imagery applications, and (iii) edge computing, e.g., on NTN low Earth orbit satellites and NTN HAPS.

3.1.4 Urban Air Mobility

It is estimated that about 70 percent of the world's population will be living in the urban areas by 2050 [5]. Hence, there will be a need to exploit the airspace above these metropolitan areas for transportation of goods and people to avoid congestion from an increase in ground-based traffic. The term "smart city" was coined to describe an urban area where networks and services are made more efficient with the use of sensors and digital solutions for the benefit of its inhabitants and business.

According to The United Nations Economic Commission for Europe (UNECE) and the International Telecommunication Union (ITU), a smart city is an "innovative city that uses information communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services, and increase competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects." Smart city services can include smarter transport networks, upgraded water supply and waste disposal facilities, and more efficient ways to light and heat buildings, monitoring the city's air-pollution.

Urban Air Mobility (UAM) has been closely linked to smart cities and is a concept towards 3D transportation to increase its efficiency in the metropolitan areas. UAM is a new concept to realize the smart mobility in the low altitude airspace in metropolitan areas. UAM provides an alternative to current ground-based transportation systems such as buses and cars, by enabling the transportation of passengers in flying vehicles. But it will also enable flying UAVs/drones that offer surveillance and monitoring services for public safety.

UAM is not only interesting in itself, but also in connection to other evolutions in the society, where it can be integrated with concepts like smart cities, Industry 4.0, and general innovation in transportation of goods and people. As cities grow they also need to automate, digitalize and build smart solutions. Digital airspace can support this transformation by also providing urban air mobility solutions. The emergence of UAM will require the regulation of airspace to ensure safety and to avoid conflicts between flying vehicles.

3.1.5 Verticals - beyond UAM

In recent years, the aviation industry has been experiencing a tremendous paradigm shift. Unmanned aerial vehicles (UAVs), also known as drones, have been used in a wide set of applications such as monitoring, search and rescue and providing wireless connectivity in remote areas. Many of the drones found on the market today are consumer drones, considered as best effort or low-cost drones, and operating in visual line of sight (LOS) based WiFi /WLAN. UAVs operating in beyond visual line of sight (BVLOS), on the other hand, would require mobile communication, which is highly interesting from a 3GPP based communications point of view.

The market for commercial UAVs is estimated to grow, which means an enormous increase in the number of deployed UAVs for different applications and business initiatives. There is an increasing trend in the research and development for UAVs, especially for their connectivity to use them at their full extent. In addition to manufacturing these flying vehicles, wireless connectivity will be required to fully operate them in a large scale and manage the aerial traffic.

Industries are constantly looking into ways for improvements within their fields and a part of Industry 4.0 is exploiting the promising potential of drones. Drones are now being used extensively for aerial photography, surveillance and 3D mapping, shipping, and remote sensing. It has found a place in almost all kinds of industrial ecosystems. The increasing interest in drones can be attributed to the easy availability of drones in the market, to the minimal change to infrastructure needed when adding them into an existing workplace, and the possibility of reducing manual labor.

3.1.6 IoT

The IoT market represents an interesting and potentially huge revenue stream for the satellite industry with opportunities in many markets, particularly vertical ones addressing the need for machine-to-machine communications with global coverage or in places where terrestrial networks are not deployed such as remote, oceanic or desert areas. It is experiencing a robust growth as companies are continually seeking out new ways to raise productivity while reducing costs. IoT communications can be used in a seemingly endless number of ways ranging from logistical tracking, telemetry, remote monitoring, geofencing, security, scientific monitoring and many others.

Europe has a strong space industry, in particular many companies producing various types of satellites. Combining these space or air-borne devices with attractive IoT services will strengthen the equipment vendors, but also IoT service providers within EU. The solutions proposed in the 6G-SKY project may boost productivity of end users and widen the business of on-ground device providers.

3.1.7 Combined ASN networks and TN integration towards ATM, UTM, societal management system & national security systems

The combined ASN networks market is in many aspects at a very early stage in the hype curve for communications. There are solutions for satellites and commercial airplanes, but the ongoing electrification and digitalization of the society, including digital airspace open up new opportunities to create solutions for communications.

In order to handle the expected growth of aerial platforms, there will be a need for a digital system that can monitor and manage the activities of aerial vehicles and that is scalable as the number of flying vehicles increases. This system is defined as Unmanned

Traffic Management (UTM) and should be included in the future air traffic management system (ATM). Air traffic management will most likely be more automated to cope with all the flying vehicles. Unmanned traffic management will emerge to complement ATM.

Smart cities may put new requirements on communication networks and require communication to and from societal management systems.

Public safety, peace keeping, and defense are foreseen to increase usage of wireless systems, which will require communication support towards national security systems. The international characteristic of 6G-SKY raises a number of security concerns. Security issues related to 6G will be at least as important as for 5G. In the case of Sweden, the Swedish Security Service has set up 16 principles that operators have to comply with for 5G [**Fehler! Verweisquelle konnte nicht gefunden werden.**]. In 6G, more issues will likely occur, e.g.,

- Satellite systems controlled by foreign companies could be a security concern.
- Localization of equipment, data processing could trigger security concerns.
- Control over critical resources is a concern for governments and regulators.

4 Highlighted value chains for combined Airspace and NTN

4.1 Connectivity for Rural and Remote Areas

This use case refers to direct-to-device satellite connectivity for consumers in rural and remote areas. It would allow mobile users to switch from terrestrial to satellite connectivity when venturing outside the reach of terrestrial networks.

4.1.1 Current developments

Companies are already working towards connecting mobile users in remote areas, and some niche solutions already exist. Some notable ones are Starlink [6, Apple [7, and Skylo [8]. However, the implementations of these services are limited and differ, which are elaborated below.

In the case of Starlink [6, as example, they plan to offer [6] a direct-to-device messaging service through their constellation of low earth orbit (LEO) satellites. In the US, they have partnered with T-Mobile [9 who offer the service to their customers [10. Through this partnership, Starlink can use T-Mobile's terrestrial spectrum on their satellites to connect to mobile phones. This would be using the unmodified LTE spectrum, allowing customers to use the service with any LTE-compatible phone, thus eliminating the need for hardware upgrades. The customer would use their phones as usual and, when they are out of reach from the terrestrial network, their phones would roam onto Starlink's network. Starlink is in this case dependent on T-Mobile's spectrum for terrestrial coverage. If they wanted to offer this service directly to customers without a mobile network operator (MNO), they could produce their own SIM cards but they would be limited to satellite connectivity.

In the case of Apple ([7they have partnered with a satellite operator, Globalstar [11, to provide emergency SOS in new iPhones [12). As described by interviewees (Ericsson reference team), this service is an emergency messaging solution and does not involve voice, data, or messaging, but only geographical coordinates in case of emergency. It does, however, provide an interesting example of device manufacturers collaborating directly with satellite operators to provide anon-terrestrial network (NTN) service.

Skylo [8 is an interesting player that has emerged in the NTN space. Several interviewees (Ericsson reference team) talked about the business model of Skylo. The company provides an Internet of Things (IoT) service through their own SIM card that utilises satellite connectivity. Skylo collaborates with satellite network operators (SNO) and through having their own 3GPP radio access network (RAN) and core network, they are able to provide the service to customers. They have built out their own base stations at the ground stations of SNOs and the SNOs wholesale capacity to them. Skylo has thus built a middle layer so that satellite networks can interoperate with terrestrial networks (TN).

4.1.2 Value network

There are several actors that need to be present in the value network to provide the service. Figure 4 shows the main actors and their respective offerings to the network following the model developed by [10 One area of contention during interviews and workshops was the way in which terrestrial and satellite networks would be connected through a roaming interface. In the value network model presented, there is a new actor called 6G NTN Operator whose role is to provide this roaming interface.

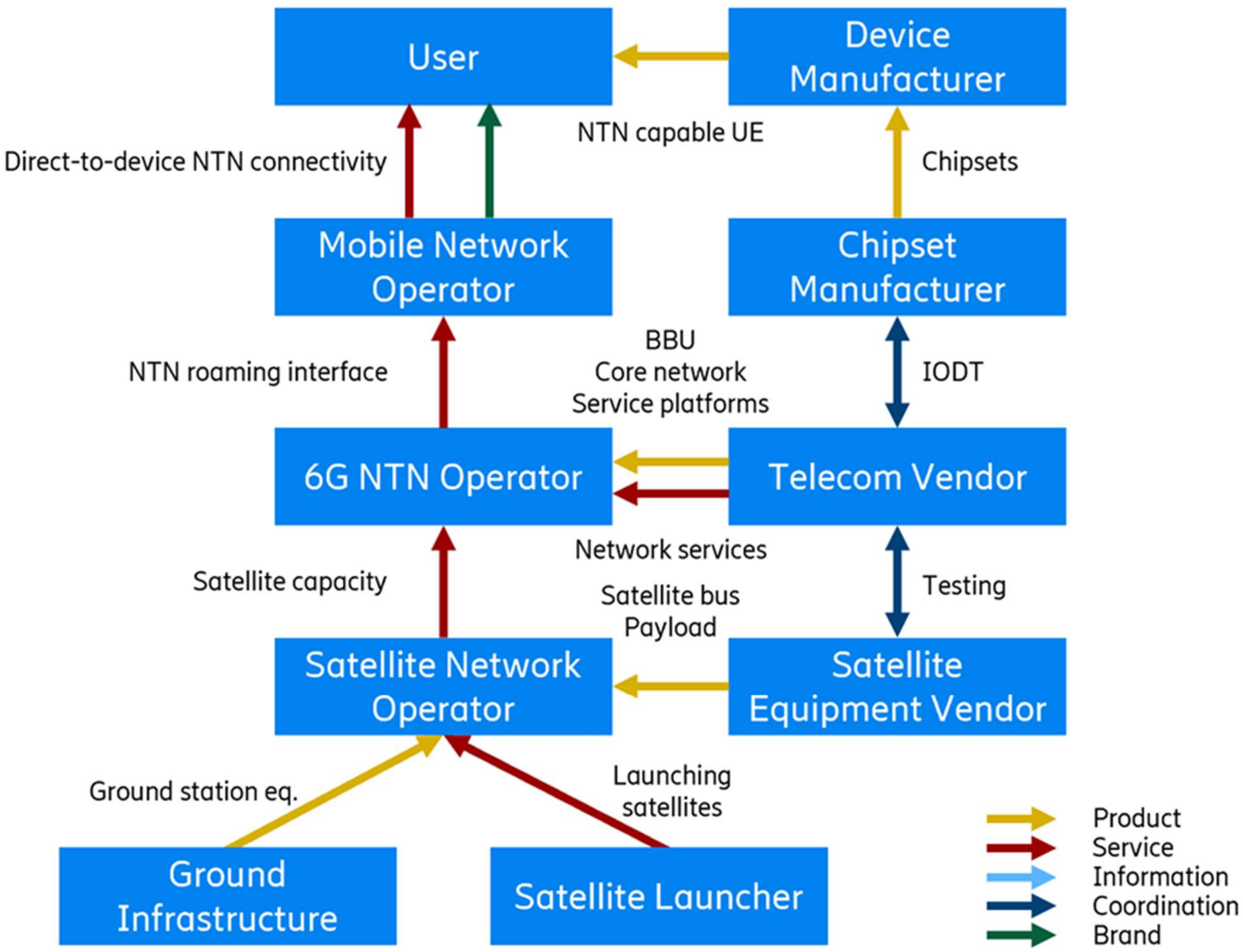

Figure [4: Value network for rural and remote connectivity

4.1.2.1 User

As per [10, the end consumer in a value network is the entity who appreciates the value proposition of the network. In this case, the user is the beneficiary of the value generated by the value network. They are a customer of an MNO, with a phone plan that includes satellite connectivity as an extra service, in addition to traditional terrestrial connectivity. This integration into the MNO's existing subscription plans is due to the fact that users are unlikely to want to enter into an additional subscription.When the user exits the coverage area of their MNO's terrestrial network, their device switches to the satellite network, allowing continued access to services. When the user is once again in range of the terrestrial network, the device switches back.

4.1.2.2 Mobile Network Operator

Following the different offerings of network actors from [10, MNOs bring both a service and brand offering, as they are the ones selling the rural and remote connectivity service to the user.

As interviewees (Ericsson reference team) pointed out, MNOs already have existing customers, sales channels, and reach on local markets, giving them a strong position in the value network, and providing an incentive for the rest of the actors to try to reach end-users through them rather than to sell the service directly. Along with consumers' desires to minimise their number of active subscriptions, this points to the likelihood that the MNO will have the customer-facing role in this value network. A mobile virtual network operator (MVNO) could of course also take on this role.

MNOs have terrestrial spectrum rights. While the most likely case seems to be that the satellite spectrum will be used for satellite connectivity, there are multiple actors attempting to create services using the terrestrial spectrum, as is the case with T-Mobile's collaboration with Starlink [10, so this is certainly a possible scenario. This would thus solidify the MNO's position in the value network.

4.1.2.3 Satellite Network Operator

SNOs own rights to the satellite spectrum. In this model, their role is to provide a wholesale service of data capacity for NTN connectivity through LEO/MEO satellite constellations, allowing users to connect their devices to the satellite to provide the necessary services where terrestrial networks do not reach.

The SNO purchases satellites from a Satellite Equipment Vendor. The satellite consists of a frame, solar cells, and payload. The payload consists of the equipment on the satellite necessary for fulfilling its function.

The architectures used for LEO constellations will depend on the specific use cases. A fully regenerative approach minimises latency but comes at a higher cost due to additional satellite complexity. Unless essential, SNOs are likely to opt for the cheaper options, especially for a use case like this where only a best-effort type of link is required.

In addition to purchasing satellites, SNOs will also need to buy ground infrastructure and launch their satellites. Ground infrastructure includes satellite gateways, data centres, fibre cables, and more.

4.1.2.4 6G NTN Operator

[11 recommends separating specific roles when designing value networks, to facilitate the analysis of how value conversion happens. Ericsson Interviewees indicated that a middle-layer between MNOs and SNOs as they have traditionally operated would be required to offer a full TN and NTN service direct-to-device, and discussions were often centred around which actor would take on this role. Traditionally, the simple B2B interface that SNOs have offered has not required them to provide any additional offerings of their own in the form of services.

When it comes to connectivity for rural and remote areas, this means that traditional SNOs currently lack the necessary capabilities to directly integrate with the networks of MNOs in order to enter into roaming agreements. The 6G NTN operator role, see figure 4, needs to be taken on by an actor in the value network in order to provide a seamless service to end-users.

While some interviewees (Ericsson reference team) believed that the SNO would take on this role in most cases, others believed that actors such as MNOs and Device Manufacturers might have motives to pursue this area. Since this is a relatively new role that needs to be taken on by some actor, it has been defined as a separate entity in this model for the sake of clarity and in order to emphasise its position as a potential battleground for different actors.

The 6G NTN Operator represents this middle-layer between the SNOs and MNOs. The service they provide is a roaming interface from the terrestrial networks of the MNOs to the non-terrestrial networks of the SNOs. This requires a RAN, core network, and service platforms for the voice, messaging, and data services that are provided. The 6G NTN Operator purchases these capabilities from the Telecom Vendor.

The start up Skylo [8 is a real-life example of such a middle-layer role between SNOs and MNOs, for the purpose of providing an integrated TN and NTN service for IoT devices. Through building their own RAN at the satellite ground stations, and having their own core network, they have become able to provide a roaming interface between geostationary orbit (GEO) satellites and service providers. They have partnered with SNOs such as Viasat [13, 14, Ligado Networks [14,15and TerreStar [16,17 as well as the customer facing IoT operator Emnify [18.

However, interviewees (Ericsson reference team) were still uncertain as to what role Skylo or other similar companies could come to play in the future, instead believing that SNOs might choose to simply purchase or develop the required resources and capabilities for themselves.

Starlink is an example of an SNO that has chosen to take on this role, aiming to offer a messaging solution through their constellation of satellites direct-to-device. While they are not making use of the satellite spectrum, they provide satellites and develop the network infrastructure that integrates into the terrestrial network.

4.1.2.5 Telecom Vendor

The Telecom Vendor will be responsible for providing the 6G NTN Operator with RAN and a core network. Mainly, the Telecom Vendor will provide RAN software functionality and baseband units, which will be located on the ground by the satellite gateway, or on the satellites, depending on the payload architecture of the satellite. The Telecom Vendor may also provide additional network services.

In a 6G scenario based on 3GPP, the Telecom Vendor will also play a coordinating role, ensuring compatibility. The coordinating role is a network-centric offering that entails managing the offerings of others [10 In this case, the Telecom Vendor will need to participate in interoperability and development testing (IODT) with Chipset Manufacturers. They may also need to conduct tests with Satellite Equipment Vendors to ensure compatibility and performance with hardware that is installed on satellites.

4.1.2.6 Chipset Manufacturer and Device Manufacturer

The Chipset Manufacturer sells its chipsets to Device Manufacturers to be used in user devices. In a 3GPP scenario, standardised chips will ensure that billions of user devices will be compatible with integrated TN and NTN services. To ensure interoperability and compatibility, the Chipset Manufacturer must participate in IODT with the Telecom Vendor.

4.1.2.7 Satellite Equipment Vendor

The Satellite Equipment Vendor builds and installs the physical components of the satellite. This includes the satellite bus, which is essentially the satellite’s structural framework, housing various subsystems like power, propulsion, and communication systems. They collaborate closely with SNOs to understand their needs and integrate features that enhance the satellite’s performance and longevity in orbit.

4.1.2.8 Satellite Launcher

The Satellite Launcher is responsible for the successful deployment of satellites into their orbits. Launching a satellite involves using specialised rockets or launch vehicles capable of carrying the satellite payload to the desired altitude and trajectory.
Ground Satellite Infrastructure Provider

The ground segment of an SNO encompasses a wide range of infrastructure and facilities on Earth that are essential for satellite communications. This includes gateways that communicate with satellites through feeder links.

4.1.3 Strategic Moves

Actors in the presented value network will have their own strategic motives in trying to shape it to their favor. As [12 notes, actors in emerging value network will act based on perceived value, meaning that each actor will want to grab larger parts of profits.

Incumbent industry actors looking to expand into this market will have certain motives to pursue different positions. In the presented value network, there are five main incumbent actors who may have their own agendas in trying to shape the value network. These are the SNOs, MNOs, Device Manufacturers, Chipset Manufacturers, and Telecom Vendors.

4.1.3.1 Strategic Motives of Satellite Network Operators

As SNOs historically have acted as a "bent pipe" provider for TV channels, they will be eager to find opportunities to expand their offering to generate larger profits. New direct-to-device NTN services are an attractive new opportunity which they likely will want to exploit to the fullest extent. As several interviewees said, it is likely that they will want to take on the 6G NTN Operator role in order to increase their service offerings and thus their revenue.

One perspective on a firm’s competitive advantage is the examination of its internal resources [13.

SNOs have two main resources: satellite spectrum rights and satellite constellations. The right to a spectrum is one of the main resources that enable a telecommunications business.

In the case of SNOs, their access to the satellite spectrum puts them in a strong position relative to other actors in the NTN space. The SNOs' resources can be analysed based on the VRIS criteria (valuable, rare, imperfectly imitable, and non-substitutable) developed by [13.

Resources that meet these criteria help firms gain and sustain a competitive advantage.

The satellite spectrum is valuable since it allows the transmission of data through satellites on certain frequencies. It is also rare, since spectrum is a finite resource with a limited number of owners. It is impossible to imitate.

Lastly, it is only to a small degree able to be substituted. As evidenced by Starlink's partnership with T-Mobile [11, it is possible to use an MNO's terrestrial spectrum with satellites.

However, this solution presents several challenges, as there is a risk of interference as well as regulatory complications related to differing local markets having different allocations of spectrum rights. Overall, the right to a satellite spectrum is a VRIS resource, affording its owner a strong position in the value network for this service.

As presented in the value network, the 6G NTN Operator role requires a RAN and a core network. A frequent topic in the interviews of the Ericsson reference team was that of the satellite architecture. As discussed by interviewees, there are transparent, semi-transparent, and regenerative architectures for LEO constellations.

Interviewees (Ericsson Reference team) seemed to believe that some type of semi-transparent architecture would be utilised in many cases. This would require parts of the RAN, including the radio, to be integrated on the satellite, while other parts would be located on the ground, at the SNO's ground stations.

[14describes asset specificity as the as the extent to which an asset has a higher value in the context of a specific transaction than in any other use. The higher the asset specificity, the more likely it is that a company will choose to vertically integrate [15. In this case, the radio is contingent upon its physical location, and network components would be located at the ground station of the SNO, indicating a high site specificity [16This would point to SNOs being likely to not only provide the satellites and ground stations, but also parts of the RAN.

In addition to the RAN, the other role of the 6G NTN Operator is to operate a core network and offer the actual service. Since there are digital components, the site specificity of the RAN components is not present. As with MVNOs who provide a mobile service through their own services and core network while utilising the RAN of other actors, it would be possible for the SNO to not operate a core network and for another actor to take this role themselves. However, owing to the probable motives of the SNOs to take a larger part of the value network and in effect appropriate larger profits, it is likely that they will have ambitions to operate their own core network as well and provide a service which can be directly integrated with those of the MNOs.

In the scenario discussed above, the role of the 6G NTN Operator would be subsumed by the SNO, who then establishes a direct relationship with the MNO. This scenario is the one that several interviewees (Ericsson reference team) envisioned as the most likely. However, expanding their infrastructure and capabilities will require large investments from SNOs, which would come in addition to the large investments made into satellite constellations. While the market seems to have potential, it is still uncertain how large it will become, and which services users will be willing to pay for.

While most current solutions offer some type of messaging solution, future solutions may incorporate voice calls and data. However, if users do not see much use of these services, the market potential may be significantly smaller than what some might have expected. There may thus be an element of risk associated with taking on a larger role in the value network for the SNO.

Should SNOs instead choose to remain "bit pipe" providers and let other actors take the role of the 6G NTN Operator, less would be required of them in terms of investments and risk. They would still benefit from the increased use of satellite communication, albeit to a lesser extent, and they would not need to venture outside of their core business.

Another alternative for the SNO would be to go at it alone and sell a direct-to-device NTN service directly to mobile users. They would thus take on the role of the 6G NTN Operator and the customer-facing MNO in the model.

In this case, users would need two contracts for their mobile connectivity needs, one with their MNO and one with the SNO, which they would likely find inconvenient. SNOs pursuing this option would be required to gain a local market presence and access to customer, as they currently do not have this. The benefit would be that the SNO could keep profits to themselves, without the use of middlemen, which the MNOs would be in the other case. However, the large efforts required to reach users would likely point to SNOs in most cases wanting to use MNOs as a go-to-market channel for the service. Interviewees (Ericsson reference team) suggested that this strategy could be an option in underdeveloped countries, as well as for B2B customers.

A third option would be for SNOs to partner with Device Manufacturers to provide the service to the users of devices. This could help SNOs reach large numbers of devices and users. Globalstar [11 is an example of an SNO using this strategy, having partnered with Apple [7 to provide satellite connectivity for recent iPhone models [12, using a proprietary chipset standard and Globalstar's satellite spectrum. This connectivity is currently only used for the Emergency SOS app, and users are yet to be charged.

4.1.3.2 Strategic Motives of Mobile Network Operators

MNOs will view NTN services as an opportunity to enhance their service portfolio and meet the evolving needs of their customers, particularly those in rural and remote areas. By offering NTN connectivity, MNOs can position themselves as comprehensive solution providers, catering to underserved populations. This customer facing role allows MNOs to maintain direct relationships with subscribers, thereby improving customer retention and loyalty.

While MNOs lack infrastructure and access to the satellite spectrum, they can leverage existing assets and partnerships to integrate NTN services into their offerings. By collaborating with SNOs, MNOs can access satellite-based connectivity without significant capital expenditures. This would allow MNOs to generate additional revenue streams with minimal investment.

With their established market presence and financial resources, MNOs may explore opportunities for vertical integration. This could involve expanding their role beyond traditional service provision to encompass elements of the 6G NTN Operator role such as elements of the core network and a service definition. This would position them as full MVNOs in the context of their relationships with SNOs. SNOs would provide the RAN while the MNO would have a core network utilising the RAN.

By assuming greater control over network infrastructure and service delivery, MNOs could capture more value and differentiate themselves in the competitive landscape. Transaction cost economics posit that vertical integration should be done when costs would be lower compared to conducting the transaction on the open market [17. From this perspective, it would only be appropriate for the MNO to take on a larger role if it would lead to reduced transaction costs.

MNOs are likely to advocate for the adoption of industry standards. Standardisation ensures interoperability and compatibility across networks and devices, allowing MNOs to seamlessly integrate NTN connectivity into their existing infrastructure. However, interviewees (Ericsson reference team) highlighted that exactly what connectivity standard gets adopted could be a point of contention.

While MNOs have traditionally been in favour of 3GPP standards, they may stand to gain more from the adoption of the Unmodified LTE standard, as in the case of T-Mobile and Starlink [10as this would make the service reliant on a spectrum that they own, solidifying their position in the network. In the US, the FCC [19 recently outlined a number of terrestrial spectrum bands that MNOs will be permitted to license out to SNOs. This serves to strengthen the value of terrestrial spectrum rights, which could be considered a VRIS resource as per [18. It is also a potential indicator that this is the direction in which MNOs are intending to take the industry.

4.1.3.3 Strategic Motives of Device Manufacturers

For Device Manufacturers, 3GPP NTN standards could enhance the value proposition of their products. By ensuring compatibility with NTN connectivity, manufacturers can offer consumers access to reliable and seamless connectivity, regardless of geographic location.
Some Device Manufacturers may explore opportunities to provide NTN services directly to consumers by collaborating with SNOs, as with the previously mentioned example of Apple's partnership with Globalstar [12.

This could avoid the inconvenience of additional subscriptions for each user, as users often already have payments for apps and services integrated into their account for their phone's app marketplace. By leveraging their brand recognition and resources, Device Manufacturers can potentially establish additional revenue streams through service provision. However, this strategy may require substantial investments in infrastructure and partnerships, as well as navigating regulatory and technological challenges.

4.1.3.4 Strategic Motives of Telecom Vendors

As NTN services evolve, Telecom Vendors are likely to push for the standardisation of technical specifications and protocols, particularly through 3GPP. Standardisation promotes interoperability and compatibility between different network components and devices, which puts the Telecom Vendors in a good position to sell their equipment and solutions.

4.1.3.5 Strategic Motives of Chipset Manufacturers

Chipset Manufacturers' chipsets will be used to develop NTN capable device, placing them in a good spot to make their chips more valuable and generating more revenue. To gain access to the vast ecosystem of devices, they will be likely to push for 3GPP standardisation. Alternatively, they may favour a proprietary solution if they can secure an agreement that locks out competitors.

4.1.4 Money flows

This section examines the value network in terms of probable money flows. The money flows are presented in Figure 5.

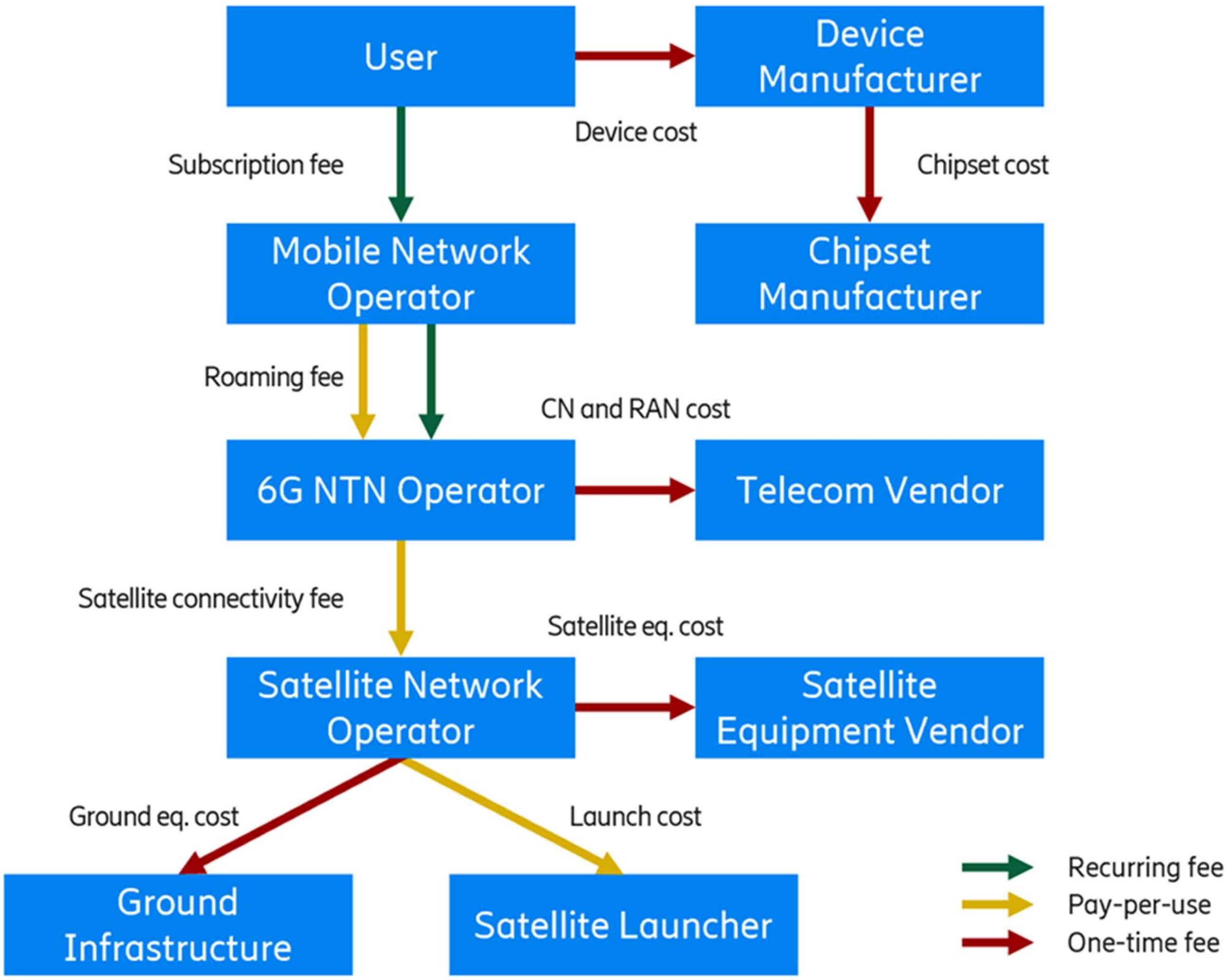

Figure [5: Money flows for connectivity for rural and remote areas

4.1.4.1 User

The user is the origin of the monetary flow in the value network, purchasing NTN-capable devices directly from the device manufacturer. While mobile phones are often sold by MNOs and other third-party retailers, the model in Figure 5 simplifies the financial flow from the user to the device manufacturer.

[20notes that customers generally expect features integrated with core offerings to be integrated in the same revenue stream. It is therefore likely that users will want to pay for NTN services through their existing MNO subscription. MNOs can charge for this by setting higher subscription rates and assigning a specific data allowance for NTN usage. The MNO may offer various NTN plans, ranging from messaging-only to comprehensive packages that include messaging, voice, and data.

This type of pricing is called tiered pricing and is beneficial to reach customers who value aspects of the product differently [19.

As customers often expect certain revenue models to be available due to them being common practice [20, other solutions that are prevalent in the telecommunications industry may of course also be possible. These may include pre-paid SIM cards or usage-based fees akin to traditional roaming charges.

4.1.4.2 Mobile Network Operator

Interviewees (Ericsson reference team) believed that the interface between the MNO and the 6G NTN Operator would work very similarly to terrestrial roaming. In traditional roaming, the operator of a visited network charges a wholesale fee for used capacity [20.

Therefore, in the proposed model, the MNO will be required to pay a roaming fee based on usage to the 6G NTN Operator to allow user access to the network. This flexibility would make it easy for the MNO to add new subscribers to the service and only pay for the service when their customers use it. The MNO's payments for NTN connectivity will therefore be based on the data consumption of each user.

4.1.4.3 6G NTN Operator

The 6G NTN Operator accesses satellites owned and operated by SNOs. The SNO functions similarly to a traditional wholesaler of capacity. Consequently, the 6G NTN Operator compensates the SNO based on the utilised capacity. Furthermore, they procure network equipment and services from the Telecom Vendor. Equipment is likely paid for up-front, while occasional services provided will likely be billed on a per-use basis [21

An alternative solution would be for the Telecom Vendor to offer a comprehensive service package, enabling the 6G NTN Operator to purchase a core network, RAN equipment, software and services like BSS/OSS as a network-as-a-service proposition, with recurring charges.

This could include an annual right-to-use software fee, or there could be a pay-as-you-grow scheme that would increase as the operator expanded. This model could be appropriate for a fledgling 6G NTN Operator, as it would lower capital expenditures and minimise financial risk [21. Furthermore, improvements to the product could be made over time, making it more valuable to the customer [22.

4.1.4.4 Satellite Network Operator

The three main costs of SNOs are the cost of satellites, launch, and ground infrastructure. Satellites and ground infrastructure are durable products that will be used a lot, pointing to an up-front payment model [23 Satellite launches are infrequent and have a very specific purpose, indicating that a usage-based model is likely in this case [21.

4.1.4.5 Device Manufacturer

In this value network, the main purchase for the device manufacturer are chipsets. Given the nature of chipsets as standardised and essential components, the purchasing of these will likely be in the form of one-time payments, as that is the standard revenue model for goods [22.

4.2 Autonomous flying taxis

4.2.1 Current development

There are multiple companies developing vehicles meant to be used as flying taxis, known as electric Vertical Take-Off and Landing Vehicles (eVTOL). These vehicles are large, electric drones that lift off vertically, and can carry one or more people. Several of the companies involved, such as REF _Ref163559346 Volocopter [22 and Embraer [23, are at this stage developing manned eVTOLs, but have expressed ambitions to develop autonomous vehicles later on. Others, such as EHang [24 and Wisk [25, are exclusively developing autonomous eVTOLs.

Joby [28 is an American developer of manned eVTOLs. Their primary focus is currently on commuting between cities and suburbs. They are open to the possibility of developing autonomous vehicles in the future, but do not see it as a certainty [29. They have entered into a partnership with Uber [30, in which it has been agreed that Joby will "integrate our aerial ridesharing service into the Uber app, and vice versa, across all U.S. launch markets" [28.

Volocopter [22 is a German developer of manned eVTOLs, although they are intend to develop autonomous vehicles later on. Apart from just eVTOLs, Volocopter is developing software to be used to order rides, as well as vertiports, thus aiming to create an entire ecosystem related to this service.

Wisk [25 is a subsidiary of Boeing that exclusively develops unmanned eVTOLs. In their concept of operations, they give some indication as to how vehicles will be managed, envisioning so-called multi-vehicle supervisors, people whose job it is to monitor flying taxis [25. While it appears that they will not directly operate as remote pilots, these supervisors could aid in contingency and emergency situations such as selecting the best emergency landing zones, and issuing additional commands. Wisk state that their eVTOLs will have behavioural protocols to ensure safe flights in cases when the connection is lost.

KookieJar [31 is a Swedish vertiport company that emphasises the democratisation of air mobility. The company aims to provide vertiports for all Advanced Air Mobility (AAM)use cases.

Skyportz [32 is an Australian vertiport company. Their goal is to establish a sizeable number of vertiports early on, ahead of the coming flying taxi business. They have also launched a wholly owned subsidiary airline, Wilbur Air, which aims to provide AAM services with priority access to Skyportz's vertiports [33.

4.2.2 Value network

The following section presents the value network for providing the necessary connectivity for autonomous flying taxis. Similar to the previous case, a value network will be presented based on the model of [10 and is shown in Figure 6.

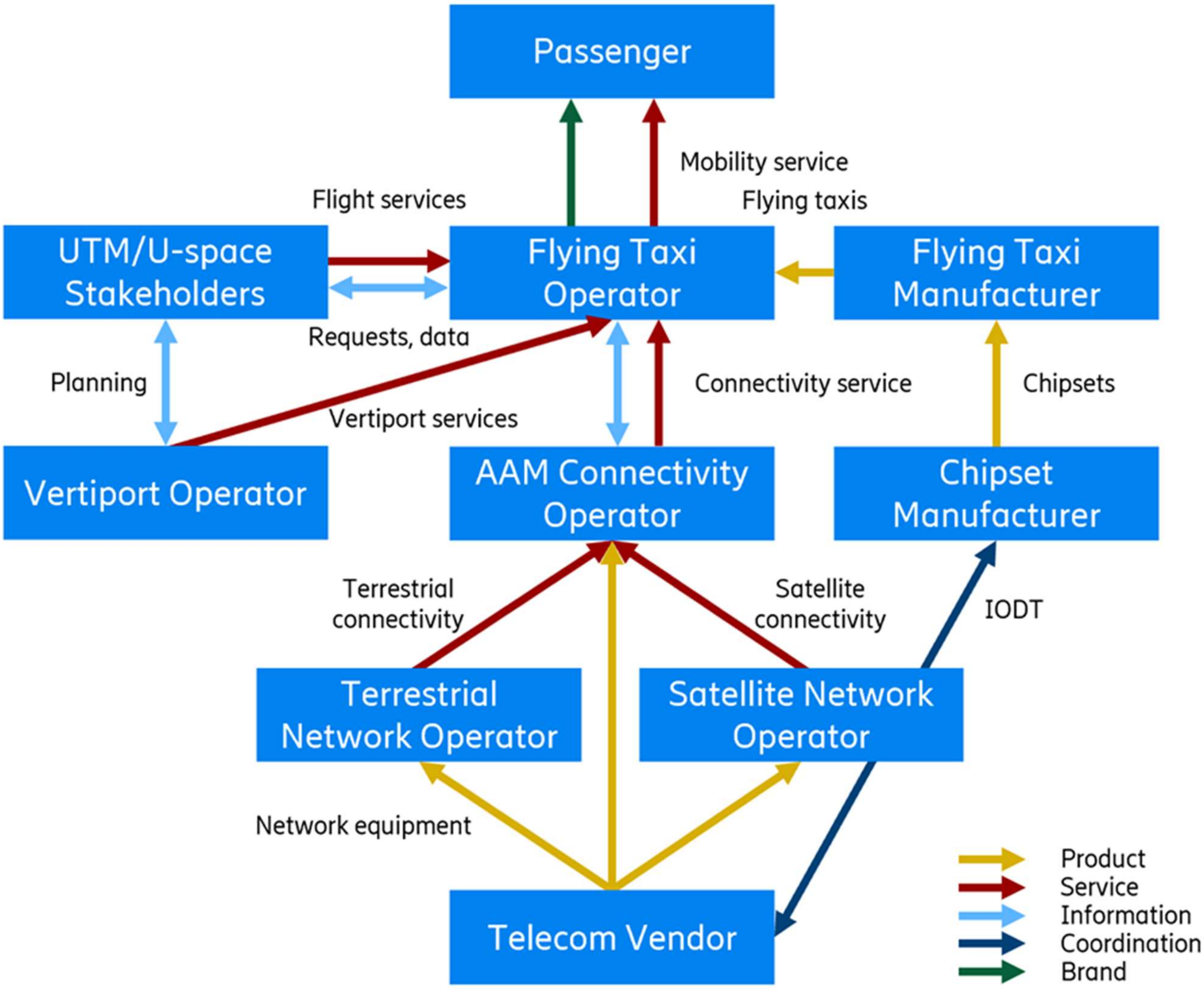

Figure [6: Value network for connectivity for autonomous flying taxis

4.2.2.1 Passenger

The passenger is the end-customer, receiving the service of mobility in the air. The passenger interacts with the Flying Taxi Operator's app or website to book a flight.
They then make their way to a pre-determined vertiport and board a flying taxi that transports them to another vertiport somewhere else. This could be within a city, from one city to another, or between a city and a specific location outside the city, such as an airport [24

4.2.2.2 Flying Taxi Operator

The Flying Taxi Operator operates a mobility service that interviewees believe will function similarly to modern taxi apps such as Uber [30, Lyft [34], and Bolt [35. That means that it owns and operates a customer-facing interface, presumably a website and an app, through which customers can book eVTOL flights. This is categorised as a service, as per [10

Unlike the aforementioned taxi services, whose drivers operate cars they own themselves, the Flying Taxi Operator will be required to either own or lease its own eVTOLs. This will likely be done directly from the manufacturer, but an intermediary could also be involved. Reliable, uninterrupted connectivity for the flying taxis over both terrestrial and non-terrestrial networks is purchased from the AAM Connectivity Operator. Access to vertiports is purchased from Vertiport Operators.

Based on [10, the Flying Taxi Operator provides a service, information, as well as a brand offering to the value network. In addition to the mobility service, their brand offering involves marketing the solution to customers and competing against other firms. Furthermore, there must be continuous interaction with the UTM/U-Space Stakeholders, as approval for flights must be requested, real-time data must be sent communicating location, flight paths and other values, and information on aspects such as traffic and weather must be received [25. They also communicate flight plans and real-time data with the AAM Connectivity Operator in order to enable seamless handover.

4.2.2.3 UTM/U-Space Stakeholders

The exact configuration of the traffic management system for flying taxis is still uncertain and may vary from country to country. Because of this, this particular role in the model has been made to include all the entities involved in the traffic management of unmanned aerial vehicles (UAV) in a given country, known as Unmanned Aircraft System Traffic Management (UTM) [36 in the US and U-Space [37 in the EU.

While the actors involved in this network may vary, they typically include a mix of governmental authorities and private companies. In this use case, their main role is to oversee the airspace to ensure safety for everyone. This is done through communicating with Flying Taxi Operators and Vertiport Operators.

Collectively, the UTM/U-Space Stakeholders receive and approve flight plans, send information on traffic and weather, and use the real-time data received to coordinate and oversee all air traffic [25.They mainly provide service and informational offerings to the value network, as per [10

Interviewees (Ericsson reference team) pointed out that U-Space is still in its very early stages, but that the general structure of it has been determined. Key roles will include the Common Information Service Provider (CISP), U-Space Service Provider (USSP), and the governmental authority. USSPs as well as CISPs will require certification from the governmental authority in order to be allowed to operate in this sector.

The CISP will provide general information about weather, airspace conditions and more. In most European countries, these responsibilities will be centralised. For example, the Swedish Civil Aviation Administration will be the sole CISP in Sweden. However, U-Space does allow for these responsibilities to be divided up among different actors [38.

USSPs will be required to provide four services to companies operating UAVs. These include a network identification service, in which the identity of Unmanned Aircraft System (UAS) operators and drone locations and trajectories are provided, a Geo-awareness service, in which information on operational conditions, airspace limitations and time restrictions are provided, a UAS flight authorisation service, which ensures that operations do not conflict with those of other UAS operators in the same airspace, and a traffic information service, which alerts UAS operators of surrounding air traffic [37.

Private companies will act as USSPs, and there will be a free market associated with these services. However, all companies providing AAM services, including Flying Taxi Operators, will be required to use the services of a certified USSP. USSPs will be free to provide additional services on top of the ones listed, and they will not be prohibited from outsourcing aspects of their services.

4.2.2.4 AAM Connectivity Operator

Interviewees (Ericsson reference team) agreed that autonomous flying taxis will have strict connectivity requirements. As [26 point out, the connections will have to be robust, support communication at altitudes between 300m and 600m, cope with speeds of around 330km/h, gather continuous and precise location data, be resistant to interference, and experience little to no loss or latency. Interviewees believed that in most cases, no single Terrestrial Network Operator would be able to provide a service with sufficient coverage for an AAM service such as this, indicating that it was likely that several TNs would be required, with satellite connectivity being used for areas outside their range, as well as for redundancy.

Due to this, the AAM Connectivity Operator provides reliable, uninterrupted connectivity to the Flying Taxi Operator and other AAM service providers by aggregating the networks of different operators, both terrestrial and satellite-based. This is a service offering as per [10

This service would involve the flying taxis roaming between these networks, always receiving the best connection available at any given location. Interviewees brought up the fact that there already exist MVNOs that offer SIM cards for IoT devices, and the AAM Connectivity Operator could be likened to this, as well as the A2G operator for in-flight broadband communication on commercial airplanes described by [27, although flying taxis will predominantly be operating within national borders.

As interviewees (Ericsson reference team) have noted, if several Terrestrial Network Operators are to be used, regulations on national roaming may need to be updated before this can happen in some countries.

As interviewees (Ericsson reference team) pointed out, it will likely be necessary for the AAM Connectivity Operator to secure agreements with multiple Terrestrial Network Operators to gain access to their network infrastructures.

This aggregator role allows Flying Taxi Operators to make an agreement with just one vendor for all of their connectivity needs. The Flying Taxi Operator thereby reduces their total number of contracts, and thus their transaction costs [15, much like with a roaming broker [28

To enable smooth handovers for flying taxis, interviewees believed that the AAM Connectivity Operator would be likely to need a core network of its own, as the A2G Operator does in one of the scenarios described by [27. This would be purchased from a Telecom Vendor. The AAM Connectivity Operator would thus act as a full MVNO, using infrastructure from several different operators.

Additionally, a continuous exchange of information between the Flying Taxi Operator and the AAM Connectivity Operator, where flight plans and real-time data are gathered, may be necessary, so connections can be planned out and communicated prior to flights taking place. This is categorised as a two-way information offering as per [10

4.2.2.5 Terrestrial Network Operator

Terrestrial Network Operators are likely to be the same companies as Mobile Network Operators, but here they have been given a different name to emphasise that their main contribution to the value network is their terrestrial network infrastructure, and that mobile phones are not being served. These operators let customers of the AAM Connectivity Operator connect to their base stations, providing terrestrial coverage. They provide a service offering as per [10.

To support UAV connectivity, Terrestrial Network Operators must either adjust their existing network equipment by tilting antennas upwards, or install new equipment [26. One interviewee also mentioned that beamforming technology could be an alternative to this. Network equipment is typically purchased from a Telecom Vendor.

4.2.2.6 Satellite Network Operator

The main role of the SNO in the value network of autonomous flying taxis is to provide satellite-based network coverage in areas that terrestrial networks do not reach, as well as to provide an additional network for redundancy. This is a service offering, as per [10This is a necessary role, as interviewees agreed that UAVs are likely to fly in areas where terrestrial networks will be unable to provide coverage due to prohibitive costs.

Although there are other possible scenarios, it is assumed for simplicity that the SNO in this case also takes on the role of the 6G NTN Operator as presented in the case for connectivity for rural and remote areas. This thus means that the SNO has the required capabilities to provide a roaming interface to the AAM Connectivity Operator. The Satellite Launcher, Ground Infrastructure Provider and Satellite Equipment Vendor, while still present, have also been removed from this model to avoid clutter.

4.2.2.7 Telecom Vendor

The Telecom Vendor plays a similar role here as in the previous use case. It provides network infrastructure and equipment to Terrestrial Operators and Satellite Network Operators. It is likely that it will sell its products, including a core network, to the AAM Connectivity Operator as well. These offerings are categorised as products as per [10

Additionally, as interviewees have suggested, the Telecom Vendor conducts IODT with the Chipset Manufacturer to ensure that the chipsets that eventually get installed in the flying taxis will be able to connect to the network adequately. This exchange is categorised as coordination as per [10.

4.2.2.8 Chipset Manufacturer

The Chipset Manufacturer coordinates with the Telecom Vendor to develop chipsets that enable the flying taxis to connect to the networks. As interviewees have pointed out, these chipsets are unlikely to be sold directly to the Flying Taxi Manufacturer, rather there will be actors in between that incorporate these chipsets into modules and components that in turn get installed in the vehicles. However, these intermediary actors have been omitted from the model for simplicity. As per [10, this can then be considered a product offering to the Flying Taxi Manufacturer.

4.2.2.9 Flying Taxi Manufacturer

The Flying Taxi Manufacturer develops and creates flying taxis. The vehicles are then made available to the Flying Taxi Operator, to be used for the mobility service. This is categorised as a product offering as per [10 although additional services or more involved partnerships are also possible, as has been seen from the intentions of current actors.

To enable connectivity, it is likely that components containing chipsets from the Chipset Manufacturer will be purchased, as interviewees have pointed out. Any other potential suppliers have been omitted.

4.2.2.10 Vertiport Operator

Vertiport Operators provide platforms for take-off and landing. Flying taxis will also be able to get their batteries charged here [29. This is categorised as a service, as per [10. Interviewees also mentioned that it may be possible for network infrastructure for AAM to be installed here.

To aid the scheduling of flights, the Vertiport Operator needs to provide data on availability to the UTM/U-Space Stakeholders. This is categorised as an information offering, as per [10.

4.2.3 Strategic moves

The value network for connectivity for autonomous flying taxis is in its early stages and can be called an opportunity network as defined by [12. Different emerging actors in the value network may have their own agendas in trying to shape the value network. This section looks into potential motivations behind different actors. Only motivations of actors involved in the provisioning or purchasing of connectivity will be considered, as other actors are considered secondary to the development of the value network.

4.2.3.1 Strategic Motives of Flying Taxi Operators

It is likely that the Flying Taxi Operator would seek out one single service that covers all of its connectivity needs, as a preference and out of necessity. Taking a transaction cost perspective [15, it makes sense for this actor to want to minimise the amount of other actors with which it makes agreements. The prevalence of roaming brokers in the telecom industry [39 indicates that this is a common mindset.

However, this may even be a prerequisite, as interviewees have suggested that only an actor like the AAM Connectivity Operator, who aggregates multiple networks and integrates them using its own core network, could provide sufficiently continuous connectivity and seamless handovers.

While it may potentially be possible for the Flying Taxi Operator to develop these capabilities itself, such an upstream vertical integration would once again require a larger number of contracts, thus increasing the transaction costs [17, and so does not make sense.

4.2.3.2 Strategic Motives of AAM Connectivity Operators

Taking a resource-based view [13, the AAM Connectivity Operator's main source of competitive advantage would be its network of partnering Terrestrial Network Operators and SNOs whose RAN it uses for its service, as well as its accumulated know-how relating to making and managing these agreements.

Another important resource would be its core network, which helps to ensure continuous connectivity, and along with this, its experience in providing this service and complying with systems like UTM and U-Space. Competitors could quite easily purchase a core network from a Telecom Vendor, but the network of partners and expertise would be harder to imitate.

It would make sense for the AAM Connectivity Operator to base its strategy on exploiting these resources and capabilities [30. One obvious way to do that would be to expand and provide its services internationally. The accumulated know-how related to managing the network and negotiating with other actors would certainly be transferable between many different countries, especially those that use a common air traffic management system, such as U-Space. However, if the service were to be provided directly by a Terrestrial Network Operator using its own network, this may not be as likely, as the resources would be less transferable to other geographies.

The geographical scope of operations for AAM Connectivity Operators will be limited by the availability of TN infrastructure, meaning that they will be dependent on the resources of Terrestrial Network Operators. As resource dependency is one of the main reasons to enter into inter-firm relationships [40, this could be an incentive to invest in installing more network infrastructure as a joint venture with Terrestrial Network Operators.

4.2.3.3 Strategic Motives of Terrestrial Network Operators

As mentioned, Terrestrial Network Operators are likely to be the same companies that are referred to as MNOs in the previous use case. That means that their main resources are their network infrastructure, which includes RAN and a core network, and their spectrum rights. These resources are valuable, though not rare or inimitable among direct competitors, and they are to a limited extent able to be substituted for satellites. They are thus hardly VRIS resources, as per [13.

The necessity for Terrestrial Network Operators to modify their existing infrastructure or invest in new equipment to support UAV connectivity underscores the concept of asset specificity as described [14. Specifically, it highlights how the unique requirements of connectivity for flying taxis create a need for specialised assets tailored to this application. This asset specificity can increase the costs and risks associated with investment decisions. This suggests that there might be an incentive for Terrestrial Network Operators who pursue these investments to vertically integrate downstream.

It has been strongly suggested by interviewees that an AAM connectivity service would require the resources of several Terrestrial Network Operators as well as SNOs to be successful. For one Terrestrial Network Operator to step up and try to take on this aggregating role, its competitors would be required not only to acquiesce to this but actively cooperate, which they may be reluctant to do.

Resource dependence is one of the main reasons for companies to enter into inter-firm relationships [40. Considering this, an AAM Connectivity Operator could instead be created as a joint venture by several Terrestrial Network Operators, if it is not an independent third party.

Alternatively, a Terrestrial Network Operator may ignore the need for other operators, and start out by providing a more limited service, only offering connectivity in specific areas where it can reliably provide coverage using its own infrastructure.

Following this, it could gradually increase its area of coverage. If static air corridors are established or other areas where the demand for AAM is high are identified, installing RAN here would certainly make sense. From a resource-based view [13, this increasing base of RAN that supports AAM, along with the increasing list of established customers, would constitute valuable and rare resources if done before competitors.

On the other hand, Terrestrial Network Operators would have to develop the appropriate skills for planning out connectivity and preparing for seamless handovers to provide this service. New relationships with Flying Taxi Operators would also need to be established. This would require time and resources to do, as well as incur increased transaction costs, which may dissuade potential Terrestrial Network Operators from pursuing this role [17.

4.2.3.4 Strategic Motives of Satellite Network Operators

SNOs' main resources are their fleets of satellites, and their associated networks, which are able to support AAM. From a resource-based view, it would make sense for SNOs to base their strategy on exploiting these resources as much as possible [30.

One obvious way to do this would be to offer services internationally. Assuming a high level of standardisation across the world when it comes to the connectivity of flying taxis, this would be very easily achievable, as any satellites deployed could immediately be used in many different countries.

This could indicate that there is an incentive for SNOs to support the development of the AAM industry around the world, as that would allow them to better take advantage of their assets. Due to this international scope, it is unlikely that SNOs would be willing to take on any additional roles in specific countries.

4.2.3.5 Strategic Motives of Telecom Vendors

Telecom Vendors' main resources are their know-how and expertise in developing telecommunication equipment. It would make sense for Telecom Vendors to want to exploit these resources as much as possible [30. As with the previous use case, this means that they are likely to push for standardisation in the wireless technology of the flying taxis to promote compatibility with their products at the lowest cost.

4.2.4 Money flows

In the following section, money flows are discussed. In Figure 7, one likely scenario is presented. After that, each exchange is explained further, with some potential alternate scenarios also discussed.

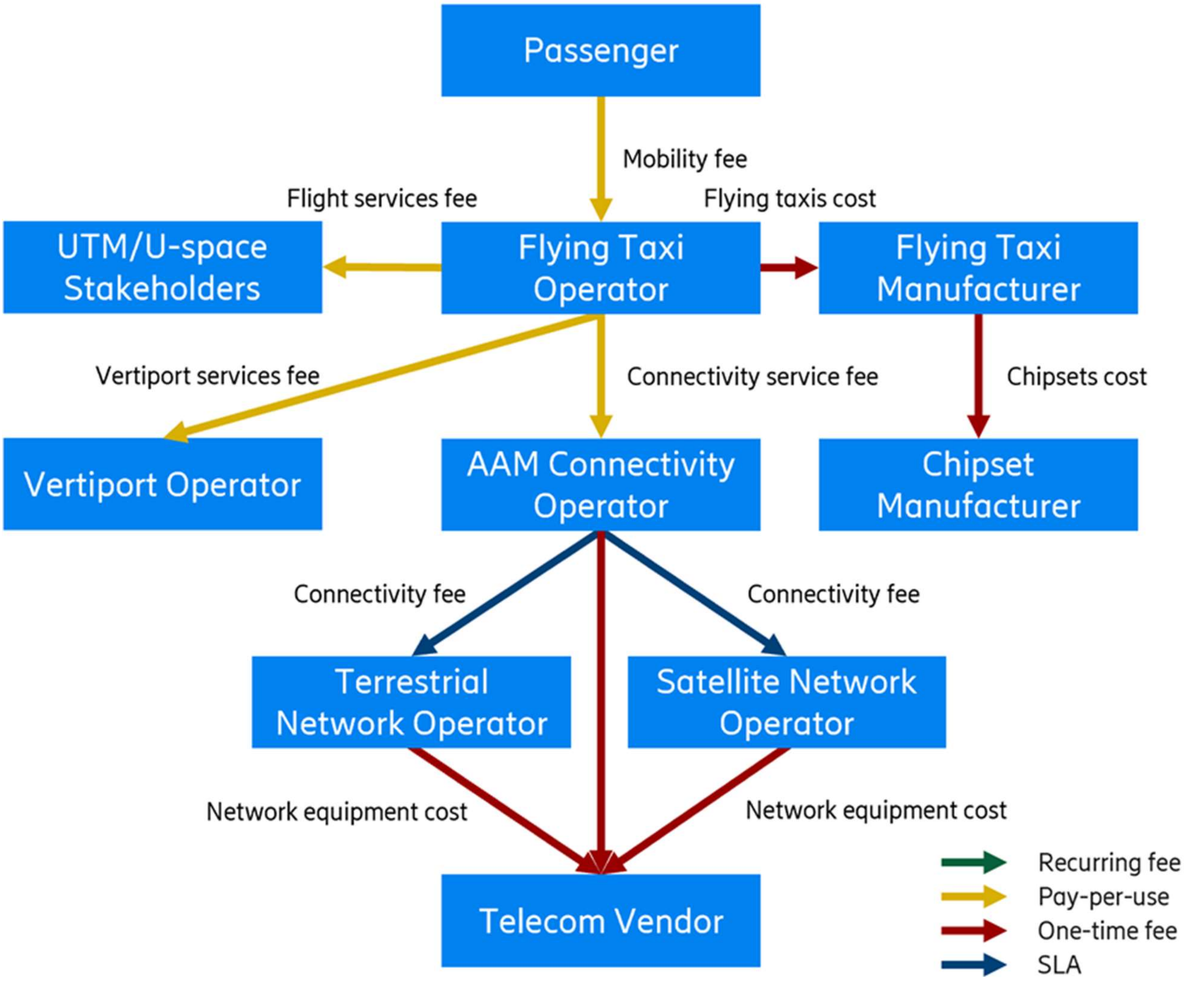

Figure [7: Money flows for connectivity for autonomous flying taxis.

4.2.4.1 Passenger

The money flow starts from the Passenger, who pays a fee to the Flying Taxi Operator for each flight. Typically, when a user only occasionally uses a service, it is more attractive for the customer to only pay when they use the service [21. The pricing could be calculated based on factors such as the distance flown, time of day, traffic, current demand, and other factors. If a passenger uses the service frequently, they may prefer a subscription-based option for convenience and potential cost savings.

4.2.4.2 Flying Taxi Operator

The Flying Taxi Operator purchases eVTOLs from the Flying Taxi Manufacturer. This is likely to be in the form of a one-time-fee model, since they are durable products and used frequently [23.

An alternative to this model would be a recurring cost for leasing the eVTOLs. That would reduce the capital expenditure required of a Flying Taxi Operator [20), and allow them more freedom to modify the size of their fleet. In a situation where the Flying Taxi Manufacturer takes on some of the responsibilities of operating the service, this could be a more likely scenario.

Vertiport Operators are likely to get paid whenever flying taxis land on their platforms, perhaps with additional fees based on what other provided services, such as charging. Since the use of vertiports will be based on how often passengers choose to fly to them, it is likely to be sporadic and irregular.

This suggests that Flying Taxi Operators would prefer their revenue model to employ a pay-per-use model [21. However, the fact that Vertiport Operators must make their vertiports available and maintain them regardless of whether UAVs land on them or not, which thus constitutes a continuous expense, could suggest that they might prefer a subscription model [20).

In order to be allowed to operate, Flying Taxi Operators will have to pay the UTM/U-Space Stakeholders for their services. While there may be one-time or recurring certification fees, it is likely that this will mainly be charged for based on the distance flown, as suggested by one interviewee, who referred to the fact that traditional air traffic management uses this revenue model. This model is thus common practice for this type of service, making it likely that customers would expect this form of payment, as per [20.

The Flying Taxi Operator must pay the AAM Connectivity Operator in order for its eVTOLs to keep them connected for the duration of each flight. The Flying Taxi Operator is unlikely to possess advanced knowledge on connectivity, and this is a relatively sophisticated service with some customisation involved, so employing a usage-based model would be in line with [31. Metrics used to determine the amount paid could include the distance travelled or amount of data. This revenue model could also serve to make the service more accessible to a broader range of AAM actors [21.

4.2.4.3 Flying Taxi Manufacturer

The Flying Taxi Manufacturer purchases modules or gateways that contain chipsets that enable connectivity for the flying taxis. These are likely to be purchased outright, with an up-front payment, as that is the traditional model used for goods such as these [22.

4.2.4.4 AAM Connectivity Operator

The AAM Connectivity Operator pays Terrestrial Network Operators and SNOs for access to their networks. Due to the strict connectivity requirements and the fact that they do not own much of the network infrastructure that enables their service, the AAM Connectivity Operator is likely to want a guaranteed high level of service from its providers.

Interviewees (Ericsson reference team) suggested that service-level agreements (SLA) with KPI-based penalties would be suitable for this. Using a performance-based model such as this would be in line with [31, who note that this revenue model is ideal for customers who wish to share risk with its providers, as well as for services that involve a high degree of collaboration among actors within a value network.

In practice, an SLA would be similar to a pay-per-use model based on data usage, but with KPI-based payment deductions in the case that connectivity performance does not meet the agreed upon requirements. This agreement would then act as a kind of insurance for the AAM Connectivity Operator [32, that somewhat redistributes the responsibility for the functioning of the service.

Additionally, the AAM Connectivity Operator will purchase some network infrastructure for themselves, including a core network. This will be provided by the Telecom Vendor.

As discussed in the previous use case, this purchase has traditionally been in the form of a one-time fee, and so will probably continue that way due to it being considered common practice [20. However, a subscription model in which the Telecom Vendor provides continuous updates and support could also be possible, as that would accommodate for AAM Connectivity Operators with less technical expertise in running a core network [20,31and give the Telecom Vendor more predictable revenue [20,21].

4.2.4.5 Terrestrial Network Operator

The Terrestrial Network Operator also purchases network equipment from the Telecom Vendor. This equipment has typically been purchased outright for a one-time fee, and this is likely to continue due to it being common practice [20.

4.2.4.6 Satellite Network Operator

The outward flowing money of the SNO in this use case is likely to be similar to that of the previous use case.

4.3 In-Flight Broadband Connectivity for commercial airplanes

Business modelling for in-flight connectivity for commercial airplanes has already been investigated by [27. The paper identified the A2G Operator and Cabin System Operator as new actors in the in-flight connectivity value chain. Through interviews with SAS and a workshop, findings from the paper have been revisited and are presented below.

4.3.1 Value network

The following section will briefly summarise the findings on actors from [27. The different roles are presented in Figure 8.

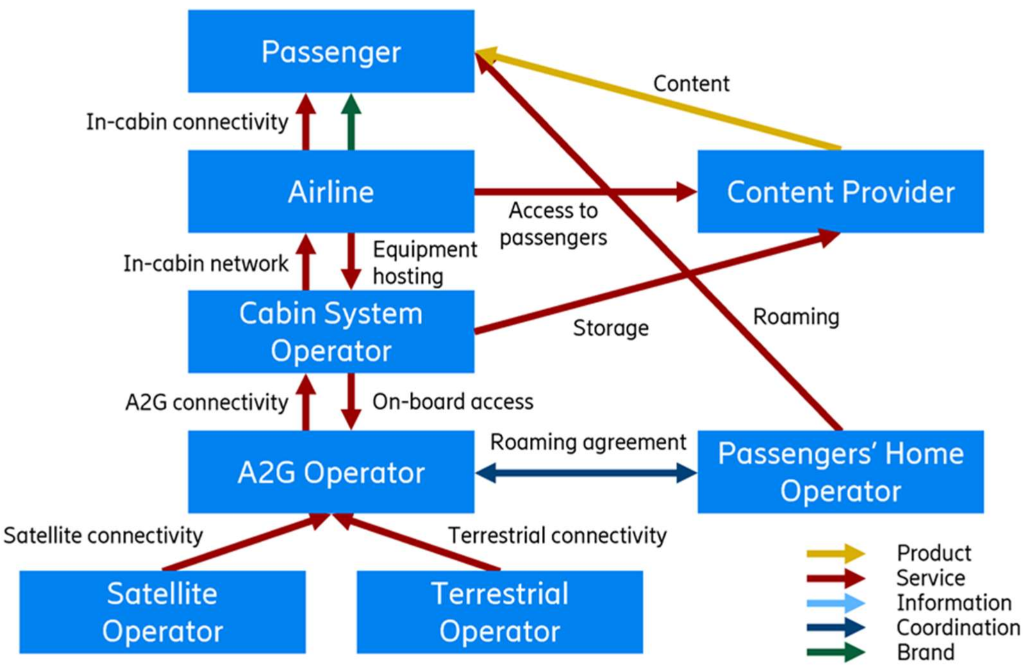

Figure 8: Value network for in-flight broadband connectivity for commercial airplanes

4.3.1.1 Passenger

Passengers benefit from Air-to-Ground (A2G) connectivity services, which enhance their in-flight experience by providing internet access.

4.3.1.2 Airline

Airlines play a hosting role in the A2G chain, providing space for the necessary equipment. They leverage this service to potentially increase ticket prices or attract more customers by offering in-flight connectivity. Furthermore, Airlines may offer special deals with content providers to their passengers. This will be discussed more in later sections.

4.3.1.3 Cabin System Operator

Cabin System Operators manage the in-flight network, offering both Wi-Fi and LTE services. They act as intermediaries, purchasing A2G connectivity and providing it to passengers.

4.3.1.4 A2G Operator

A2G Operators manage the connectivity between cabin system operators and terrestrial or satellite networks. They act as a consortium, coordinating services and capacity from multiple operators. This setup helps streamline interactions and agreements across different countries and regulations.

4.3.1.5 Content Provider

Content Providers can offer special deals through partnerships with Airlines. In this case, “content” can signify both digital offerings such as video streaming, as well as physical goods and services. They may also store digital content in the cabin system operator’s network to provide content for passengers offline.

4.3.1.6 Satellite and Terrestrial Operators

Satellite and Terrestrial Operators provide backhaul connections and ensure connectivity to the core networks of passengers' home networks, either through letting the airplane connect to satellites or terrestrial base stations. Wherever possible, the in-flight network will attempt to secure a terrestrial connection, but will switch to a satellite-based connection when this is no longer possible. Satellite Operators play a crucial role in maintaining the A2G link, especially for areas with insufficient terrestrial coverage.

4.3.1.7 Passenger’s Home Operator

Home operators offer on-board connectivity as an extension of their services, treating A2G Operators as roaming partners.

4.3.2 Challenges for airlines

Airlines using GEO satellites face significant challenges due to limited suppliers and proprietary solutions, which lead to minimal competition and high costs. Investment cycles are very long because aircraft are designed to be in service for around 20 years, with the true service life often being extended by another decade.

Installing new systems requires taking planes out of service, causing costly production losses. Furthermore, hardware expenses are very high, as are the data costs paid to satellite operators. Developing a viable business case for customers to pay for connectivity is thus currently challenging for airlines.

The technological aspect poses additional challenges. Aircraft equipment requires special regulatory compliance and certification, leading to long lead times for changes.

This environment is tough to navigate amid rapid technological advancements. Airlines must carefully time their technological investments to avoid obsolescence and costly replacements. Staying updated with technology without prematurely committing to a specific solution is crucial, as outdated technology can be expensive and complex to upgrade. There is also a need for interoperability to avoid dependency on proprietary solutions from specific suppliers.

Different airlines adopt varied strategies. Traditional network airlines have mostly passive strategies regarding connectivity, whereas many US airlines are moving towards a model where the service is offered for free. However, this approach is currently unaffordable for most European airlines. The hope is that new players and technologies will reduce the cost of providing these services, but timing remains uncertain.

Reliability and maintenance, particularly for antennas, also pose significant operational problems. Continuous maintenance is challenging because taking planes out of service is undesirable, leading to delays in fixing issues.

4.3.3 Increasing Revenue streams

Airlines can examine various strategies to enhance revenue through onboard services and making connectivity solutions profitable. Partnerships with content providers, such as Netflix or Amazon, can attract passengers by offering exclusive content and discounts. The idea is to develop a retail solution where airlines earn commissions or kickbacks from sales generated through these partnerships.

Creating unique offers for passengers and incorporating loyalty programs can drive engagement and additional revenue. Passengers could earn points for purchases or use points to buy products, seamlessly integrated into the airline's digital platform. This approach not only enhances the passenger experience but also incentivises non-members to join the loyalty program. This way, the connectivity becomes a way to entice and attract customers, who can then be directed towards other, more profitable offerings.

Airlines can control the setup with content providers, deciding which services and products to feature, and earning revenue from these arrangements. Offering free services for a limited time or at tiered quality levels (e.g., free SMS, paid premium services) are other methods that could be considered to attract and retain passengers to use in-flight connectivity services.

4.3.4 Money flows

The following section presents the money flows for in-flight broadband connectivity for commercial airplanes. [27 developed several money flows models.

One model, called "Free services", assumes that the passenger pays the airline for in-flight connectivity through higher ticket prices, and that the airline then distributes money down in the chain of actors. This is akin to the traditional connectivity model that airlines use today, and will thus not be discussed further.

The second scenario, "On-board fee", involves the passenger instead paying their home operator a roaming fee which is then distributed to the other actors. This model is presented in Figure 9.

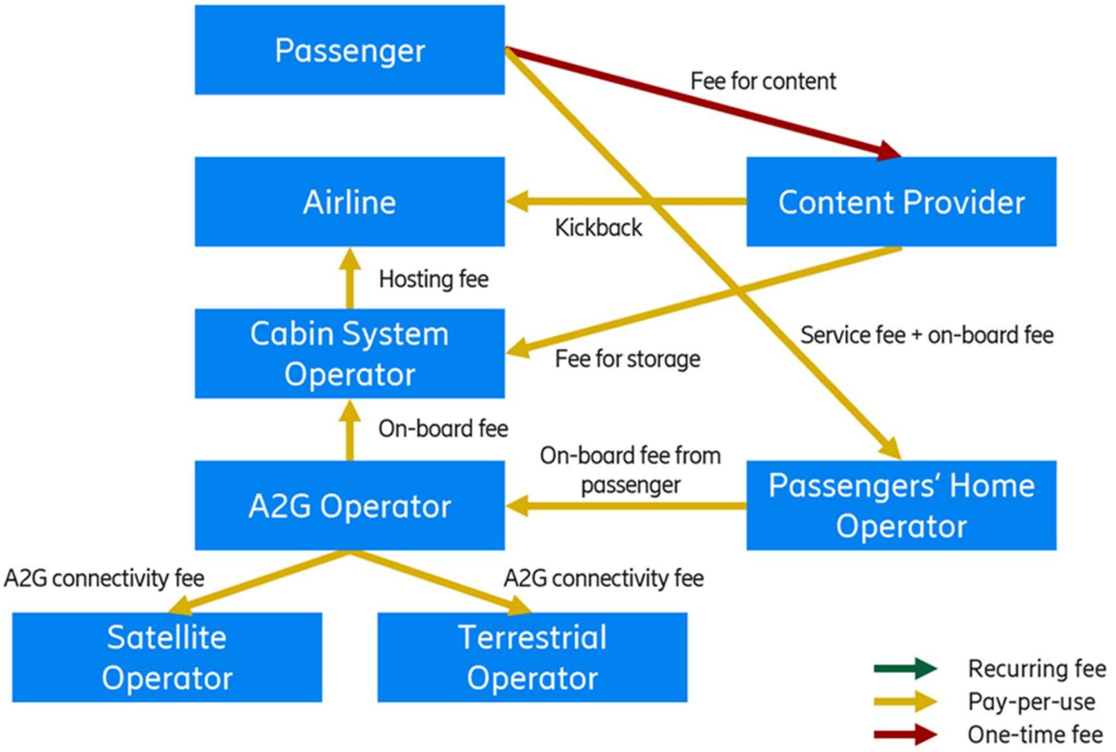

Figure [9: "On-board fee" model for in-flight broadband connectivity for commercial airplanes

Airlines aim to offer competitive ticket prices while providing in-flight connectivity. Typically, airlines might increase ticket prices to cover connectivity costs. To avoid this, the "On-Board Fee" model allows airlines to provide in-flight connectivity without direct charges to passengers.

In this model, Passengers pay for the connectivity through their Home Operator, either via subscriptions or pay-per-use deals. This approach keeps Airline costs unchanged while still enabling a connectivity service. Revenue is collected by the Home Operator, who then pays the A2G Operator based on network usage. The Cabin System Operator charges the A2G Operator for networking services and pays a hosting fee to the Airline according to usage.

Considering that making in-flight connectivity profitable is a major challenge for airlines, this model becomes especially promising. It enables airlines to offer new services and generate additional revenue without increasing ticket prices. The risk of the connectivity business model is effectively shifted over to the A2G Operator, who becomes an independent actor that simply pays an on-board fee to be able to conduct business on the airplane. The airline provides a platform for a business model, rather than being a driver of it.

Additionally, partnerships between content providers and airlines can still exist, further enhancing the potential appeal of this model. Special offers can be made to passengers, where content providers are paid directly by passengers, and airlines receive a kickback from these transactions.

4.4 Logistics Centre Monitoring with a Swarm of Drones

In intermodal logistics centers such as the Logistic Center Austria Sued (LCAS), containers are transferred between rail and road transport, typically at the edges of urban areas.

To improve efficiency, a drone-based monitoring system is proposed to perform periodic state estimation of the logistics terminal.

A drone swarm equipped with cameras captures aerial imagery to identify container positions and detect operational anomalies such as congestion, incorrect container placements, or idle equipment.

The collected data supports real-time route re-planning for trucks and reach stackers, helping reduce unnecessary movements, lower energy consumption, and decrease the CO_2 footprint of the terminal.

In the long term, this approach also lays the foundation for coordinated operations with autonomous electric vehicles and reliable V2V and V2I communication, enhancing overall terminal efficiency and throughput. Further information about this use case can be found in 6G Sky deliverable D1.5 while the following sections focuses on the value network and money flows.

4.4.1 Value Network

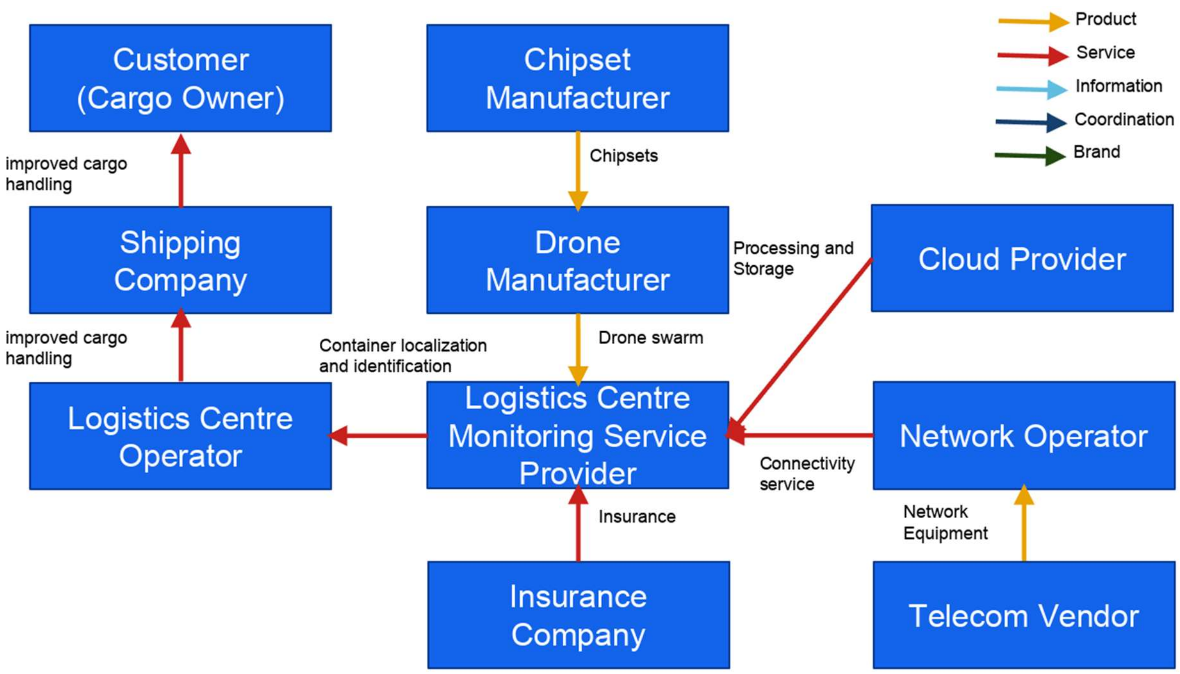

Figure [10: Value network for logistics centre monitoring

4.4.1.1 Logistics Centre Operator

It manages the logistics hub, including both physical infrastructure (yard, loading areas) and operational systems. The operator is responsible for integrating drone-based monitoring into site logistics. It activates the monitoring service to improve efficiency in locating and identifying containers and to support modal transitions (e.g., between rail and road).

4.4.1.2 Shipping Company and Cargo Owner

The Shipping Company utilizes the logistics hub to transfer goods between transport modes, such as rail and road. It benefits from improved transparency, faster container handling, and reduced delays through real-time container identification and location data. These operational improvements also indirectly benefit the actual Cargo Owner — the Shipping Company's customer — by enabling more reliable and timely transport of goods. However, the Cargo Owner's benefits are indirect, as they arise from the enhanced efficiency and coordination achieved within the logistics hub.

4.4.1.3 Logistics Centre Monitoring Service Provider

It is responsible for operating the drone-based monitoring system. It deploys the drone swarm, manages flight operations, handles data capture, and delivers processed results to the logistics centre operator and, where relevant, to shipping companies.

4.4.1.4 Drone Manufacturer

It provides the drone swarm platform used for monitoring andsupplies both the physical drone hardware and integrated sensor and communication systems necessary for real-time container recognition and tracking.

4.4.1.5 Chipset Manufacturer

It supplies the chipsets embedded in the drones to enable communication. Intermediate suppliers and integrators are omitted.

4.4.1.6 Cloud Provider

The cloud provider offers the computing and storage infrastructure required to host and process sensor data collected by the drones. It supports real-time analytics, enabling live visualization of container locations and statuses.

4.4.1.7 Network Operator

It ensures the communication backbone for drone operations and data transfer. It provides both local connectivity for drone swarm coordination and uplink to the cloud for analytics and result delivery.

4.4.1.8 Telecom Vendor

It provides network infrastructure components used by the Network Operator. This includes base stations, radio equipment, and supporting hardware needed for reliable drone swarm connectivity in the logistics centre environment.

4.4.1.9 Insurance Company

It provides mandatory insurance coverage for the drone fleet, in accordance with EU regulations for unmanned aerial systems. Also, it covers liability and operational risk during monitoring operations.

4.4.2 Money flows

This section describes the money flows for the real-time logistics centre monitoring service enabled by a drone swarm. In this model, the Logistics Centre Operator acts as the primary customer, contracting the monitoring service to enhance operational efficiency, reduce unnecessary container movements, and lower the CO_2 footprint.

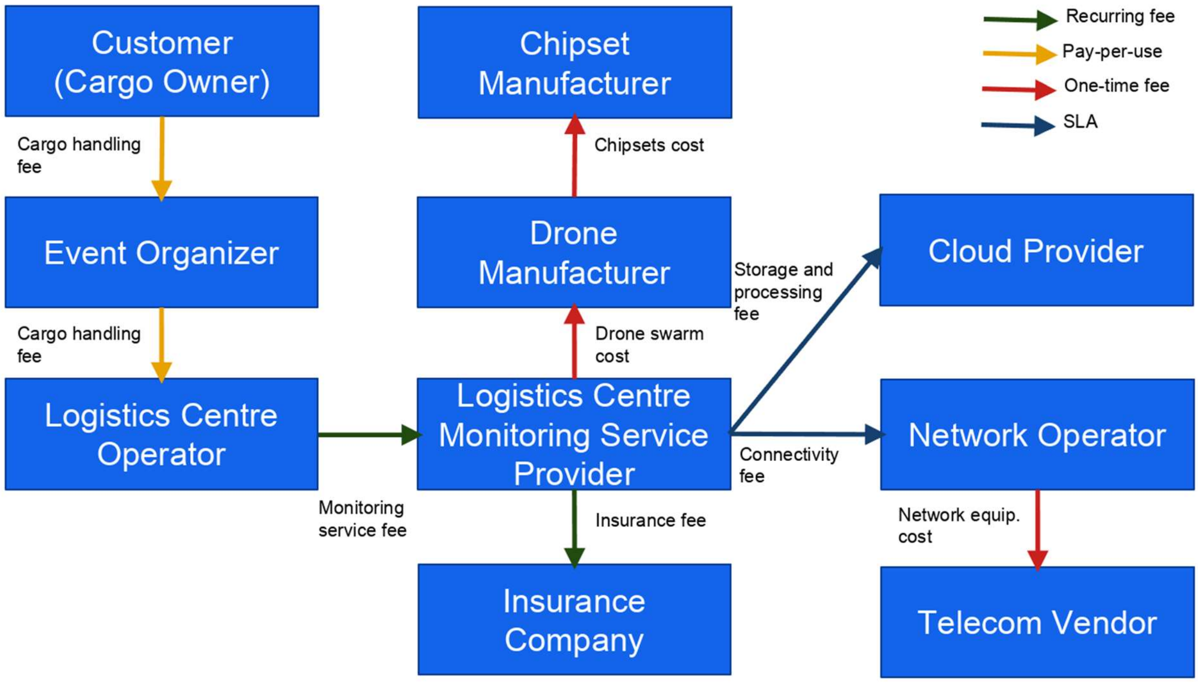

Figure [11: Moneyflows for logistics centre monitoring

The Logistics Centre Operator pays a monitoring service fee to the Logistics Centre Monitoring Service Provider. This fee is typically structured on a subscription basis (e.g., monthly or quarterly). Through this arrangement, the Logistics Centre Operator gains access to continuous or periodic updates on container positions and terminal state, enabling better route planning and resource allocation.

Shipping Companies, while benefiting from improved logistics operations and reduced delays, do not directly pay for the monitoring service. Instead, they experience indirect value through the enhanced efficiency provided by the Logistics Centre Operator's investment in monitoring capabilities. However, in some future business models, it could be considered that premium services (such as prioritized container handling) could involve separate fees paid by Shipping Companies.

The Logistics Centre Monitoring Service Provider incurs several operational and capital expenses to deliver the service. It pays a recurring insurance fee to the Insurance Company to ensure compliance with EU drone operation regulations.

It also pays a connectivity fee to the Network Operator, usually governed by a Service Level Agreement (SLA), to guarantee reliable real-time drone communication and data transfer. Similarly, a cloud service fee is paid to the Cloud Provider, also under an SLA, covering storage and processing of the sensor data and the provision of analytics services. Capital investment is required for drone acquisition.

The Monitoring Service Provider pays a one-time purchase cost to the Drone Manufacturer for the drone swarm platform. In turn, the Drone Manufacturer pays a one-time chipset cost to the Chipset Manufacturer for the necessary communication hardware embedded into the drones.

Additionally, the Network Operator, who ensures connectivity within the logistics hub, purchases necessary network equipment from the Telecom Vendor, incurring a network infrastructure purchase cost to maintain robust communication services for drone operation.

This money flow model supports a structured and scalable service delivery chain, where the Logistics Centre Operator can dynamically enhance operational efficiency while service providers share the cost and risk across different layers of the technology stack.

4.5 Parking Lot Monitoring for Large Fair Events with a Swarm of Drones

Drone swarms can be used to monitor and manage parking areas and traffic flow at large trade fairs and event venues. These events often feature dynamically organized parking zones that differ depending on the specific fair, making flexibility and adaptability crucial.

A swarm of drones can provide real-time aerial monitoring, enable automated classification of vehicles, and support adaptive coordination of traffic flows—particularly in areas that are difficult to oversee with static infrastructure.

This use case explores how such a drone-based monitoring system is integrated into the value network of large-scale events. It addresses the operational and business relationships among stakeholders, including visitors, exhibitors, event organizers, the fair venue operator, and various service and technology providers.

The system enables a premium parking experience for attendees through real-time information and routing, while supporting the venue in optimizing space utilization and preventing congestion.

The monitoring capability is typically activated for larger or more complex events and is offered as an optional, per-event service by the Fair Venue Operator.

The service is delivered by a dedicated Parking Monitoring Service Provider, supported by a layered ecosystem of network, cloud, drone, and component suppliers.

The financial and operational flows between these parties are defined by a mix of pay-per-use fees and service-level agreements, forming a scalable and demand-driven model for modern event logistics.

4.5.1 Value Network

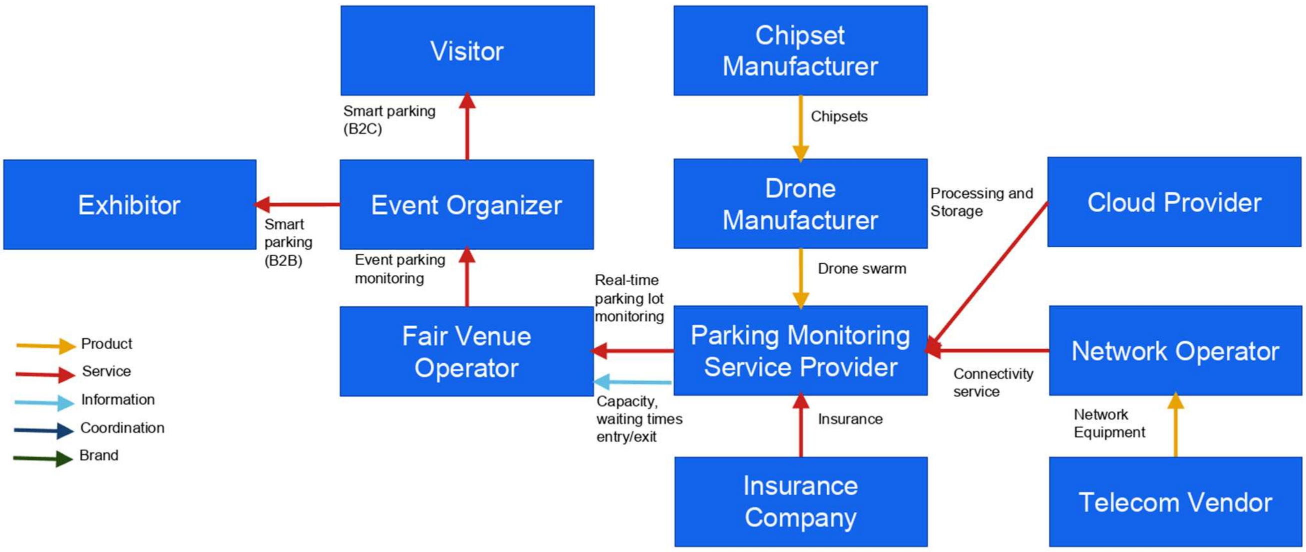

Figure [78: Value network for real-time parking lot monitoring.

4.5.1.1 Visitor

Visitors can use on-premise parking (often as part of premium packages). They benefit from real-time information about available spaces and optimal entry/exit routes.

4.5.1.2 Exhibitor

Exhibitors require on-premise parking for operational efficiency. They benefit from real-time information about the available capacity and guidance for access and navigation.

4.5.1.3 Event Organizer

The event organizer offers parking services to both exhibitors and visitors. It coordinates with the fair venue operator in advance to plan parking capacity and distribution based on expected attendance. Acts as a key customer of the parking monitoring service.

4.5.1.4 Fair Venue Operator

The Fair Venue Operator manages the physical venue, including its on-premise parking facilities. This role is consistent across all events, regardless of size or organizer. In contrast, advanced services such as real-time parking monitoring are optional and event-dependent. These services are typically activated for larger or high-profile events, based on the requirements of the Event Organizer and the expected complexity of traffic and visitor flows.

4.5.1.5 Parking Monitoring Service Provider

The Parking Monitoring Service Provider is responsible for the operation of the monitoring. This includes the operation of the drone swarm including all required equipment and services. Manages the drone swarm, its deployment, and the delivery of monitoring data to relevant stakeholders.

4.5.1.6 Drone Manufacturer

The Drone Manufacturer supplies the drone swarm. This includes the drone platform including all sensors and the communication equipment required for monitoring operations.

4.5.1.7 Chipset Manufacturer

Provides the chipsets that are required for the drone swarm connectivity. Similarly to other use cases (e.g. see Section 78 other parties that are between the chipset manufacturer and the drone manufacturer have been omitted.

4.5.1.8 Cloud Provider

The Cloud Provider supplies scalable computing resources for storing and analysing the sensor data in order to gather the real-time parking lot information.

4.5.1.9 Network Operator

The Network Operator provides the connectivity within the drone swarm and for the sensor data transfer to the cloud provider, as well as the transfer of the analysis results.

4.5.1.10 Telecom Vendor

The Telecom Vendor plays a similar role here as in the previous use cases. It provides network infrastructure and equipment to Terrestrial Network Operators.

4.5.1.11 Insurance Company

The Insurance Company provides coverage of the the drones, as required under EU drone regulations.

4.5.2 Money Flows

This section outlines the money flows for the real-time parking lot monitoring service used at large-scale trade fairs and event venues.

The model assumes a flexible, event-driven deployment of a drone-based monitoring system, activated based on demand and scale.

It allows the Fair Venue Operator to offer premium parking services without bearing all associated costs, while enabling Event Organizers to enhance the attendee experience through real-time information and streamlined access.

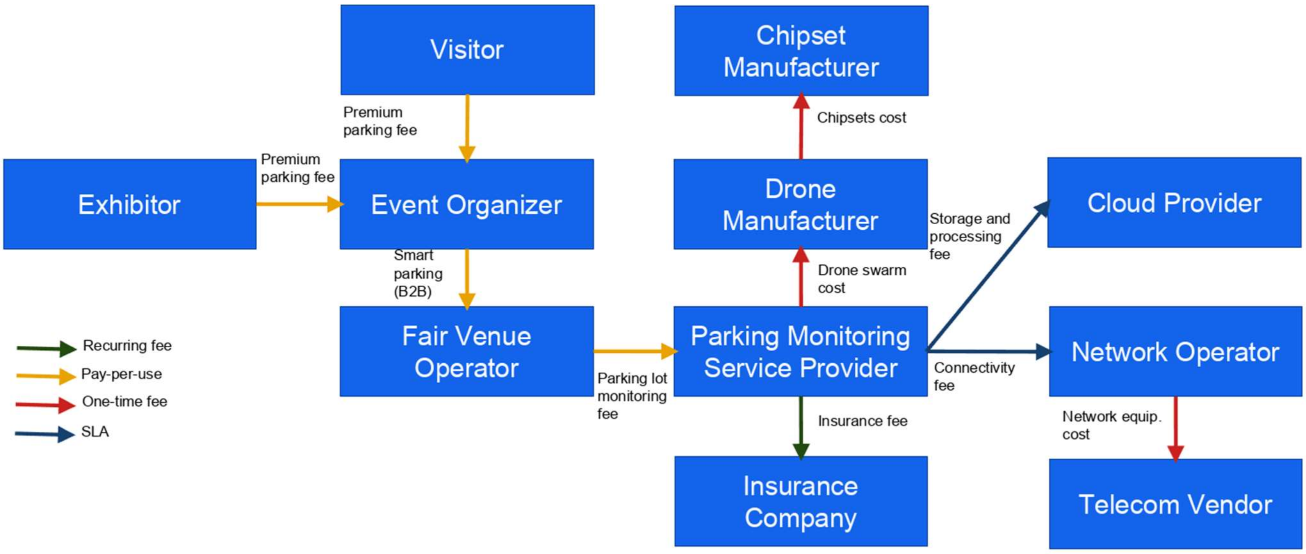

Figure [13: Money flows for real-time parking lot monitoring.

In this model, both exhibitors and visitors pay a premium parking fee to the Event Organizer. This pay-per-use fee grants them access to prioritized on-premise parking that is enhanced through real-time availability data and optimized routing. The Event Organizer, acting as an intermediary, pays a corresponding Smart Parking (B2B) fee to the Fair Venue Operator. This fee covers the use of the physical parking infrastructure and supports differentiated service levels for premium users.

To enable the real-time monitoring capability, the Fair Venue Operator pays a parking lot monitoring fee to the Parking Monitoring Service Provider. This is also a per-use fee, triggered on a per-event basis when the service is required. Smaller or lower-complexity events may choose not to activate this service, highlighting its optional and demand-driven nature. This arrangement allows the Fair Venue Operator to maintain a flexible and cost-efficient operations model.

The Parking Monitoring Service Provider is responsible for the operation of the drone swarm, data collection, and real-time analytics delivery.

To support this, it incurs several downstream costs. A recurring insurance fee is paid to the Insurance Company to comply with European drone operation laws. Additionally, the provider pays a connectivity fee to the Network Operator under a Service Level Agreement (SLA), ensuring ultra-reliable, low-latency communication for the swarm. It also pays a storage and processing fee to the Cloud Provider, likewise governed by an SLA, for hosting and analyzing sensor data in near real time.

The Parking Monitoring Service Provider must also make capital investments. It pays a one-time purchase fee to the Drone Manufacturer to acquire the drone swarm, including hardware, sensors, and communication modules.

The Drone Manufacturer, in turn, pays a one-time fee to the Chipset Manufacturer for the necessary chipsets that power the drone connectivity and onboard processing. Finally, the Network Operator purchases network infrastructure from the Telecom Vendor, incurring a network equipment cost to maintain the quality and coverage required for inter drone communication (for coordination) and data communication.

This money flow model distributes costs and responsibilities across a multi-layered value chain. It enables Event Organizers to offer premium services to attendees without direct investment in infrastructure, and allows the Fair Venue Operator to scale service quality based on event needs.

Meanwhile, the Parking Monitoring Service Provider acts as the operational core, supported by a network of hardware, connectivity, and cloud suppliers, each participating in a flexible, usage-driven revenue structure.

4.6 Conclusions and Comparisons

In the presented value networks, it is evident that new roles will need to be played. In the case of rural and remote connectivity, focus was on the 6G NTN Operator role which delivers the roaming interface between MNOs and SNOs.

In autonomous flying taxis, the AAM Connectivity Operator aggregates terrestrial and satellite networks to provide a full connectivity service to keep flying taxis connected.

This role is similar to that of the A2G Operator that was identified in the case for in-flight broadband connectivity. In each case, there is still uncertainty regarding which actors will ultimately assume these responsibilities with players having different strategic motives to act in the value networks.

The certainty of the presented value networks varies. Companies like Apple [7 and Starlink [6 are challenging the rural and remote connectivity use case, suggesting that alternative constellations might emerge.

In contrast, in the value network for flying taxis, is it difficult to envision drastically different scenarios. The in-flight connectivity network remains uncertain due to unclear passenger willingness to pay. If LEO technology suffices, Wi-Fi might eliminate the need for an A2G Operator. This raises questions about the value of investing in advanced connectivity services without assured consumer demand.

In-flight connectivity currently faces low willingness to pay among passengers, necessitating the exploration of additional revenue streams to make it viable. This challenge raises the question of whether rural and remote connectivity might encounter similar issues, requiring innovative approaches to generate sufficient revenue and sustain the service.

In the case of parking lot monitoring at large fair events, the value network centers around a Parking Monitoring Service Provider, who enables on-demand monitoring of event parking areas using drone swarms and real-time data processing.

Unlike the infrastructure-driven connectivity use cases, this role is activated flexibly on a per-event basis and is linked to premium parking services offered to visitors and exhibitors. While the service promises significant operational benefits for both event organizers and attendees, the overall willingness to pay remains uncertain, particularly given the potentially high costs associated with deploying and operating a drone swarm at scale.

Similarly, the logistics monitoring use case introduces a service where a drone swarm locates and identifies shipping containers in a logistics center. Here, the focus is on operational efficiency and inventory management, with the value network organized around a Logistics Monitoring Service Provider. Since logistics centers directly benefit from improved asset visibility and faster operations, the willingness to pay is expected to be strong, making this use case comparatively more robust in terms of business viability.

5 Business model canvas analysis

5.1 Connectivity for rural and remote areas

[33 defines the network focal as the entity whose business model relies on the value network. In the value network for connectivity for rural and remote areas, the 6G NTN Operator role was identified as the focal actor in this network, owing to the fact that this role delivers the actual direct-to-device NTN connectivity service.

This is done by partnering with traditional Satellite Operators and delivering the service through MNOs to the end-customer. This section presents a business model canvas based on [6 for the 6G NTN Operator to highlight what this role entails in the value network. Some aspects may only be relevant if the 6G NTN Operator is its own independent actor. The business model canvas is presented in Figure 10.

Key Partnerships	Key Activities	Value Proposition	Customer Relationships	Customer Segments
• SNOs • Telecom Vendors • MNOs	• Maintaining and monitoring network performance and reliability • Building the network **Key Resources** • Core network • RAN software functionality and baseband units • OSS/BSS	• Provides the necessary interface between MNOs and SNOs to enable coverage in rural and remote areas via satellite	• Personal assistance/technical support **Channels** • Direct channels	• Customer-facing MNOs/MVNOs
Cost Structure • Core network and RAN (purchase or lease) • Fee for satellite capacity • Overhead costs			**Revenue Streams** • Roaming fee	

Figure [14: Business model canvas for 6G NTN Operator

5.1.1 Customer Segments

For this end-consumer-centred use case, there is only one main customer segment, consisting of customer-facing MNOs and MVNOs. The value proposition itself has been specified to suit this kind of company, and so they are the only ones who can take full advantage of it.

5.1.2 Value Propositions

The value that is offered by the 6G NTN Operator is the provision of the necessary interface between an MNO and an SNO to enable customers of the MNO to get coverage through the SNO's network when outside the range of the MNO's network. An important aspect of this offering is that very little is required of the MNO in terms of labour or financial investment. Since it is the 6G NTN Operator and the SNO that provide the actual network, the MNO only needs to negotiate a roaming agreement and then enable its customers to opt in to the service. This means that MNOs stand to increase their revenue at virtually no risk.

5.1.3 Channels

As this kind of agreement is likely to be between relatively large companies, negotiations and sales will probably be done through direct channels as defined by [34. The 6G NTN Operator may contact MNOs directly to attempt to sell their service, or MNOs may contact them if their reputation is strong enough.

5.1.4 Customer Relationships

While aspects such as billing may be automated, the customer relationship type from [6 that the 6G NTN Operator will provide will likely be some form of dedicated personal assistance where they will find the best solution for each customer.

5.1.5 Revenue Streams

The main revenue stream for the 6G NTN Operator will come from MNOs whose customers are roaming on their networks. The money received for providing this service will likely be a usage fee as defined by [34, based on the amount of voice calls, text messages and mobile data used, as is normally the case with terrestrial roaming [35. They may also charge some form of recurring subscription fee for access to the service [80.

5.1.6 Key Resources

Of the resources defined by [34, the main resources the 6G NTN Operator will have are physical ones. This includes network infrastructure that the 6G NTN Operator owns, consisting of the core network, RAN and BSS, which are necessary to provide this service.

5.1.7 Key Activities

The key activities are maintaining and monitoring the network to ensure performance and reliability. The network is the main offering that the actor has, so ensuring that it works as well as possible is of the utmost importance. This will involve monitoring values from the core network, inspecting hardware placed at gateways, and cooperating with the SNO to ensure that the satellites are working as they should.

5.1.8 Key Partnerships

There are several actors that the 6G NTN Operator must enter into partnerships with to provide this service. [34 highlights partnerships as a means to access resources and activities of others. This is the main purpose of partnerships for the 6G NTN Operator.

The SNO is a crucial collaborator, as this actor provides the network of satellites that the NTN will make use of. There will have to be close cooperation here, as it must be ensured that the satellites are able to facilitate the connectivity. This is especially true if a regenerative architecture is to be used, as that involves network infrastructure being placed on satellites.

While some network infrastructure could be developed in-house, it is very likely that most if not all of it is purchased from a Telecom Vendor. This may involve some cooperation, as the offering will be somewhat customised for the 6G NTN Operator's needs.

MNOs are customers as well as key partners. It is through the MNO that the 6G NTN Operator reaches a mass market, so it is a key enabler of the entire business model.

5.1.9 Cost Structure

As mentioned, network infrastructure such as the core network and RAN is likely to be purchased from a Telecom Vendor, and this may be in the form of an outright purchase or some kind of leasing agreement where the core network and RAN are provided as a service.

The 6G NTN Operator pays a wholesale price for the satellite capacity that it uses. Furthermore, there are overhead costs, consisting of salaries for employees, and rent for office space, ground infrastructure etc.

5.2 Autonomous flying taxis

Following a similar line of reasoning as in the previous use case, and the definition of the network focal from [33, the AAM Connectivity Operator was identified as the focal actor of this use case since they will be the central entity bringing the different actors together to deliver the value proposition to the end-user. This section shows the business model through the business model canvas of [34 for the AAM Connectivity Operator in order to gain further insight into what this role will entail.

<table>
<tr>
<td rowspan="2">Key Partnerships
• TN operators
• SNOs
• Telecom vendor</td>
<td>Key Activities
• Dealing with partners to ensure network performance and reliability
• Enabling seamless handover
• Dealing w/regulators</td>
<td rowspan="2" colspan="2">Value Proposition
• Keep all flying taxis always connected per specific requirements
• Custom solutions based on customers' needs</td>
<td>Customer Relationships
• Personal assistance</td>
<td rowspan="2">Customer Segments
• Flying taxi operators (inter-city, intra-city, airport shuttle)
• (Other autonomous drone operators)</td>
</tr>
<tr>
<td>Key Resources
• Network access
• Intellectual resources</td>
<td>Channels
• Direct channels</td>
</tr>
<tr>
<td colspan="3">Cost Structure
• Cost for access to terrestrial and satellite networks based on SLA
• Core network
• Overhead costs</td>
<td colspan="3">Revenue Streams
• Usage fee (amount of data, time connected, number of flights, or distance travelled)</td>
</tr>
</table>

Figure [15: Business model canvas for AAM Connectivity Operator

5.2.1 Customer Segments

The AAM Connectivity Operator will serve different customer segments within advanced air mobility. For autonomous flying taxis, they will provide connectivity services for intra-city, airport shuttle, and inter-city mobility.
Using the categories identified by [34, the customers served can be considered a niche market, as AAM actors will have quite specific needs that differ from typical consumer offerings. However, they could also come to be categorised as segmented, depending on how much the needs of various kinds of AAM actors differ.

5.2.2 Value Propositions

The AAM Connectivity Operator's value proposition is to provide the Flying Taxi Operator with reliable connectivity that meets the strict requirements that are likely to be set for autonomous flying taxis, ensuring safe operations in the areas where they intend to operate. Preliminary requirements for connectivity for autonomous flying taxis have been outlined above, and the main value that AAM Connectivity Operator will bring is to meet these requirements.

Using the categories identified by [34, this value proposition can be considered to be "getting the job done", as it fills a need that Flying Taxi Operators have at the required level. There may also be an aspect of customisation, as different AAM actors may need unique solutions, perhaps only requiring coverage in certain areas. Additionally, while meeting the requirements is the most important aspect, it is possible that AAM Connectivity Operators may come to compete based on performance.

5.2.3 Channels

Owing to the relatively large and few customers, it is likely that AAM Connectivity Operators will communicate directly with customers on local markets. This would be categorised as a direct sales force, as per [34.

5.2.4 Customer Relationships

As discussed, AAM Connectivity Operator will need close collaboration with its customers, Flying Taxi Operators. In the beginning, there must be personal communication and cooperation to plan out how the service will work. Going by the categories identified by [34, establishing and maintaining this kind of relationship will most likely require personal assistance, or even dedicated personal assistance.

However, as certain operational functions may be automated, such as with the continuous communication of flight plans that allows AAM Connectivity Operators to better plan out capacity in their networks and prepare seamless handovers, there may also be an element of automated services.

5.2.5 Revenue Streams

AAM Connectivity Operator will sell a connectivity service to Flying Taxi Operators. There are several possibilities for how to charge customers for the service. Some possibilities include charging customers based on amount of data used, total time vehicles have been connected, per-flight, or total distance travelled. These can all be categorised as volume dependent usage fees, as per [34. They are discussed in more detail in the next section.

5.2.6 Key Resources

As mentioned in the previous section, the AAM Connectivity Operator's main resources are its network of partnering Terrestrial Network Operators, its know-how related to making agreements and providing the connectivity service, as well as the core network and other related systems that it owns. Using the categories identified by [34, the first two can be considered intellectual resources, while the last one is a physical resource.

5.2.7 Key Activities

The main key activities are dealing with partnering Terrestrial Network Operators and SNOs to ensure that network performance and availability meet the requirements, and planning connectivity to ensure that handovers are seamless. Furthermore, dealing with regulators in local markets could also become a key activity for the AAM Connectivity Operator. Going by the categories identified by [34 these can be considered platform/network activities, as the AAM Connectivity Operator is essentially providing an advanced platform for connecting network providers with AAM actors. Another key activity is communicating with customers and making sales, which involves defining what the customers' needs are and finding a solution for them, and thus has an element of problem solving.

5.3 Key Partnerships

The strict requirements for connectivity as well as the fact that AAM Connectivity Operators are unlikely to own their own network infrastructure makes close partnerships with Terrestrial Network Operators and SNOs very important.

To guarantee adequate networks performance, certain agreements will need to be put in place to ensure accountability between the different parties. Using the categories identified by [34, this kind of partnership can be considered an acquisition of particular resources and activities, since it is mainly for their resources that these partnerships are entered into.

Additionally, AAM Connectivity Operators will have partnerships with the Telecom Vendors from which they buy their network equipment. This is instead a partnership motivated by a desire for optimisation and economy of scale.

5.3.1 Cost Structure

The main expenses for AAM Connectivity Operators will be paying for access to terrestrial and satellite networks, purchasing the core network, and overhead costs related to salaries and rents. The first two can be categorised as variable costs, and the third as a fixed cost, as per [34. The nature of the payment to providers is explored further in the next section.

5.4 In-flight broadband connectivity for commercial airplanes

[36 discuss the role of the A2G Operator and present a business model canvas for it, indicating that that is the focal actor of this value network. Figure 12 is a revised business model canvas for this actor.

<table>
<tr>
<td rowspan="2">Key Partnerships
• Airline
• Terrestrial Operator
• Satellite Operator
• Passengers' Home Operator
• Cabin Operator</td>
<td>Key Activities
• Network maintenance
• Provision of connectivity service
• Negotiating with network operators
• Dealing with regulators</td>
<td rowspan="2">Value Proposition
• In-flight connectivity for airline passengers
• Roaming enabled for mobile devices
• Reliable Wi-Fi connection for all devices</td>
<td>Customer Relationships
• Collaboration with cabin system operator
• Roaming agreements with home operators</td>
<td rowspan="2">Customer Segments
• Cabin System Operator/Airline
• Home Operators</td>
</tr>
<tr>
<td>Key Resources
• Core network
• Access to satellites
• Access to DA2GC network</td>
<td>Channels
• Direct sales (Airlines, Home Operators)
• Home Operator ads (passengers)
• Airline ads, ticket sales pages (passengers)</td>
</tr>
<tr>
<td colspan="2">Cost Structure
• Infrastructure
• Connectivity fee to terrestrial and non-terrestrial operators</td>
<td colspan="3">Revenue Streams
• Connectivity fee based on connection, data usage, and QoS (from Airline ticket sales)
• Roaming fee (from home operators)</td>
</tr>
</table>

Figure [16: Business model canvas for A2G Operator

5.5 Logistics Centre Monitoring with a Swarm of Drones

This section describes the business value canvas for the Logistics Centre Monitoring Service.

<table>
<tr>
<td rowspan="2">Key Partnerships:
- Logistics centre operator
- Network operator
- Cloud provider</td>
<td>Key Activities
- Real-time data collection
- Real-time data analysis
- Data communication and storage
- Result visualization</td>
<td rowspan="2">Value Proposition
- Real-time aerial container tracking
- Higher terminal throughput due to improved routing</td>
<td>Customer Relations
- Close collaboration during deployment and training</td>
<td rowspan="2">Customer segments
- Logistics centre operators managing multi-modal hubs</td>
</tr>
<tr>
<td>Key Resources
- Drone swarm incl. sensors and communication equipment
- Network access
- Computing resources</td>
<td>Channels
- Direct relationships with logistics centres
- Tailored consultations and sales relationships</td>
</tr>
<tr>
<td colspan="2">Cost Structure
- Drone swarm infrastructure
- Drone operation and maintenance
- Computing (Processing, Storage) and Networking</td>
<td colspan="3">Revenue Streams
- Subscription fees for continious service (pricing based on area, frequency,...)
- Pay per use for event-driven deployments</td>
</tr>
</table>

Figure 1016[17: Business model canvas for Logistics Centre Monitoring Service Provider

5.5.1 Customer Segments

The Logistics Centre Monitoring Service Provider serves primarily logistics centre operators who require enhanced operational efficiency at multimodal hubs where rail and road transport intersect. Although shipping companies and cargo owners benefit from improved logistics, the direct customer relationship is with the operator.

5.5.2 Channels

Given the limited number of logistics hubs and specialized nature of the service, customer engagement will occur through direct sales relationships. The Logistics Centre Monitoring Service Provider will work closely with local or regional logistics centres, offering tailored consultations and service agreements.

5.5.3 Customer Relationships

Close collaboration with the Logistics Centre Operator is essential to configure and deliver the service effectively. Initial deployment phases require personal assistance and technical coordination to integrate drone monitoring into site operations. Over time, certain functionalities such as reporting dashboards and data feeds may become more automated, but human interaction will remain important for service customization and support.

5.5.4 Revenue Streams

Revenue will be generated through subscription fees for continuous monitoring or pay-per-use fees for periodic or event-driven monitoring deployments. Pricing models may vary based on the scale of monitoring (area size, frequency, number of drones) and the complexity of the data services offered.

5.5.5 Key Resources

The provider's key resources include the drone swarm infrastructure, network connectivity services, cloud computing resources for data storage and processing, and technical expertise in drone operations and logistics optimization. The drones and associated hardware are physical resources, while operational know-how and software systems are intellectual resources.

5.5.6 Key Partnerships

Strategic partnerships are needed with Network Operators for communication, Cloud Providers for data hosting and processing, and Drone Manufacturers for equipment supply. Insurance partnerships are also critical to meet regulatory obligations. In some cases, partnerships with equipment vendors for optimization and cost management will be important.

5.5.7 Cost Structure

The cost structure includes fixed costs for drone acquisition and system setup, and variable costs for drone operation, network connectivity, cloud computing, and insurance coverage. Staffing, maintenance, and regulatory compliance costs also factor into the operational expenses.

5.6 Parking Lot Monitoring for Large Fair Events with a Swarm of Drones

This section describes the business value canvas for the Parking Monitoring Service Provider.

<table>
<tr>
<td rowspan="2">Key Partnerships:

- Event Organisator
- Fairground operator
- Fair exhibitors and visitors</td>
<td>Key Activities

- Real-time data collection
- Real-time data analysis
- Data communication and storage
- Result visualization</td>
<td rowspan="2">Value Proposition
- Efficient, dynamic parking lot management</td>
<td>Customer Relations
- Support for exhibitors with special parking requirements
- Self-Service for visitors using app/info screens</td>
<td rowspan="2">Customer segments
- premium parking customers (exhibitors and visitors)
- standard parking customers</td>
</tr>
<tr>
<td>Key Resources
- Drone swarm incl. sensors and communication equipment
- Network access
- Computing resources</td>
<td>Channels
- Mobile app/Web portal
- Info screens
- On-Site personell</td>
</tr>
<tr>
<td colspan="3">Cost Structure
- Drone swarm infrastructure
- Drone operation and maintenance
- Computing (Processing, Storage) and Networking</td>
<td colspan="2">Revenue Streams
- Higher ticket fees (payed by visitor)
- Higher exhibition fees (payed by exhibitors)
- Premium parking lot management (subscription service for fairground operator)</td>
</tr>
</table>

Figure [1816: Business model canvas for Parking Monitoring Service Provider

5.6.1 Customer Segments

The Parking Monitoring Service Provider serves multiple customer segments within the context of large fairground events. Their customers include event organizers who purchase the service to enable premium parking capabilities, and fairground operators who may subscribe to or activate the service for specific events. While some customers may use the service regularly across multiple events, others may only require it occasionally.

5.6.2 Value Propositions

The Parking Monitoring Service Provider delivers real-time aerial monitoring of parking lots using drones, supporting dynamic allocation of parking zones and smoother traffic flows during busy events.

The service offers tangible benefits such as improved space utilization, reduced congestion, and enhanced visitor experience. It helps event organizers manage complex on-site logistics and enables fairground operators to provide premium services without permanent infrastructure changes.

While the core value lies in delivering the needed monitoring capability reliably and on-demand, the service may also be customized based on the size and layout of the event.

5.6.3 Channels

Given the relatively small number of potential customers and the tailored nature of the service, Parking Monitoring Service Providers will primarily engage customers through direct sales and personalized service relationships. Sales and coordination typically take place locally or regionally, with dedicated points of contact to ensure smooth service integration and delivery.

5.6.4 Customer Relationships

Close collaboration with event organizers and venue operators is essential. Initial deployments will often involve personal interaction to define requirements, configure the system, and manage logistics. Over time, aspects such as monitoring dashboards or reporting tools may be partially automated, but the core relationship is still built on trust, coordination, and responsiveness, especially during live events.

5.6.5 Revenue Streams

The service is typically monetized through pay-per-use event fees, charged to the event organizer or fairground operator based on deployment duration, number of drones, or area covered. In some cases, subscription-based models may be used for frequent service users, such as permanent venue operators hosting many events per year.
Pricing structures must reflect both the operational value delivered and the relatively high cost of drone operation.

5.6.6 Key Resources

Key resources are the drone swarm, including sensors and communications equipment, as well as network connectivity and cloud-based processing infrastructure for real-time data analysis and distribution. In addition, specialized technical know-how in drone operations, event logistics, and system integration is essential for delivering a reliable and responsive service.

5.6.7 Key Partnerships

To deliver the service effectively, the Parking Monitoring Service Provider relies on partnerships with Network Operators, Cloud Providers, and Drone Manufacturers. These partnerships are critical for ensuring high availability, data reliability, and operational scale. Additional collaboration may be needed with insurance providers, venue operators, enabling regulatory compliance, cost efficiency, and consistent performance.

5.6.8 Cost Structure

The cost structure includes fixed costs such as drone infrastructure and acquisition, and variable costs related to drone operation, network connectivity, cloud processing, insurance, and event-specific logistics. While drone hardware is a one-time investment, the ongoing costs to operate and maintain the service — especially for high-demand or complex events - can be significant, impacting the pricing model and scalability.

6 Techno-Economic Analysis of Cellular Networks for Aircraft Operational Connectivity

Aviation is a rapidly expanding industry that facilitates the transportation of both goods and passengers [81].

The rise of e-commerce, drop-shipping, and tourism has further accelerated this growth, driving demand for fast and efficient air travel. For example, Munich Airport handles over 417, 000 flights annually [41]. As air traffic increases, the need for reliable aeronautical communication for commercial aircraft becomes more critical, positioning it as a key component of future mobile networks [38].

Commercial aircraft have three primary traffic profiles: in-flight broadband connectivity for passengers, operational connectivity to ensure the safe operation of the aircraft, and bulk data transfer for transmitting data generated by onboard sensor systems [39].

To address the broadband demands for in-flight connectivity, business ecosystems leveraging direct air-to-ground communication (DA2GC) through collaboration among industry stakeholders have been proposed [40].
These ecosystems primarily focus on providing broadband connectivity for passengers while managing network operations, provisioning, and regulatory aspects among key players such as airlines, content providers, and network operators.

Existing studies have explored the feasibility of using ground networks for in-flight broadband connectivity [41]–[43].

In [41], a multi-base station (BS) selection scheme is introduced to balance network load and optimize aircraft user latency using a bipartite matching approach.

The authors in [42] advocate for utilizing fifth-generation new radio (5G-NR) across various spectrum bands, including sub-7 GHz and millimeter-wave (mmWave) frequencies, to enhance in-flight connectivity.

Meanwhile, [43] focuses on optimizing antenna tilt and inter- site distances in 5G-NR networks to improve connectivity during flights.

Additionally, [44] presents a precoding scheme designed to maximize transmit power from ground networks for aeronautical MIMO communication.

Further advancements include multi-hop routing strategies between ground BSs and an ad-hoc aircraft network to minimize delay and enhance throughput [45],[46].

While these approaches are well-suited for over-the-sea flights, they may be less effective in airport environments. In contrast to these studies, there is a need to evaluate the performance of existing 4G/5G ground networks around airports, particularly for aircraft connectivity at low altitudes during landing and takeoff phases.

For the bulk data transfer, efficient uplink data transfer to ground servers is crucial. Aircraft are equipped with numerous sensors that generate vast amounts of data during flight, which must be processed to ensure seamless airline operations and maintenance.

To address this, [47] proposes deploying a BS near the center of the runway to offload data during descent, utilizing dedicated sub-6 GHz and mmWave spectrum. Similarly, [48] explores capacity enhancements through beam steering towards aircraft and satellite communication to complement ground networks. Although it suggests that 5G could enable a theoretical uplink capacity of 4.4 terabyte (TB) per aircraft at the gate using two modems operating at 10 Gbit/s, there is a need for a more realistic assessment that accounts for multiple aircraft simultaneously requiring high- throughput uplink.

For operational connectivity, the feasibility of air-to-ground (A2G) communications within a 5G network designed for terrestrial coverage has been evaluated, e.g., demonstrating that an 8 × 8 Active Electronically Scanned Array on air- craft can achieve up to 81.3% availability with acceptable Signal-to-Interference Ratio (SIR) [49].

However, achieving reliable high-throughput data transfer necessitates advanced interference management strategies and optimized utilization of available on-campus bandwidth.

There is also a critical need to ensure five-nines (99.999%) availability for operational connectivity, particularly for services requiring 1 kbps and 3 Mbps uplink rates.

Another key application is air traffic management (ATM), which relies on services such as On-line Data Interchange (OLDI) supported by the Flight Message Transfer Protocol (FMTP). Although these services have low data rate requirements, they demand extremely high communication reliability [39].

6.1 Context and Contributions

In this context, we evaluate the capability of existing 4G/5G networks to support the required data rate and availability standards for aircraft connectivity around airports—an aspect that, to the best of our knowledge, remains largely unexamined despite studies on connectivity during the cruising phase.

Our analysis focuses on leveraging current network infrastructure without significant hardware upgrades, considering existing BS deployments near airports with down-tilt antennas. For uplink data transfer as well as operational connectivity, the transmission of 1 TB is to take place within a 35-minute window while the aircraft is on the ground.

This period includes approximately 90 seconds of flight, 1 to 3 minutes of taxiing, and a 30-minute turnaround phase. To efficiently offload this large data payload to ground servers, aircraft establish connectivity with ground BSs starting from landing, continuing through taxiing, parking, and takeoff. The entire process, spanning 35 minutes, is illustrated in Figure 19.

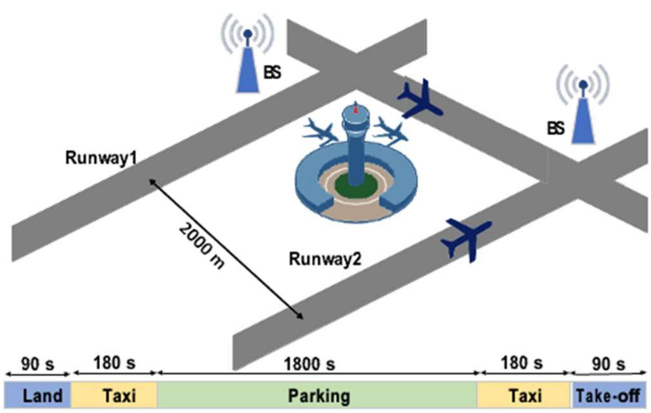

Figure [78]: System Model

To enhance capacity, our analysis examines the maximum achievable throughput and availability of existing ground networks without modifications. It also considers currently deployed public networks, as well as the impact of adding hardware at the transmitting end—such as additional antenna arrays—to enable beam forming.

Beyond public networks, the study explores the use of private cellular networks, including local and regional ("campus") networks, as well as global networks operating on dedicated spectrum.
Furthermore, the analysis evaluates the deployment of additional equipment on aircraft to enable beam forming, ensuring adequate aerial coverage. For the same operational scenario, we assess the economic feasibility of provisioning a global network slice to support the deployment of A2G services. Additionally, we explore how various industry stakeholders can collaborate within an A2G connectivity ecosystem around airports.

The key contributions of this section revolve around addressing the following research questions:

- How well do current 4G/5G networks at airports support the required data rates and availability for various aircraft connectivity services?
- What solutions can be implemented when existing net- works fall short of meeting these requirements?

To answer these questions, we analyze a real-world scenario based on Munich Airport, leveraging existing 4G/5G network deployments while incorporating additional bandwidth from campus networks and coverage from their side-lobes. For uplink capacity enhancement, we explore the use of beam-forming at the aircraft to improve performance. Additionally, we propose a business model that includes value-chain analysis and financial flows to assess economic feasibility. Given the importance of developing a sustainable revenue-generating framework, we examine the broader business ecosystem, integrating both technical and commercial perspectives to ensure viable deployment strategies.

6.2 Technical Feasibility

In this section, we assess the capability of existing net- works to meet the throughput and availability demands of the specified use cases. To achieve this, we analyze the following traffic profiles, each with its respective data and availability requirements:

- Operational Connectivity:
    - (1) 1 kbps uplink/downlink with 99.999% availability (aeronautical telemetry and control).
    - (2) 3 Mbps uplink with 99.999% availability (pilot communications and operational data).
- Bulk Data Transfer:
    - (3) 1 TB uplink data transmission for aircraft health monitoring and data offloading.

To support these connectivity and data transfer needs, we model cellular A2G connectivity within a 10 km radius around airports, utilizing public networks as currently deployed. At airports, public cellular networks are primarily designed to provide ground-level coverage for passengers, including terminal areas, gates, and access roads. However, A2G connectivity can enable aircraft to initiate data downloads while still in flight during the approach and landing phases.

The approach and landing phases are characterized by altitudes of approximately 500 m, airspeeds of up to 400 km/h, and a minimum horizontal separation of 2, 000 m between aircraft landing on the same runway. This horizontal separation helps determine the aircraft density served by a single BS.
To analyze aircraft mobility and network performance, we simulate a landing aircraft scenario using a Python-based simulation framework. This framework replicates aircraft movement over a 10 km approach distance, assigning each aircraft a destination runway and a predefined flight path. The orientations of these landing paths are based on real-world data from a major European airport—Munich Airport—to ensure accuracy and relevance.

6.2.1 Simulation Framework

Each flight progresses through distinct approach, taxi, and parking phases, each defined by unique parameters based on real-world observations, such as maximum speed, altitude, and duration of taxiing and parking. During the landing and taxi phases, up to 10 aircraft are considered, each following the same approach path with a 2 km separation between them.

In the parking phase, an average of 50 aircraft are positioned within the airport parking area. The model assumes that aircraft positions in this phase are known, allowing for optimized coordination between serving BSs. This coordination facilitates efficient communication, mitigates Doppler shifts by applying opposite frequency adjustments during transmission and reception, and enhances overall network performance.

We develop a Python simulation to model the airport environment, incorporating actual base BS locations from existing 4G/5G deployments within a 20 km radius around the airport. In this scenario, 10 aircraft share the spectrum with both neighboring aircraft and ground users.

To obtain average results, we simulate the system over 100 runs. The primary focus is to evaluate the signal quality and communication capacity available to a single aircraft, particularly the uplink (from the aircraft to BSs) for transmitting data to a ground server.

Signal propagation is largely influenced by Line of Sight (LoS) conditions across all flight phases. Therefore, we apply a conventional free-space path loss (PL) model, which takes into account both LoS and non-LoS components, with the loss dependent on distance (d) and frequency (f). The probability of LoS is determined using parameters for suburban environments [43]. We consider carrier frequencies of 800 MHz and 2 GHz. The channel model incorporates the consolidated PL, beam forming antenna gain, and carrier frequency.

For the feasibility analysis of the existing A2G communication system, we assume omnidirectional and beam forming antennas on the aircraft, while keeping the ground network configurations unchanged. The BSs are equipped with omni- directional antennas with a 3 dB gain, while the aircraft use either omnidirectional antennas or beam forming antennas with a 4x4 array and precoding.

To ensure accurate communication, we also account for Doppler shift compensation at the receiver. Additionally, we model maximum handovers, where an aircraft is associated with the BS that provides the best channel gain, optimizing throughput and improving the overall efficiency of the communication system in dynamic aircraft landing scenarios.

Spectrum sharing between cellular ground users and aircraft is a critical factor, requiring an interference management scheme for the communication links. In our analysis, we allocate up to 100 MHz of bandwidth for data transmission during the parking phase at airports, and up to 40 MHz for the other flight phases.

6.2.2 Technical Feasibility Results

Figure 20 shows the relationship between achievable throughput and allocated bandwidths, along with the corresponding transmit antenna types of omnidirectional and beam forming, for different numbers of aircraft users in the network.

The throughput values are averaged over 100 simulation runs, taking into account interference from other aircraft users in the network. The results demonstrate that the 3 Mbps throughput threshold is consistently met for all aircraft, with higher bandwidth allocations leading to increased throughput.

For a network with a maximum of 10 aircraft, and with 10 MHz, 20 MHz, and 30 MHz bandwidths, the results show throughput values of 2.9 Mbps, 4.8 Mbps, and 7.3 Mbps with omnidirectional antennas, and significantly higher values of 7.4 Mbps, 14 Mbps, and 22 Mbps with beam forming antennas, respectively.

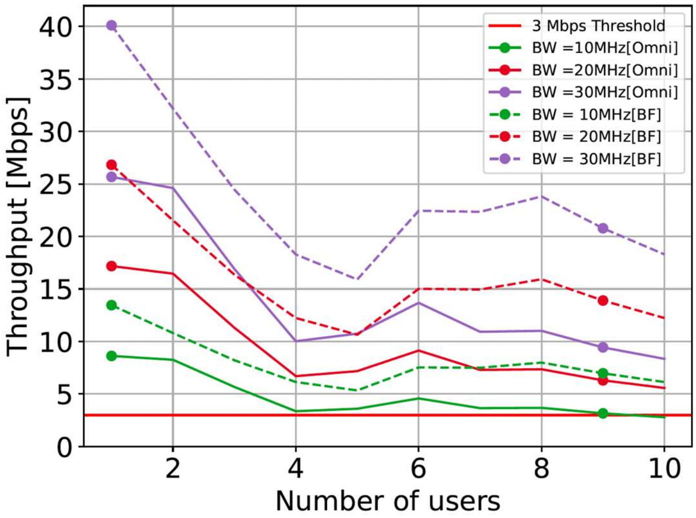

Figure [20

The simulation results in Figure 21 illustrate the availability performance of the communication service for operational connectivity. For the first profile, which requires a 1 kbps uplink/downlink, the availability is assessed in terms of the bit error rate (BER) for a packet size of 2 Bytes. To meet the availability requirement of 99.999%, with a latency of 16 ms and a throughput of 1 kbps, a signal-to-noise ratio (SNR) of up to 16.5 dB is required.

The analysis shows that this requirement is successfully met with beam forming alone. In the second profile, which demands a 3 Mbps uplink, availability is considered in relation to achieving a throughput greater than 3 Mbps.
The existing networks successfully fulfill the availability requirements, achieving 98.8% availability for 1 kbps with beam forming at landing aircraft, and 99.6632% availability for 3 Mbps with the same configuration.

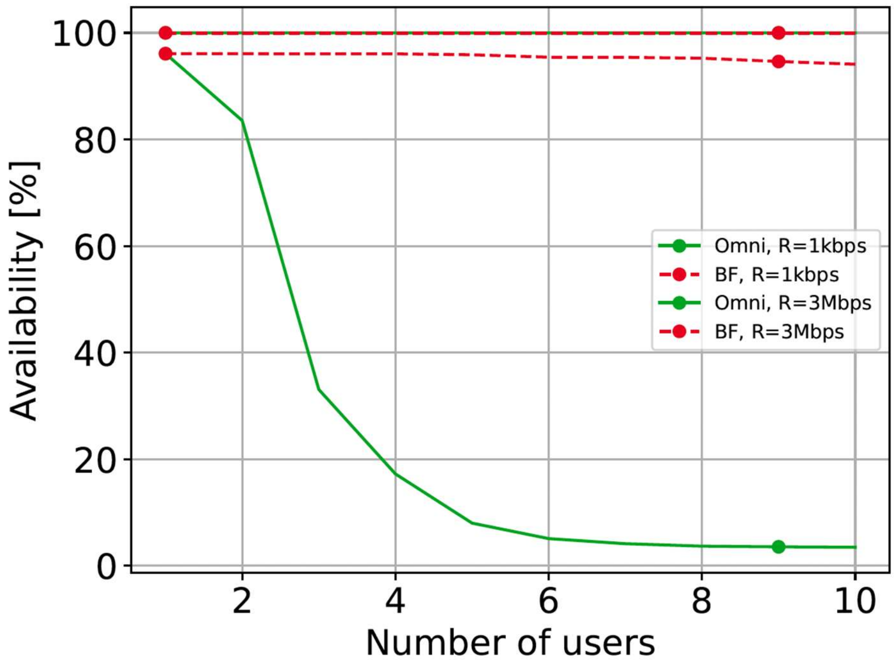

Figure [21

We also estimate the bandwidth required to meet the throughput demands of flight connectivity and bulk data trans- fer services. For a payload transfer of 1 TB over a duration of 35 minutes, the required throughput is 3.5 Gbps.

The bandwidth needed to achieve specific throughput requirements varies, as shown in Figure 22. With omnidirectional antennas, the required bandwidth for 10 aircraft users to achieve 1 kbps, 3 Mbps, and 3.5 Gbps is calculated to be [0.0475 MHz, 4.2 MHz, 2100 MHz], while with beam forming, the requirements are [0.0035 MHz, 1.2 MHz, 360 MHz], respectively.

Consequently, the existing networks may not be able to deliver the 1 TB payload to the ground server. However, this can be achieved by utilizing an additional 100 MHz bandwidth from campus licenses and employing efficient interference management, which improves the SNR.

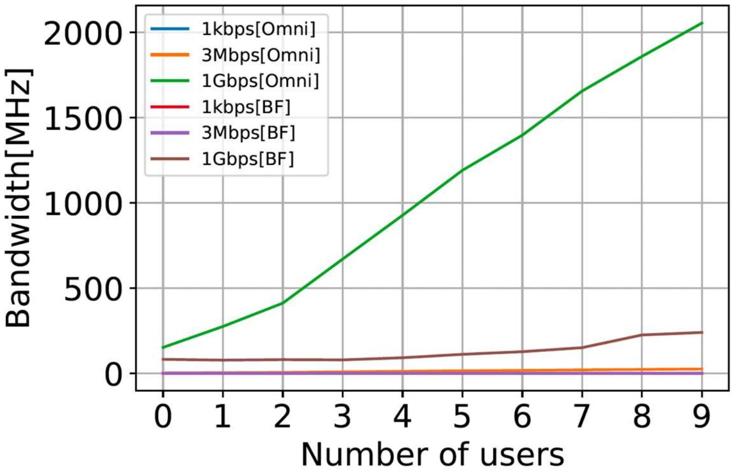

Figure [22

Interference management plays a critical role in the system, and we introduce a factor between 0 and 1 in our simulations to represent the effectiveness of interference control within the network. A value close to 0 indicates efficient interference management, while values closer to 1 reflect less effective interference mitigation. Each BS is allocated 100 MHz of bandwidth, shared among the associated aircraft.

In our simulation, we model the simultaneous connection of 50 aircraft with approximately 6 BSs located at the airport.

These settings offer a realistic framework for evaluating connectivity performance and efficiency under various conditions. With an interference factor of 0.3, beamforming at the transmitting aircraft, and an additional 100 MHz of bandwidth, the aircraft can offload 1.109 TB of data to the ground server.

This is achieved by maintaining a throughput of 10 Mbps during the landing and takeoff phases (each lasting 90 seconds), 32 Mbps during both taxi phases (each lasting 90 seconds), and 580 Mbps during the parking phase (lasting 1800 seconds).

6.3 Economic Viability

In the airline industry, several business models are used to address the varying needs of customers and adapt to changing market conditions. The ecosystem business model involves collaboration between airlines, airports, suppliers, and service providers to create integrated value, often through alliances and travel platforms.

The platform business model connects travelers with services via digital platforms, enhancing the travel experience and generating new revenue opportunities.

The open business model fosters innovation by utilizing both internal and external resources, encouraging partnerships with tech companies to improve services. The product-centric model focuses on selling seats and cargo space, aiming for operational efficiency and cost control.

On the other hand, the service-centric model emphasizes customer service and creating unique travel experiences to differentiate offerings. The franchise model expands market reach by allowing regional carriers to operate under a major airline's brand.

The subscription model offers fixed-price travel packages, fostering steady revenue and customer loyalty. Finally, the freemium model provides basic services for free, with premium features available for a fee.

In summary, the airline industry utilizes a diverse range of business models to cater to various customer needs and market demands. Ecosystem and platform models emphasize collaboration and integration, while open models encourage innovation. Product-centric and service-centric models focus on efficiency and customer experience, respectively, while franchise, subscription, and freemium models provide unique approaches to expanding market presence and generating revenue.

6.3.1 Business Model: The players

Our vision is that future A2G communication for commercial flights will be enabled through collaboration within a business ecosystem involving multiple stakeholders.

This section outlines the key players involved and defines their respective roles. It is important to highlight that some players may assume multiple roles within the business value chain. The economic relationships between these participants will be discussed in detail as follows:

1. **Airlines:** The airline serves as the primary customer in the A2G business model. Its role in the A2G value chain is to provide connectivity services by leasing resources from various operators, including system operators, terrestrial operators, and A2G service providers. Additionally, as a front-end player in the market, the airline benefits from this service by either raising ticket prices or attracting more customers through the introduction of new service offerings.

2. **Virtual Terrestrial Operators:** Connectivity between the airline and the ground network is provided by virtual terrestrial operators. These operators deliver A2G connectivity and backbone services to the core networks of the airline's home operator and A2G service providers, supporting applications with specific QoS requirements. The virtual terrestrial operator handles the transmission of operational connectivity (for traffic profiles 1 and 2) and the collection of data for aircraft health monitoring. Additionally, it manages the data storage on the aircraft prior to transmission to the ground server. The installation and maintenance of the transmission equipment, including the beamforming antennas on the aircraft, are also overseen by the virtual terrestrial operator.

3. **A2G Operators:** The A2G operator is responsible for managing the A2G connection on behalf of the virtual terrestrial operator, leveraging both terrestrial and airline operators depending on the type of data traffic and the aircraft's location. The virtual terrestrial operator operates as a consortium, consisting of all relevant terrestrial and airline operators, with optional participation from the virtual terrestrial operator and the airlines' home operator. As a virtual operator or customer, the A2G operator acquires services and capacity (radio and backhaul) from terrestrial operators. In this relationship, the virtual terrestrial operator acts as a virtual operator or customer to the A2G operator. Additionally, the A2G operator serves as a roaming partner for the airlines' home operator.

The establishment of the A2G consortium is crucial due to the complexities involved in navigating airspace across multiple countries in Europe, each with its own frequency regulations, diverse home operators, and various terrestrial operators. Creating numerous agreements between the virtual terrestrial operator, home operator, and terrestrial operators in each country can be challenging for new entrants to the business.

To simplify this process, the A2G consortium acts as a single point of contact for all partners, enabling different operators to manage frequency regulations within their respective countries. This structure streamlines market entry for new home and virtual terrestrial operators, allowing them to secure agreements with all partners through the A2G operator.

The A2G business model presents several possibilities, with two primary scenarios. In the first scenario, the A2G operator functions purely as a business entity that manages interactions between terrestrial operators across different countries.

In this model, the A2G operator does not own network infrastructure, and various terrestrial operators connect to the home operator's core network through separate links. While this scenario simplifies contractual management, it limits the potential for advanced collaboration between terrestrial networks. In the second scenario, the A2G operator owns the network infrastructure, with terrestrial networks from different countries connected to a shared core network.

This setup allows for advanced cooperation techniques, such as seamless cross- border connections, efficient scheduling, resource allocation, and coordinated multi-point strategies.

This architecture also facilitates market entry for newcomers by utilizing existing communication networks, resulting in lower capital expenditure (CAPEX). Aircraft connect to the ground network through the A2G operator's packet data network gateway, enabling policy exchanges between the A2G operator and the airlines' home operator via their respective policy and charging rules functions.

6.3.2 Business Model: Economic Viability

The economic viability of implementing a global cellular connectivity service through a worldwide slice requires a thorough assessment of several factors. First, it is essential to determine the number of aircraft served per unit of time on a global scale. Establishing a clear pricing model per aircraft is necessary to understand the potential revenue stream. From the service provider's perspective, cost calculations must consider factors such as roaming fees in different countries, especially outside the EU. The roaming cost model for a Virtual Mo- bile Network Operator (VMNO) must be clarified, including whether it is based on a flat fee, per aircraft, per day, or total data volume.

Once the payment rates for aircraft and the investment/deployment costs are determined, the economic feasibility of the network can be evaluated over a break-even period, typically measured in years. By utilizing input parameters like cost and pricing models, Net Present Value (NPV) and Total Cost of Ownership (TCO) analyses can be generated. These financial models provide a detailed understanding of the economic feasibility of deploying a worldwide slice for cellular connectivity.

6.3.3 Business Value Chain

The business value chain described here begins with the mobile operator of a country, which provides connectivity services. In the first step of the chain, the mobile operator sells connectivity to a VMNO. The

VMNO then assumes the role of the global service operator for aircraft connectivity, offering these services to airline operators.

The methodology for calculating economic viability involves several key steps.

First, the TCO for the mobile operator is calculated. To ensure profitability for the VMNO, the pricing model is established with an appropriate profit margin. The VMNO's revenue is then calculated based on a flat pricing rate, taking into account the number of aircraft served per year.

Lastly, the economic viability is assessed by determining how many years it will take for the revenue generated to cover the TCO associated with the service. This approach ensures a comprehensive assessment of the economic feasibility of the connectivity services across the entire value chain.

6.3.4 Economic viability results

The simulation results evaluate the economic viability of globally provisioning a slice for the deployment of the necessary A2G connectivity service, utilizing the existing public network infrastructure without requiring additional hardware. The analysis covers various bandwidth profiles, including configurations with omnidirectional and beam forming antennas, along with the corresponding required bandwidths.

		1 **kbps**	3 **Mbps**	1 **TB**
Revenue	**Flat Price**	300 €/ Month	500 €/ Month	4.5 €/GB
	Data Delivered	0.09 MB [90 seconds]	33 MB [90 seconds]	1 TB [35 min]
	Per year earning	3.6 k€	6 k€	1876 million €
Cost	**Power cost**	1261 k€	1261 k€	1261 k€
	BW cost [Omni]	5.94 k€	525 k€	176391 k€
	BW cost [BF]	0.437 k€	150 k€	135108 k€
	Total Cost [MO]	1267 k€	1786 k€	177652 k€
	Total Cost [VMNO]	2534 k€	3572 k€	355304 €
Viability	**Years [Omni]**	5.48 Years	6.43 Years	0.199 Years
	Years[BF]	2.15 Years	2.57 Years	0.132 Years

Table [1

Table I presents a summary of the revenue and cost calculations for various traffic profiles. Using a flat price rate of 4.5 €/GB and accounting for data delivery at different rates (1 kbps and 3 Mbps) within a 90-second window, the revenue per flight is calculated by multiplying the per-flight revenue by the annual number of flights (417, 000), yielding the total revenue for each data profile.

The power cost for the deployed networks is predefined. Once the required bandwidth for both omnidirectional and beamforming (abbreviated as BF in Table I) antennas on the aircraft is determined, the bandwidth cost is calculated.

The total cost, which includes both the power and bandwidth costs, is then computed for the mobile operator. Additionally, the VMNO's cost is derived from the TCO, with profit margins of 50% or 100%, respectively.

The evaluation also considers the number of years needed to recover the total cost for each bandwidth profile, highlighting the promising economic outlook for the A2G communication service, making it a profitable and sustainable business opportunity.

6.3.5 Cost Computation

We contemplate an average of 50 aircraft being parked at the airport simultaneously. Notably, the expense associated with implementing beamforming antennas at the transmitting end on the aircraft rests with the aircraft vendor.

For the mobile operator, the cost structure includes both operational expenditure (OPEX) and CAPEX. The OPEX covers leasing costs, which amount to a monthly fee of 1300 €, as well as power consumption, with each BS using 1.2 kWh of electricity. The electricity cost in Europe is 0.12 €/kWh. The bandwidth cost is set at 0.15 €/MHz 81[50]. The annual electricity cost is calculated as 10512 kWh multiplied by 0.12 €/kWh, resulting in a total of 1261.4 k€ per year.

These elements contribute to the overall cost structure, which emphasizes low CAPEX and OPEX while maintaining efficient operations. This cost break- down serves as the foundation for evaluating the economic feasibility of data transmission during the parking phase, ensuring a thorough analysis of operational and bandwidth- related costs.

In our aviation scenario, the maximum annual flight frequency is capped at 417, 000 flights. During the crucial landing phase, covering a distance of 10 km at a speed of 400 km/h, the landing time is fixed at 90 seconds. In this brief period, the data delivery is significant: at 1 kbps, 0.09 MB is transferred, while at 3 Mbps, the data transfer amounts to 33 MB.

To calculate the time required to deliver 1 TB of data, we consider the total time for landing (90 seconds), taxiing (180 seconds), and parking (30 minutes), summing up to 35 minutes (2100 seconds). The fixed network cost for the leased lines is 300 €/month for 1 kbps, 500 €/month for 3 Mbps, and a flat rate of 4.5 €/GB for the 1 TB data transfer profile. Given the fixed power and bandwidth costs, the total costs for the mobile operator (MO) and VMNO are presented in Table I. For example, the costs for the 1 TB data transfer profile are 177, 652 k€ for the MO and 355, 304 k€ for the VMNO. The VMNO cost is calculated using a TCO rate of 50%. This analysis demonstrates the revenue generation and confirms the economic viability of the service.

6.4 Conclusion

In conclusion, the simulation results offer a thorough evaluation of communication service performance across various traffic profiles.

The system successfully meets the requirements of the first two profiles, providing reliable up-link/downlink at 1 kbps and 3 Mbps with 99.999% availability. However, challenges arise in the third profile, which involves transmitting 1 TB of data, revealing the limitations of the existing network within the 30 MHz bandwidth.

Throughput analysis shows promising average values across different band- width scenarios and antenna configurations, with beamforming providing a significant boost in throughput, which will be enabled by 5G non-stand-alone (NSA) networks. The bandwidth requirements for specific throughput demands differ based on the use of omnidirectional or beam forming antennas.

While existing networks can meet availability requirements for lower data rates without requiring hardware upgrades in current 5G deployments at urban airports, the difficulty of transmitting 1 TB of data highlights the need for enhanced infrastructure.

The economic viability analysis indicates a positive outlook, with significant revenue generation and a strong business case for deploying the required A2G connectivity service. The annual revenue supports the service's economic feasibility by ensuring a sustainable break-even period.

Additionally, effective interference management makes it possible to meet the ambitious target of transmitting 1 TB of data within a 35-minute window, confirming the system's adaptability to the demands of 50 connected aircraft and 6 ground BSs. Overall, this study offers valuable insights into network capacity, economic prospects, and the necessary infrastructure enhancements, laying a solid foundation for informed decision-making regarding the deployment of A2GC services.

7 HAPS seasonal coverage and Whitespot coverage

If we consider HAPS as an alternative for providing cellular coverage, it should overall have lower cost than the cost of current terrestrial methods.

In following we present two scenarios, one representing temporary coverage (for example weekend or seasonal coverage) and another addressing whitespot coverage (to close the gaps in current terrestrial network coverage). We present "minimum" and "maximum" cost range figures to illustrate cost differences in different countries.

7.1 Seasonal Coverage

For event/seasonal coverage, we can provide high level indication on cost of temporary coverage provided by traditional "Cell on Wheels" (COW) solution, by taking as example an event coverage solution that requires 20x20 km area to be covered over a period of weekend. Further we consider "aggressive" site grid requiring 30 CoW units and "conservative" deployments requiring 10 CoW units.

OPEX	Per CoW	Total	Per hour
MIN	10,000 €	300,000 €	5,000 €
MAX	25,000 €	750,000 €	12,500 €

Table [2 Operational Cost estimate for aggressive temporary coverage

OPEX	Per CoW	Total	Per hour
MIN	10,000 €	100,000 €	1,667 €
MAX	25,000 €	250,000 €	4,167 €

Table [3Operational Cost estimate for conservative temporary coverage

Tables 2 and 3 provide an "ball-park level" indication of the overall OPEX required for temporary coverage.

7.2 Whitespot Coverage

While population coverage of European MNOs reaches high levels in general, national regulators have started to discuss increasingly strict requirements for geographic coverage. This means that MNOs are forced to reduce the so called whitespot no-coverage areas and increasingly invest to areas with very low population density.

Whitespot coverage reduction aims to address existing coverage gaps in current terrestrial networks. Generally, the whitespots are not contiguous large areas but numerous separate smaller areas. Addressing then using terrestrial sites therefore requires large number of sites.

To study the case, we assume that a country/area of 130,000 km^2 would require 1000 terrestrial new sites to fulfil geographic coverage obligations and calculate total cost of ownership (TCO) over 10 year period. The resulting figures are presented in Tables 4 and 5:

Again, “min” and “max” figures represent cost differences in different countries.

CAPEX	New Tower Cost	Total
MIN	250,000 €	250,000,000 €
MAX	500,000 €	500,000,000 €

Table [4Capital Expenditure for 1000 new terrestrial sites

OPEX	Per Tower per year	Total for 10years
MIN	6,000 €	60,000,000 €
MAX	10,000 €	100,000,000 €

Table [5Operational Expenditure for 1000 new terrestrial sites over 10 year period

Assuming that one HAPS can cover an area with 50 km radius, we would need minimum of 20 HAPS to address the same total area. Further, we assume that the HAPS fleet needs to be 25% larger for maintenance and other operative reasons, leading to total of 25 HAPS.

Scaling the figures of table 4 and 5 for single HAPS, we conclude that in order to have cost parity, one HAPS TCO must be 12.4mEUR (min) to 24mEUR (max) range.

8 Digital airspace & NTN impact on sustainability

The information and communications technologies (ICTs) industry plays a vital role for combating the world’s climate change and sustainability challenges. The United Nation’s introduction of its sustainable development goals (SDGs), which include a framework of the 17 areas that need to be addressed and that works as a guideline for reaching a sustainable world [83

The ICTs are the backbone of today’s digital economy and have enormous potential to accelerate the progress for reaching the SDGs and improve people's lives by enabling and providing worldwide mobile connectivity and global coverage [43 ICT is crucial for achieving all the 17 SDG goals (displayed in the Figure 23 below) and should be considered as a catalyst for accelerating the three pillars of sustainable development: economic growth, social inclusion, and environmental sustainability.

Figure [23:The United Nation's 17 Sustainable Development Goals.

With more than half of the world's population already living in urban environments, and with the estimation that about 70% of the world's population will be living in urban areas by 2050 [**Fehler! Verweisquelle konnte nicht gefunden werden.**. But while the benefits of a continued growth in air traffic for European citizens are clear in terms of mobility, connectivity, and availability of new services (e.g., services that will be enabled by drones/UAV etc.), this growth also brings concerns about climate impacts. These concerns are prompting the aviation industry to accelerate its efforts to address air travel environmental sustainability.

The EU has a plan to cut greenhouse gas by at least 55% by 2030 and reach its carbon neutral goal by 2050 [46. In support of this goal, the SESAR project has prioritized solutions that will gradually contribute to the elimination of environmental inefficiencies caused by the aviation infrastructure. This will be done by ensuring that it provides solutions that will exploit the potential offered by next generation aerial vehicles and aircraft. The main ambition of the SESAR project is working towards the digitalization of ATM and to support electrification of aerial vehicles, where the overall goal is to strive for a more climate neutral aviation industry.

The challenges of global climate change and the need to reduce our carbon footprint makes it critical that the next generation 6G networks employ the most energy efficient available technologies, that will reduce the dependency on non-renewable sources and use solely renewable energy sources.

In addition to energy consumption and emissions, the ICT sector's overall environmental impact must also be considered, including the handling of water consumption, raw material sourcing, and waste handling etc. 6G is considered by many to be the sustainable "Green G" [47 Use cases that will emerge related to 6G and also to 6G-SKY, including all key actors in the entire value chains, will need to embrace a strong focus on sustainability and work actively towards reducing any climate change impacts.

In terms of future spectrum strategy and regulations, these should be seen as an enabler for technology with an essential focus on sustainability and will also work towards spectrum being used as efficiently as possible. The ITU has stated that it strongly supports and encourages the efforts of countries to leverage technology to accelerate progress towards the SDGs and is also developing a framework for assessing the impact – both positive and negative – of digital technologies on the climate" [48.

The 6G sustainability study in [49 has shown for a city scenario that HAPS can reduce grid energy of a mobile network by 10% to 50% by switching off terrestrial base stations. Large part of rural terrestrial sites are deployed for providing coverage and not for capacity need. HAPS can replace such towers in wide sparsely populated areas. Furthermore, novel hydrogen based power solutions are promising carbon free network operation.

9 Conclusion

The 6G-SKY project has the overall purpose to evolve business modelling, architecture and technical solutions for combined airspace and non-terrestrial network (ASN) to support 6G introduction.

Massive growth of aerial platforms will require automatization and digitalization of airspace systems for air traffic management. To meet the communication needs, combined Airspace and NTN (ASN) networks are needed for 6G that integrate 3GPP, ATM/UTM, governmental and societal networks.

Over time, more advanced requirements on communication will appear, requiring wireless systems to cater to evolved 3D solutions.

Currently, there is a high pace of concurrent changes and potential disruption within technology, use of networks, sustainability, society and for value networks.

Business modelling studies can greatly impact choice of business targeting, offers, regulatory impacts and governmental policies.
The D1.6 provides a major contribution for visualising the business modelling of holistic combined Airspace and NTN networks and provides a foundation for further studies. It is unique in it its approach to provide a comprehensive study of business models for combined airspace and NTN integrated with TN networks.

10 References

10.1 Figures

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1. Revenue and cost computation.
2. Operational Cost estimate for aggressive temporary coverage
3. Operational Cost estimate for conservative temporary coverage
4. Capital Expenditure for 1000 new terrestrial sites
5. Operational Expenditure for 1000 new terrestrial sites over 10 year period

10.3 References

10.3.1 Papers & Books

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