Mobile and wireless communications Enablers for the Twenty-twenty Information Society-II

Deliverable D1.1
Refined scenarios and requirements, consolidated use cases, and qualitative techno-economic feasibility assessment

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Abstract

This document describes scenarios, consolidated use cases and associated requirements for wireless access networks in the 2020-2030 timeframe. These are based on METIS project and also taking into account work done in other 5G projects and forums such as ITU-R and NGMN. The document introduces spectrum authorization modes and describes spectrum usages scenarios, spectrum bands and spectrum demand for 5G services. Finally, this document provides qualitative techno-economic feasibility assessment by analyzing main players involved in service delivery, from the radio access network point of view, and describing their mutual positions and relationships.

Executive summary

One objective of the METIS-II is to facilitate the discussion on scenarios, use cases, KPIs and requirements for 5G, building upon the comprehensive work conducted in the METIS project [MET13-D11] and taking the work of other European projects and other bodies such as ITU-R, NGMN etc. into account. This document identifies five 5G use cases that cover the three main services (xMBB, mMTC and uMTC), have stringent requirements and whose technical solutions are expected to serve also for other similar use cases, as follows:

- the “Dense urban information society” use case is concerned with the connectivity required at any place and at any time by humans in dense urban environments,
- the “Virtual reality office” use case is related to the evolution of today’s tele-presence services into high-resolution 3D versions, which will allow people to have the amazing experience “as if you were there”,
- the “Broadband access everywhere” use case is related to the constant increase of the demand for very high data rate Internet access at any time and at any place and to the challenge of satisfying the ubiquitous capacity demands of future users in areas with sparse network infrastructure, such as scarcely populated areas, rural and even suburban areas,
- the “Massive distribution of sensors and actuators” use case covers the massive deployment of low cost and low energy consumption devices that need to communicate with other devices and with the network,
- the “Connected cars” use case addresses information exchange among vehicles and with the infrastructure to enable the provision of safety hints to the driver or warnings about the road status. It also addresses xMBB services on-board of cars.

Having defined these use cases, this document addresses the analysis of the use cases and technical solutions developed in METIS-II from a qualitative techno-economic feasibility point of view. This qualitative assessment consists in exploring the mobile access network ecosystem evolutions, based on the spectrum scenarios and the first 5G RAN design considerations developed in METIS-II. We identified the main current players in the Radio Access Network and presented the possible evolutions of their positioning in the value chain in the 5G era. We also identified new players that may play important roles in 5G and identified their relationships with the classical players. These ecosystem evolutions are also highlighted by a value net analysis, where mobile operators occupy the center of the scene and the current and new players surround them within four categories: customers, suppliers, competitors and complementors. In order to be more specific, we end the document with a detailed analysis of the dense urban information society use case, where the roles of the key players are presented for different possible 5G network deployment strategies.

Contents

List of abbreviations and acronyms

2G	Second Generation
3D	Three Dimensions
3GPP	Third Generation Partnership Project
4K	refers to a resolution of 4000 pixels
5G	Fifth Generation
5G-PPP	5G Private Public Partnership
ADSL	Asymmetric Digital Subscriber Line
AEP	Application Enablement Platform
API	Application Programming Interface
ARPU	Average Revenue Per User
ATG	Air-to-Ground
B2B	Business-to-Business
B2B2C	Business-to-Business to-Customer
B2C	Business-to-Customer
BB	Base Band
BBU	Base band Unit
C-RAN	Centralized/Cloud-Radio Access Network
CAPEX	CAPital EXpenditures
CBRS	Citizens Broadband Radio Service
CDN	Content Delivery Network
CDP	Connected Device Platform
CEPT	European Conference of Postal and Telecommunications Administrations
CN	Core Network
CP	Control Plane
CRM	Customer Relationship Management
D2D	Device-to-Device
DAS	Distributed Antenna System
dB	decibel
DL	DownLink
E2E	End-to-End
ECU	Electronic Control Unit

FCC	Federal Communications Commission
FM	Facility Manager
GAA	Generalized Authorized Access
GEO	Geostationary Earth Orbit
GPRS	General Packet Radio Service
HARQ	Hybrid Automatic Repeat reQuest
HTHP	High Tower High Power
HW	Hardware
IaaS	Infrastructure as a Service
ICT	Information and Communication Technology
IEEE	Institute of Electrical and Electronics Engineers
IMT	International Mobile Telecommunications
IMT-2000	term used by ITU for a globally harmonized standards for 3G
IoO	Internet of Objects
IoT	Internet of Things
ISP	Internet Service Provider
ITU	International Telecommunication Union
ITU-R	ITU Radiocommunication Sector
ITS	Intelligent Transport Systems
KPI	Key Performance Indicator
LAA	Licensed-Assisted Access
LEO	Low Earth Orbit
LTLP	Low Tower Low Power
LPWA	Low Power Wide Area
LSA	Licensed Shared Access
M2M	Machine-to-Machine
MAC	Medium Access Control
MBB	Mobile BroadBand
METIS	Mobile and wireless communications Enablers for the Twenty-twenty Information Society

MFCN	Mobile/Fixed Communications Network
MMC	Massive Machine Communication
MNO	Mobile Network Operator
mMTC	Massive Machine-Type Communications
MSP	Managed Service Provider
MTC	Machine Type Communication
MVNO	Mobile Virtual Network Operator
NaaS	Network as a Service
NEP	Network Equipment Provider
NF	Network Function
NFV	Network Function Virtualization
NGMN	Next Generation Mobile Network
NRA	National Regulatory Authority
NW	NetWork
OPEX	Operational EXpenditures
OSS	Operational Support System
OTT	Over The Top One Trip Time
PaaS	Platform as a Service
PAL	Priority Access License
PDCP	Packet Data Convergence Protocol
PPDR	Public Protection and Disaster Relief
PVNO	Private Virtual Network Operator
QoE	Quality of Experience
QoS	Quality of Service
RAN	Radio Access Network
RAT	Radio Access Technology
RF	Radio Frequency
RLC	Radio Link Control
RRC	Radio Resource Control

RTT	Round Trip Time
SCaaS	Small Cell as a Service
SCells	Secondary Cells
SDN	Software Defined Network
SINR	Signal-to-Interference-plus-Noise Ratio
SMS	Short Message Service
SON	Self-Organising Network
SW	Software
TC	Test Case Tower Company
TOo5G	Tower Overlay over 5G
UAV	Unmanned Aerial Vehicle
UC	Use Case
UE	User Equipment
UHD	Ultra-High Definition
UL	UpLink
uMTC	Ultra-reliable Machine-Type Communications
UP	User Plane
V2D	Vehicle-to-Device
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Anything
Wi-Fi	Wireless local access network technologies according IEEE 802.11 specifications and certified by the Wi-Fi Alliance
WRC-15	World Radiocommunication Conference 2015
WRC-19	World Radiocommunication Conference 2019
XaaS	Anything as a Service
xMBB	Extreme Mobile BroadBand

Glossary

Abbr.	Long	Explanation
-	Baseline (Reference) System	If not explicitly defined, baseline system refers to LTE-A with features from Rel. 13
-	Interface	In the context of METIS-II an interface is a logical connection between two dissimilar objects, devices or systems through which information is passed
-	Multi RAT	Refers to the integration of legacy (e.g., LTE-A or other RAT like 802.11ac) and/or novel 5G RATs
-	Test Environment	Set of simulation models and all necessary components that are needed for performance evaluation of a given use case (e.g. deployment, traffic, channel models, user distribution etc.).
5G	5th Generation	An overall wireless communications system expected to be rolled out in the 2020+ timeframe and consisting of both novel air interface elements and an evolution of legacy standards such as 2G, 3G, 4G, Wi-Fi, etc.
C-RAN	Centralized RAN	Hardware and software of multiple access nodes of a given RAN (except antenna elements), usually serving same geographical area, that is pooled together in a central entity for performance or cost reasons
SCell	Secondary Cell	Mobile cell operated on a carrier frequency within license-exempt spectrum by carrier aggregation with at least one primary cell operated on a carrier frequency in licensed spectrum in the LAA regime.
D2D	Device-to-Device	Direct communication on a user plane between access devices without passing through the network infrastructure
KPI	Key Performance Indicator	A quantifiable measurement, agreed beforehand, that reflects the critical success factors of a proposed solution; Multiple KPIs typically reflect the goals captured by each use case (UC)
MC	Multi Connectivity	Ability to connect simultaneously (via control and/or user plane) to several access nodes
RAN	Radio Access Network	Hardware and software realization of RAT
RAT	Radio Access Technology	Type of technology used for radio access, for instance E-UTRA, UTRA or GSM. Performing direct D2D transmission within a certain RAT does <u>not</u> count as a separate RAT.
TeC	Technology	Pseudonymously Enabler: A methodology,

	Component	algorithm, module or protocol that enables features of the 5G system
UC	Use Case	Definition of a particular service (or a group of services with similar application types) from the end user perspective
-	Use Case Family	Refers to the major service type, i.e., xMBB, mMTC, and uMTC. Usually one use case family has similar requirements especially in terms of fundamental KPIs

1 Introduction

1.1 Objective of the document

The main objectives of this document are to:

- **Refine the key scenarios** for wireless access networks in the 2020-2030 time horizon which have been established in the METIS project, taking into account the work in other 5G projects and forums such as ITU-R and NGMN,
- **Consolidate the existing 5G use cases (UCs) into a small set of main use cases** that are most suitable for being adopted in the 5G standardization process,
- **Present preliminary 5G spectrum scenarios,** both below and above 6 GHz**,**
- **Develop qualitative techno-economic feasibility assessment** by analyzing the main actors involved in the service delivery, from a radio access network (RAN) point of view, and describing their mutual positions and the relationships between them.

1.2 Structure of the document

The rest of the document is organized as follows:

- Section 2 provides five Metis-II 5G use cases and their associated requirements,
- Section 3 presents the preliminary 5G spectrum scenarios,
- Section 4 details the evolutions of the mobile telecommunications ecosystem with 5G,
- Section 5 summarizes the findings,
- Appendix A presents the main KPIs for 5G services,
- Appendix B exposes the process followed for selecting METIS-II use cases, based on the analysis of 5G use cases in the literature,
- Appendix C provides detailed descriptions of the use cases and their requirements,
- Appendix D provides a detailed analysis of the current value chains in the mobile sector.

2 METIS-II 5G use cases

In this section the METIS-II 5G use cases are briefly presented before they are described in detail in Section 2.1, and their main requirements are provided in Section 2.2. The methodology for selecting these use cases is presented in Appendix B and the detailed requirements are given in Appendix C.

Three use case families are considered as the corner stones, where each use case addresses at least one use case family. These three use case families are contained in the system concept of the METIS-I project (and are referred to as generic services). In [MET15-D66] they are e.g. described as follows:

- Extreme Mobile BroadBand (xMBB) provides both extreme high throughputs and low-latency communications, and extreme coverage improving the Quality of Experience (QoE) by providing reliable moderate rates over the coverage area.
- Massive Machine-Type Communications (mMTC) provides wireless connectivity for dozens of billions of network-enabled devices (in the order of 100 000 per access point). Scalable connectivity for an increasing number of devices; wide area coverage and deep indoor penetration are prioritized over peak rates as compared to xMBB.
- Ultra-reliable Machine-Type Communications (uMTC) provides ultra-reliable low-latency and/or resilient communication links for network services with extreme requirements on availability, latency and reliability, e.g. Vehicle-to-Anything (V2X) communication and industrial control applications.

It goes without saying that considering each service type separately and building a 5G network accordingly, we would likely end up with very different RAN designs and architectures. However, only a common RAN that accommodates all three service types is an economically and environmentally sustainable solution. For this reason, the METIS-II RAN design is performed specifically towards a set of 5G use cases that typically combine multiple service types. More precisely, the project has performed an analysis of the 5G use cases considered by various entities (see appendix B), classified them into families considering the special characteristics of these (e.g., covered services, mobility, and/or number of users, infrastructure, etc.), and chosen five use cases that are seen as most representative of these different families. Figure 2-1 provides an overview of the complementary requirements and service scopes addressed by each use case and thus describes the motivation for selecting each of them.

Family	Use Case (UC)	Scope of requirements (network/user perspective)	Scope of services (service perspective)	Source
xMBB, mMTC	Dense urban information society	Experienced user data rate / Traffic vol. per subscriber / Nb. of users and devices / Energy efficiency	Broad range of communication services covering needs related to both indoor and outdoor urban daily life (excl. office and factory)	METIS-I test case enriched by NGMN UC Mobile video surveillance
xMBB	Virtual reality office	Experienced user data rate / Traffic volume per subscriber / Latency	Broad range of communication services in the (indoor) office context	METIS-I test case
xMBB	Broadband access everywhere	Experienced user data rate / Availability / Mobility / Energy efficiency	Full coverage topic addressing outdoor/indoor communication needs especially in rural areas	NGMN use case 50+ Mbps everywhere incl. METIS-I test case Blind spot
mMTC	Massive distribution of sensors and actuators	Availability / Number of devices / Energy efficiency	Broadest range of IoT services covered	METIS-I test case Massive deployment of sensors and actuators
xMBB, uMTC	Connected cars	Latency/ Reliability / Mobility	Strong expectation from the (automotive) industry Belong to the first uMTC services expected to be commercialized	METIS-I test case Traffic efficiency and safety complemented by MBB aspects

Figure 2-1: An illustration of the METIS-II 5G use cases and to which use case family or families these use cases belong to. Further, the scopes in terms of requirements and services are illustrated as well as where each use case originates from.

5G network is envisioned to be able to serve 1000 times more traffic volume, for xMBB services, compared to 4G Release 11 networks. This target has been highlighted by several sources, including METIS project [MET15-D15], NGMN [NGM15], ITU-R [ITU15] and 5G PPP [5GPPP15], leading to challenging targets on traffic volume densities as highlighted in Appendix C. METIS-II is working towards quantifying the deployment scenario and the amount of spectrum required for reaching these targets.

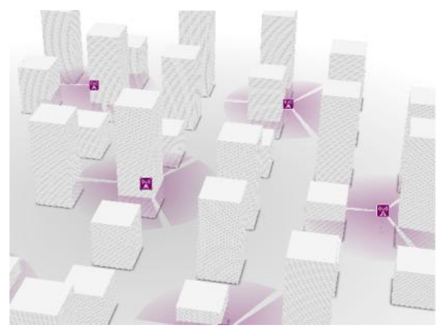
As of energy efficiency, it is considered as an overall design goal for the entire 5G system. For xMBB service, the energy consumption of infrastructure is very important, while battery life is critical for mMTC services. METIS-II project has adopted the principle that energy efficiency improvement in 5G systems should follow at least capacity improvement, i.e. energy consumption should not be greater than [ITU-R M.2083-0] or even reduced [NGMN 5G White Paper] compared to existing networks. Since hundreds or thousands of traffic volume increase of 5G system relative to legacy one is expected with no greater or even less overall energy consumption of the infrastructure, the network energy efficiency of 5G system is required to be improved by a factor of hundreds or thousands compared to legacy one. Energy efficiency evaluation methodology is still under discussion in METIS-II. The methodology is not straightforward and needs to account for spatial and temporal traffic variation as well as 5G services mix. Consequently evaluation scenario and methodology for energy efficiency could possibly differ from evaluation scenario of other metrics like experienced user throughput, latency, etc. which would likely be evaluated under extreme traffic scenario.

2.1 Consolidated use cases

In this section the consolidated use cases are described. The “Broadband access everywhere” use case originates from NGMN [NGM15], whereas the other four use cases are developed from METIS-I test cases [MET13-D11].

2.1.1 UC1: Dense urban information society

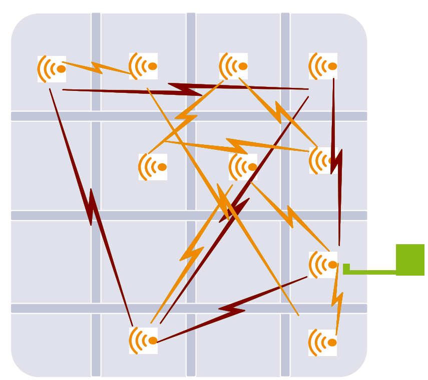
The “Dense urban information society” use case is concerned with the connectivity required at any place and at any time by humans and machines in dense urban environments, including both indoor and outdoor environments. We consider here both the traffic between humans and between human and the cloud, and also direct information exchange between humans or with their environment for new 5G services, such as immersive Ultra-High Definition (UHD) video streaming, cloud gaming, etc. Device-to-device (D2D) communication in dense urban environment provides opportunity to offload traffic as well as to cut-short traffic path by enabling proximity based discovery and communication. Besides, in the dense urban scenario, machine type communication such as ubiquitous mobile video surveillance may evolve to be available for monitoring houses/buildings, targeted areas and special events, etc.



This use case is mainly based on test case two of METIS-I (Dense urban information society), see [MET13-D11], and has been slightly updated following NGMN requirements [NGM15]. It mainly addresses the use case families xMBB and mMTC.

2.1.2 UC2: Virtual reality office

The importance of interactive video communication will increase in the future, for personal as well as professional use. Today’s tele-presence services will evolve into high-resolution 3D versions, which will allow friends and relatives to have the amazing experience “as if you were there”. On the professional side, the technology developed will support this kind of complex interactive work, by means of e.g. virtual reality imaging. An inexpensive and flexible wireless communication system, able to exchange the huge amount of data generated during the process, will be an essential part of the technical solution. It is likely that it will find use also in other areas.



Today’s wireless technologies are not capable to provide, at reasonable costs, the high data-rate and capacity requirements posed by this type of applications on the access and the in-building backhaul to the wireless access points.

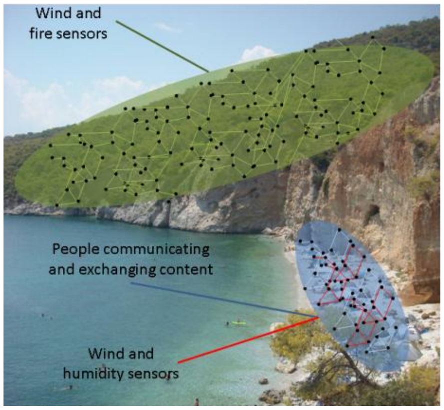
This use case is based on test case one of METIS-I (Virtual reality office), see [MET13-D11]. It mainly addresses the use case family xMBB.

2.1.3 UC3: Broadband access everywhere

The demand for very high experienced user throughput Internet access at any time and at any place is constantly increasing. The ubiquitous capacity demands of future users will be challenging to satisfy in areas with sparse network infrastructure, such as scarcely populated areas, rural and even suburban areas. A consistent user experience with respect to throughput, needs a minimum experienced user throughput guaranteed everywhere. The target value of 50 Mbps everywhere should be understood as the minimum experienced user throughput and not a single user's theoretical peak rate. Furthermore, it is emphasized that this user rate has to be delivered consistently across the coverage area (i.e. even at cell edges). Furthermore, the battery consumption of smart phones and tablet terminals in areas with low coverage increases significantly due to higher propagation losses. A target of 50% energy consumption reduction compared with legacy network should be achieved both at network infrastructure and at end user level. While cell densification is promising for boosting capacity in future urban environment, wide coverage solutions as well as flexible, energy and cost efficient solutions must be developed in future wireless communication systems to provide ubiquitous coverage in suburban and more or less remote rural areas.

This is a new METIS use case built on elements of a NGMN use case [NGM15] combined with some aspects from the METIS-I test case seven (Blind spots) in [MET13-D11]. This use case mainly addresses the use case family xMBB.

2.1.4 UC4: Massive distribution of sensors and actuators

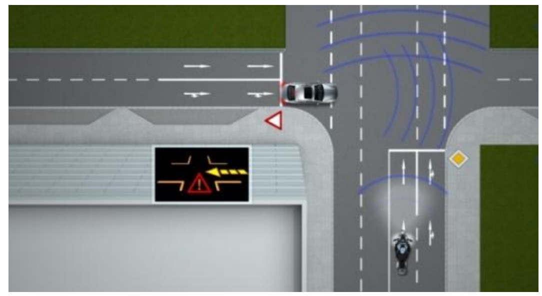


The importance of this use case will grow together with the massive deployment of low cost and of low energy consumption devices. In order to get the maximum of information from these devices, to increase environmental awareness and better user experience, there is a need for these devices to be able to communicate with other devices, the network, or with other mobile phones. People communicating and exchanging content can take place in combination with receiving wind, fire and humidity updates from sensors.

This use case is based on a test case eleven in [MET13-D11]. It mainly addresses the use case family mMTC.

2.1.5 UC5: Connected cars

The use of remote services is also applicable at higher user mobility, e.g. while driving cars or using public transportation, and not merely taking place in slow mobility or stationary settings. With higher user mobility enabled on-the-way workers as well as a leisured people can enjoy the benefits of real-time remote computing for mobile terminals. At the same time the connected car also provides a safe and efficient journey via the communication to its surrounding. This communication enables the car to avoid accidents, but it also enables other types of traffic planning such as avoiding traffic jam queues and minimizing fuel consumption. Thereby the connected car enables traffic safety, efficiency and real-time remote services.



This use case is based on test cases eight and twelve of METIS-I [MET13-D11]. It mainly addresses the use case families uMTC and xMBB.

2.2 Refined requirements

The main KPIs and requirements of the METIS-II use cases are given in Table 2-1. The detailed requirements are given in Appendix C.

Table 2-1: Summary of main KPIs and requirements for each METIS-II use case.

Use Case (UC)	Key Performance Indicator (KPI)	Requirement
UC1 Dense urban information society	Experienced user throughput	300 Mbps in DL and 50 Mbps in UL at 95% availability and 95% reliability
	E2E RTT latency	Less than 5 ms (augmented reality applications)
UC2 Virtual reality office	Experienced user throughput	5 (1) Gbps with 20% (95%) availability in DL 5 (1) Gbps with 20% (95%) availability in UL both with 99% reliability
UC3 Broadband access everywhere	Experienced user throughput	50 Mbps in DL and 25 Mbps in UL at 99% availability and 95% retainability
UC4 Massive distribution of sensors and actuators	Availability	99.9%
	Device density Traffic volume per device	1 000 000 devices/km^2 From few bytes per day to 125 bytes per second
UC5 Connected cars	E2E one-way latency	5 ms (traffic safety applications)
	Experienced user throughput	100 Mbps in DL and 20 Mbps in UL (service applications) at 99% availability and 95% reliability
	Vehicle velocity	Up to 250 km/h

These use cases, along with their key requirements, are illustrated in Figure 2-2.

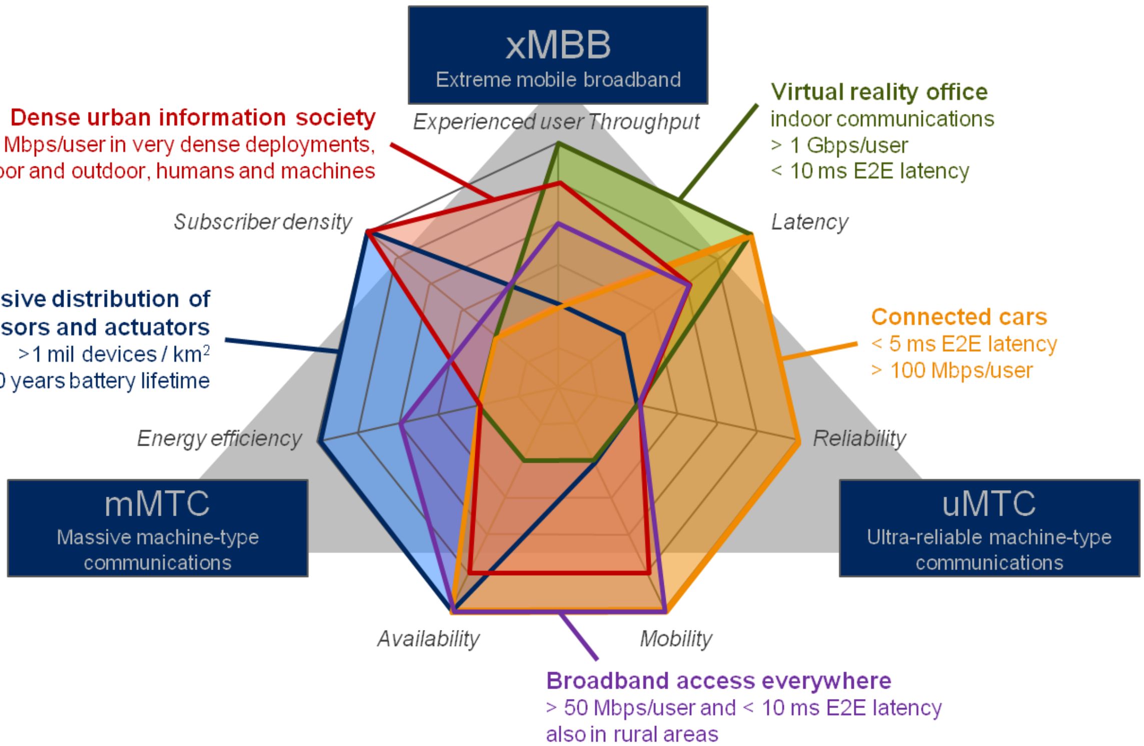


Figure 2-2: The METIS-II 5G use cases and their mapping to the 5G services.

3 5G spectrum scenarios

In this section the preliminary 5G spectrum scenarios are introduced. Spectrum authorization modes and usage scenarios, spectrum bands for the 5G generic services xMBB, mMTC and uMTC, and spectrum demand are considered. Globally harmonized frequency bands below 6 GHz, as well as bands between 24 - 86 GHz under study in ITU-R for IMT systems are briefly reflected.

3.1 Spectrum authorization modes and usage scenarios

In general the use of radio spectrum can be authorized in two ways: Individual Authorization (Licensed) and General Authorization (License Exempt / Unlicensed). Authorization modes recognized as relevant for wireless communications are *Primary user mode*, *LSA (Licensed Shared Access) mode* and *Unlicensed mode*.

Five basic spectrum usage scenarios can be identified for these authorization modes: dedicated licensed spectrum, limited spectrum pool, mutual renting, vertical sharing and unlicensed horizontal sharing (see Figure 3-1, depicting the relations between parts of the domains which are either necessary (mandatory: continuous lines) or supplementary (optional: dotted lines)).

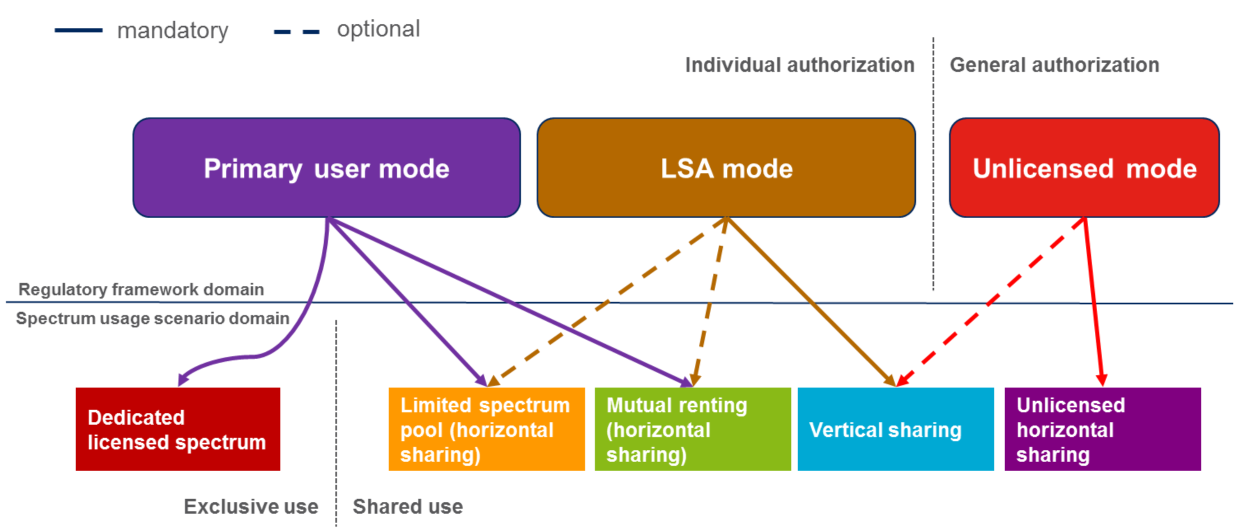


Figure 3-1: Spectrum usage/sharing scenarios [MET15-D54].

The general conclusion with regard to spectrum authorization for 5G is that:

- exclusive licensed spectrum is essential for the success of 5G to provide the expected QoS and to secure investments,
- shared spectrum can be considered in addition, provided that predictable QoS conditions are maintained, e.g. by LSA regime,
- license-exempt spectrum might be suitable as a supplementary option for certain applications, for instance using the LAA (License-Assisted Access) scheme explained below.

In Europe LSA is the recognized approach by CEPT (European Conference of Postal and Telecommunications Administrations) for administrations wishing to introduce Mobile/Fixed Communications Networks (MFCN) in the band 2300-2400 MHz while maintaining the current incumbent use [ECC14-DEC02], [ECC14-REP205]. Different LSA trials are currently on-going in Europe.

In the US, the FCC has announced the first set of rules for the band 3550-3700 MHz, termed Citizens Broadband Radio Service (CBRS), to enable deployment of relatively low powered network technologies like small cells [FCC15-47]. The rules require a Spectrum Access System (SAS) based on exclusion/protection zones and sensing to implement a three-tiered regulatory framework in which incumbents operate in the top tier, Priority Access License (PAL) users operate in the second tier and Generalized Authorized Access (GAA) users operate in the third tier (Figure 3-2).

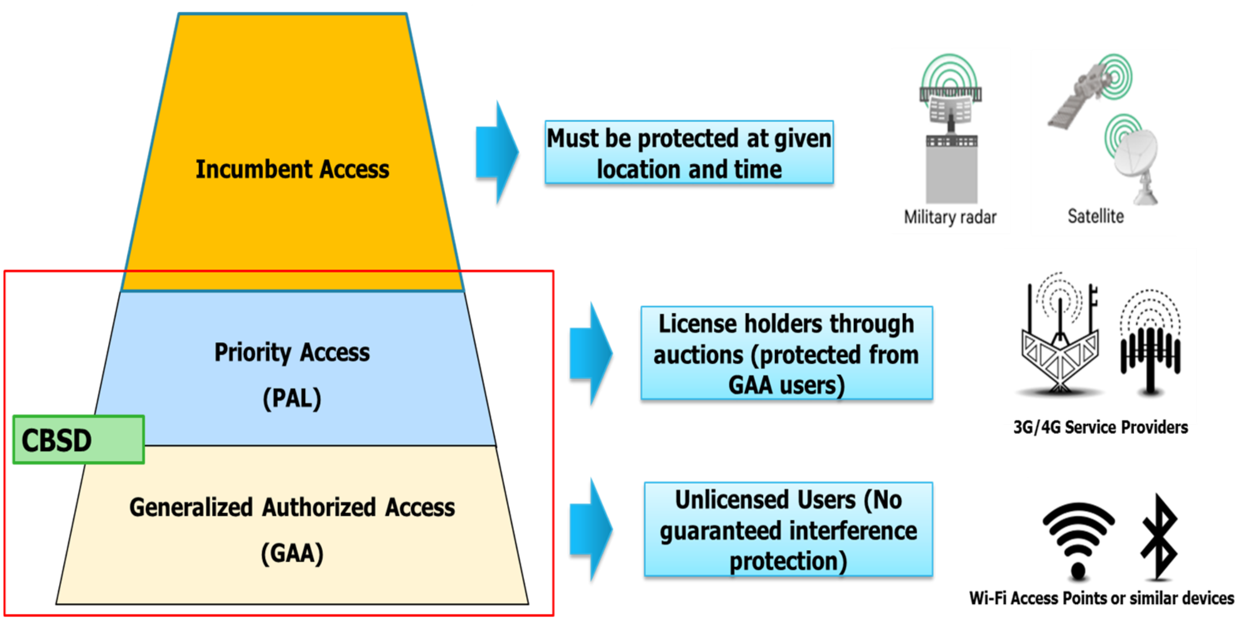


Figure 3-2: FCC Terminology at 3.5 GHz [KRB15].

The incumbents which have the highest priority spectrum access can require all secondary systems in a spatial region to relinquish all or portions of spectrum at any time. To the secondary devices from the PAL tier exclusive channels are allocated that provide guaranteed interference protection, similar to traditional long term licenses. The GAA tier provides no interference protection and therefore, allows multiple independent networks to use a given channel not used by incumbent or PAL users.

LAA is an innovative approach for unlicensed horizontal sharing in the *Unlicensed mode* that aims at enabling the operation of LTE in the 5 GHz unlicensed spectrum for low power Secondary Cells (SCells). 3GPP has conducted a corresponding study [3GPP14-LAA], summarizing the necessary modifications to LTE and the relevant regulatory requirements (e.g. to achieve co-existence with Wi-Fi).

LAA targets carrier aggregation operation in which one or more low power SCells are operating in unlicensed spectrum. LAA deployments encompass scenarios with and without macro coverage, both outdoor and indoor small cell deployments, and both co-location and non-co-location (with ideal backhaul) between licensed and unlicensed carriers. Figure 3-3 shows four LAA deployment scenarios, where the number of licensed carriers and the number of unlicensed carriers can be one or more.

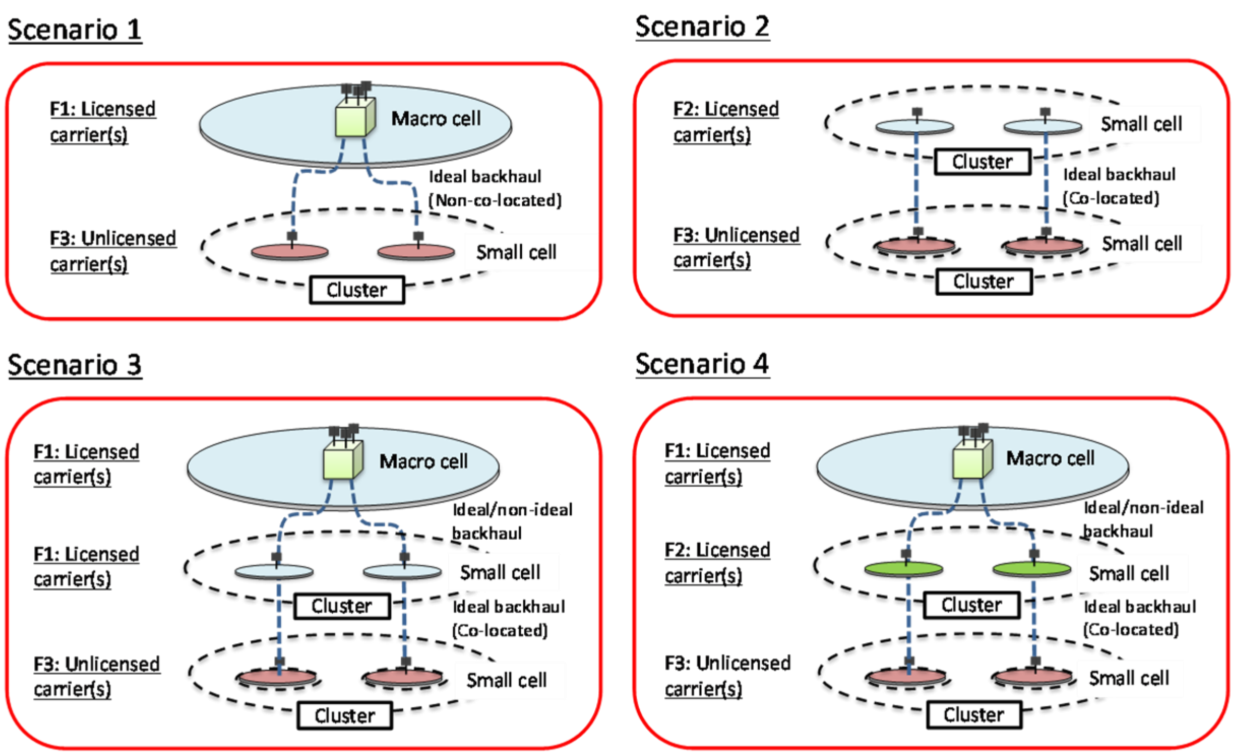


Figure 3-3: LAA deployment scenarios [3GPP14-LAA].

Based on the study results, 3GPP adopted a work item to specify support for DL transmissions for LAA SCells for Release 13. Specification of support for UL transmissions for LAA SCells is planned to be added in future releases, without modifications to the DL design.

3.2 Spectrum bands for 5G generic services

The following general conclusions on the suitability of spectrum bands for the 5G generic services as defined by METIS – xMBB, mMTC and uMTC - can be drawn:

- For xMBB, a mixture of frequency spectrum comprising lower bands for both coverage purposes and data traffic, and higher bands with large contiguous bandwidth to cope with the ever-increasing traffic demand, including wireless backhaul solutions, is required. Exclusive licensed spectrum is essential to guarantee the coverage obligation and QoS, supplemented by spectrum authorized by other licensing regimes, e.g. LSA or unlicensed access (e.g. Wi-Fi offload) or new enhanced unlicensed access schemes (e.g. LAA) to increase overall spectrum availability.
- For some mMTC applications, frequency spectrum below 6 GHz is most suitable and spectrum below 1 GHz is needed in particular when large coverage areas and good penetration are needed. Exclusive licensed spectrum is the preferred option. However, other licensing regimes might be considered depending on specific application requirements.
- Licensed spectrum is considered most appropriate for uMTC. For safety V2V and V2X communication the frequency band 5875-5925 MHz harmonized for Intelligent Transport Systems (ITS) [ECC08-DEC01] is an option. Another option is the sub-1GHz spectrum, particularly well-suited for high-speed applications and rural environments.

3.3 Spectrum demand

The variety of 5G services, scenarios and use cases puts high demands on future mobile networks with regard to coverage, capacity and reliability, for which the availability of a spectrum amount of several GHz is required, to be sought in a combination of suitable frequency bands allocated to the mobile service.

An example in [MET15-R31] with an assumed traffic increase of xMBB application 4K video up to 70 Gbps/km^2 in the year 2025 shows that additional bandwidth of several hundreds of MHz per operator will be needed. Another example in [MET15-R31] shows that uMTC also needs similar bandwidths as xMBB, i.e. in the order of several hundreds of MHz, due to the overall impact of latency and reliability requirements and the amount of devices at the same time.

The use case “Virtual reality office” has been detected as the most bandwidth demanding scenario evaluated in the METIS project [MET14-D53]. The assumptions considered to carry out the analysis were spectrum agnostic, but depending on the actual SINR distributions achievable (which at the end will depend on the technology components performance in the selected scenario), leading to the outcomes summarized in

Table 3-1. These evaluations have been focused on the spectrum needs, independent of a specific frequency range, and therefore represent a good starting point to balance the bandwidth requirement with the technology components performance, and with the network deployment.

Table 3-1: Bandwith demand for "Virtual reality office" [MET14-D53].

Available bandwidth	Mean values for SINR distribution needed in the network
4500 MHz	5 - 10 dB
3000 MHz	10 - 15 dB
1500 MHz	> 20 dB

The values presented in Table 3-1 are from the METIS-I project and might be revisited during the METIS-II project.

3.3.1 Spectrum below 6 GHz

Spectrum requirements for the year 2020 have been calculated for pre-IMT systems, IMT-2000, and its enhancements, and IMT-Advanced [ITU-2290]. Due to differences in markets, deployments, and timings of the mobile data growth in different countries, two settings have been evaluated to characterize lower and higher user density settings. The results are presented in Table 3-2.

Table 3-2: Total spectrum demand calculation for the year 2020.

Total spectrum requirements for "Pre-IMT systems, IMT-2000 and its enhancements, and IMT-advanced" in the year 2020	
Lower user density settings	1340 MHz
Higher user density settings	1960 MHz

Spectrum bands currently identified for IMT in the ITU-R Radio Regulations will have to cope with the mobile traffic demand until the year 2020. In Europe, for example, the overall amount of spectrum identified for IMT is 1232 MHz, however, not all of those IMT identified bands are available for mobile communications in every country.

3.3.2 Result of WRC-15 on bands above 6 GHz

WRC-15 has agreed that ITU-R will conduct and complete in time for WRC-19 the appropriate sharing and compatibility studies by 31 March 2017, for the frequency bands:

- 24.25-27.5 GHz, 37-40.5 GHz, 42.5-43.5 GHz, 45.5-47 GHz, 47.2-50.2 GHz, 50.4-52.6 GHz, 66-76 GHz and 81-86 GHz, which have allocations to the mobile service on a primary basis; and
- 31.8-33.4 GHz, 40.5-42.5 GHz and 47-47.2 GHz, which may require additional allocations to the mobile service on a primary basis.

Some of these frequency bands enable wide contiguous bandwidths which would enable to cope with the spectrum requirements of high bandwidth demanding xMBB applications. For the study in time for WRC-19, development of new methodology for the spectrum requirement estimate should be the priority, considering the 5G environment. Moreover, the new methodology should take into account 5G system requirements and its applications from the use cases to focus on 5G that can make people enjoy new services in terms of higher data rate, so called ‘application-based approach’.

4 Ecosystem evolutions

This section builds on the 5G use cases and spectrum scenarios described above and on RAN architectural considerations to construct preliminary business models. Section 4.1 starts by describing the current value chains in the mobile sector. Section 4.2 presents the general trends for the evolution of the value chains by identifying new actors and their relationships. Section 4.3 focuses on business models of the dense urban information society use case.

4.1 Current value chains in the mobile sector

4.1.1 Identification of the main players and their respective roles

This section presents the main existing players through the RAN, which are involved in the mobile service value chain and their respective roles. Details are given in Appendix D.1.1.

Figure 4-1 provides an overview of current main players involved in radio connectivity services. The roles of MNOs, MVNOs, outsourcing players, device manufacturers and OTTs/content owners are detailed in Section 4.1.2 as they are directly present in the mobile networks value chain. Other players are also presented in Figure 4-1, whose roles are more related to specific services like in-flight connectivity, M2M and IoT and Public safety and public protection players; their value chains are detailed in Appendix D.

Figure 4-1: An illustration the main existing players that revolve around the RAN.

As of Figure 4-2, it positions the players on two axes related to the radio connectivity landscape, ad related to the throughput they provide to their users (x axis) and the coverage they ensure (y-axis).

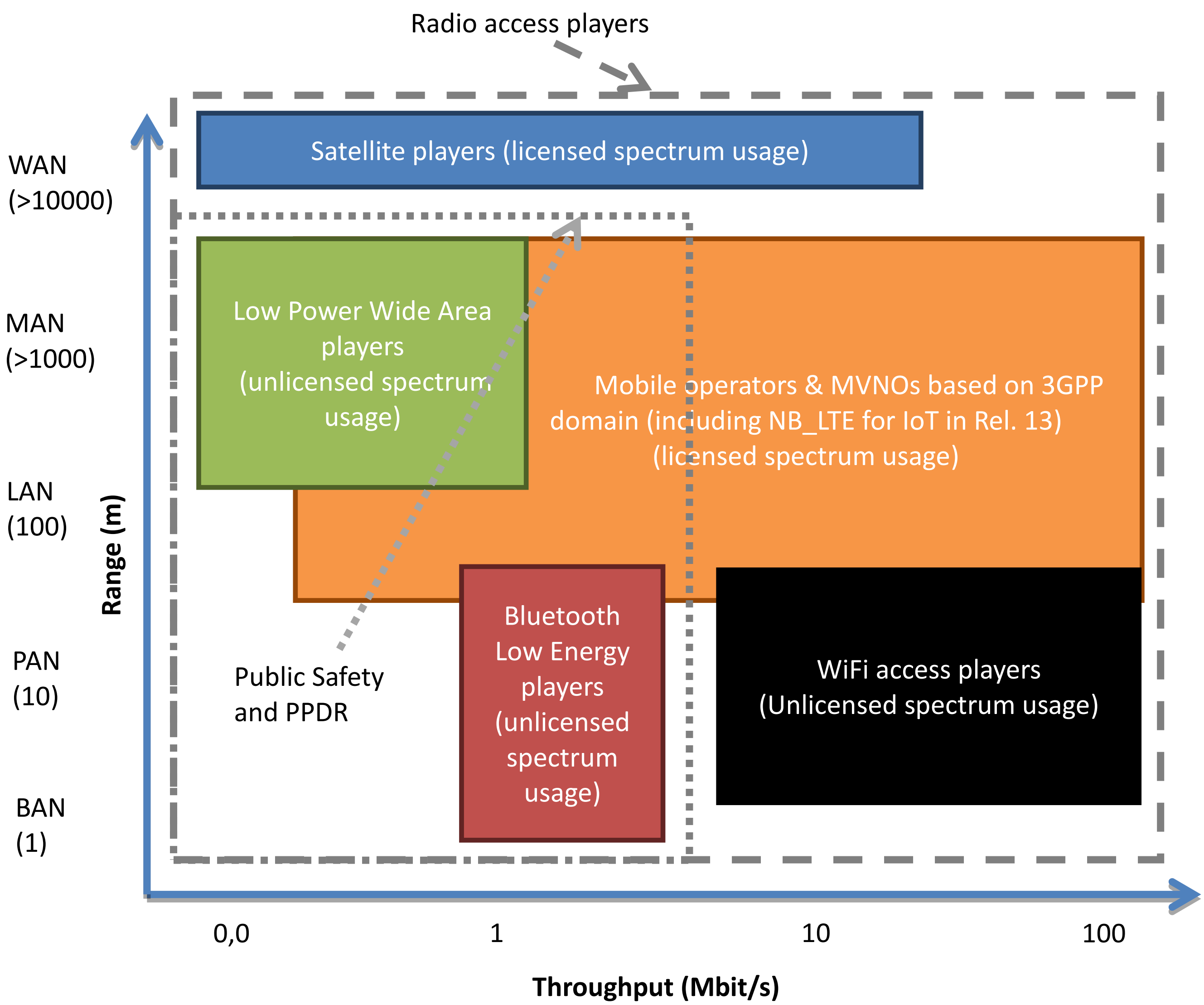


Figure 4-2: Main players mapped on the radio connectivity landscape.

4.1.2 Presentation of the current value chains

In this section, we describe the current value chain of the mobile networks. The following value chains in the mobile sector are provided in the Appendix D:

- Mobile value chain
- Urban street furniture value chain
- Satellite value chain
- Content value chain
- OTT value chain
- M2M value chain
- Automotive value chain
- In-flight connectivity value chain

The telecommunications industry has been characterized by a rapid change, almost continually since its commercialization in 1983. Among these changes, the following have had a tremendous effect on the value chain: (1) deregulation of markets, (2) increased competition (3) advancing technologies. At the industry level, mobile network operators have traditionally controlled and managed most of the value chain from network operation to front-end services, but, as observed in the telecommunication industry all over the world, this is changing.

The mobile ecosystem has evolved from a linear relationship between cellular networks and cellular customers to a network of specific companies involved at different stages in the value chain. The value chain has become specialized into segments that include content related services and applications, network infrastructure, integration services, access devices, and a multitude of sub segments and niche applications. Moreover, regarding the highly dynamic nature of telecommunications industry, one can understand that the value chain is also in dynamic changing. Figure 4-3 presents the up-to-date value chain of wireless telecommunications industry.

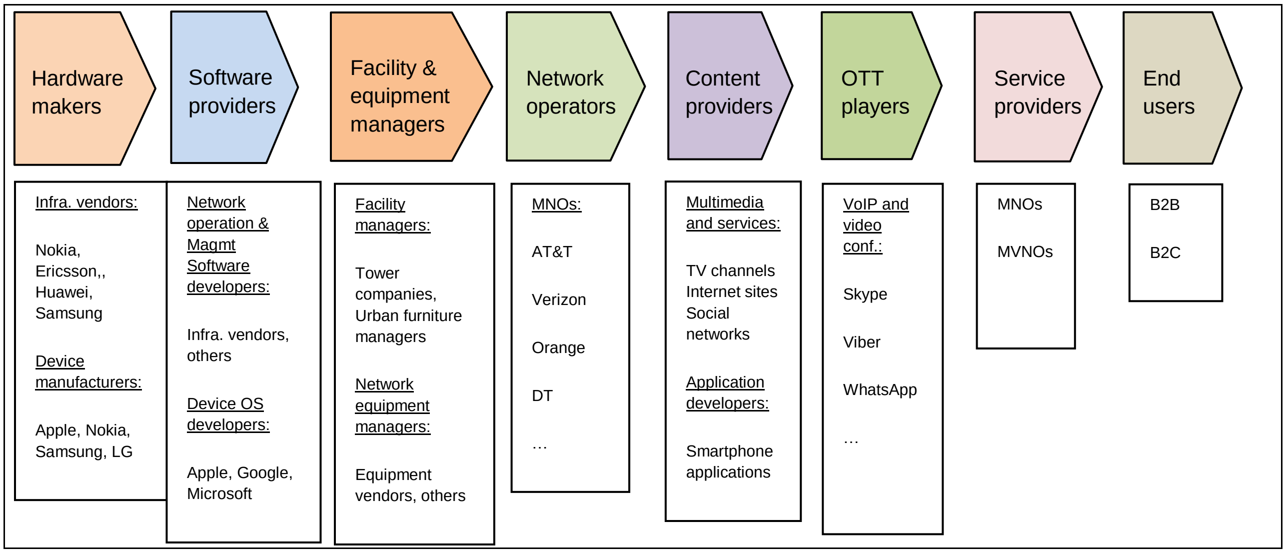


Figure 4-3: Value chain of wireless telecommunications industry.

1- **Hardware providers:** The value chain starts with the hardware providers that manufacture network equipment (base stations, network controllers, gateways, etc.) and user devices (mobile phones, smartphones, tablets, dongles). These providers include infrastructure vendors (for instance, Ericsson, Nokia, Huawei, Samsung, etc) as well as device manufacturers (Apple, Samsung, LG, Nokia, etc). Indeed, base stations and user devices are the starting point for any telecommunication industry.

2- **Software providers**: The software providers, developing software enablers (middleware and applications) constitute the second activity as they allow operating infrastructure and devices. In more details, these software actors include firms that develop middleware for operating, monitoring and managing network infrastructures, as well as Operating System developers that allow operating user devices (e.g. Apple with its iOS, Google with its Android and Microsoft with its Windows Mobile). Note that, in most cases, base station manufacturers are still providing software for operating, monitoring and managing their equipment. However, as networks are increasingly composed of equipments from different manufacturers (several vendors), external software actors provide solutions to operate and monitor the resulting heterogeneous system.

3- **Facility and equipment managers:** MNOs are increasingly referring to players owning assets which can be useful for mobile network coverage and capacity extensions. Tower companies, facility managers and urban furniture managers fall into this group. MNOs are also subcontracting some of the network operation and management tasks to equipment vendors or specialized companies.

4- **Network operators:** A key activity is that of network operators who own the licenses for operating mobile networks. MNOs deploy equipments and operate them using software enablers, even if they are partially relying on facility and equipment managers. AT&T, Verizon, Vodafone, Orange are examples of network operators.

5- **Content providers:** Content providers come next as they provide the contents that interest clients (note that, in the case of voice networks, the role of content providers is less important). Examples of content providers in modern mobile networks (dominated by smartphones) are Google (maps, gmail, etc.), news agencies, TV channel providers, cloud providers, social networks, etc.

6- **Over-The-Top (OTT) players:** OTTs are not classically considered within the value chain of wireless telecommunications industry, or are considered in the same category of content providers. However, we believe that OTT players, especially those that provide telecommunication services (voice and video conferencing), are becoming major actors in the wireless telecommunication chain. These OTTs include Viber, Skype, etc.

7- **Service providers:** Service providers are the companies that offer wireless services to end clients. Their services include***:***

- Voice calls local, regional, national, and international

- Voice services like voice mail, caller ID, call waiting, call forwarding…
- Data services like SMS messages, Text Alerts, Web browsing, e-mailing, streaming, etc.
- Mobile TV services

8- **End users:** The value chain ends with customers (individual users, companies, administrations) who adopt to wireless products and services offered by service providers. End-users although acting independently through their own actions are influenced by each other's actions and create increasing returns by creating a critical mass that accelerates adoption of service.

Figure 4-4 below summarizes the activity levels in the different market fields (based on a three stages) of the most important player groups in the wireless telecommunication industry. Note that mobile operators (incl. MVNOs) are in a key position to "own" the relationships with their customers. In the figure a differentiation was made between the direct relation to the paying customer (here noted as CRM) and the usage behind. MNOs know very well the connectivity behavior of their customers (data volume, voice call duration, etc.), but not the detailed usage profile in the virtual world (Internet, etc.) which is often characterized by separate IDs (e.g., accounts of social networks).

To maintain their position, the MNOs developed few years ago what was called "walled gardens" portals. By offering all mobile Internet services only through their portals, MNOs made sure that they could constantly track what is being done on their networks. This also meant that MNOs were not merely a "dumb pipe" offering only connectivity. Some players were fast in dismantling their walled garden, and welcomed third-party applications being downloaded through their networks.

A dissolution of boundaries between traditional roles has also been taking place over the last years with e.g. end-users increasingly acting as both service and content providers.

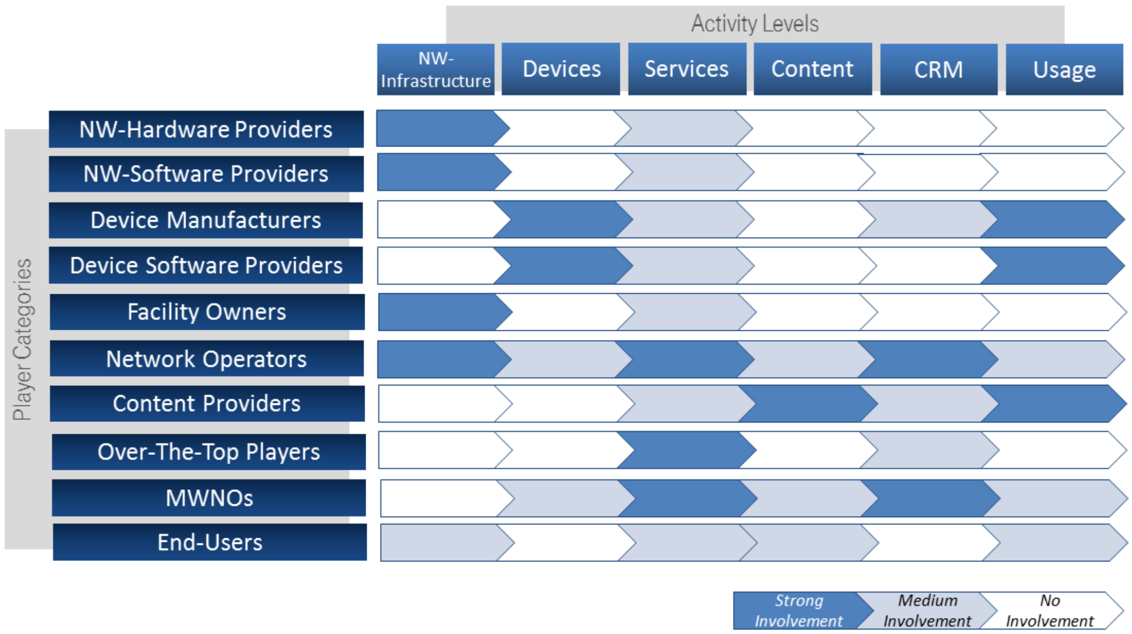


Figure 4-4: Focus on different players activities in the value chain.

Generally, most players in the value chain aim at getting full knowledge of customer behavior including the service usage which would allow using that information for business purposes via tools like big data analysis. The business opportunities range from targeted advertisement and highly personalized customer services to use of data for optimized and automated network operation.

This target to learn more about the users will drive the further evolutions of the value chains and also strongly impact future business models in the context of 5G.

4.2 General trends for the evolution of the value chains

4.2.1 Assumptions on 5G architecture

In its 5G White Paper [NGM15], NGMN released a vision for the overall 5G architecture. This vision is illustrated in Figure 4-5 and includes new concepts such as E2E network (NW) slicing.

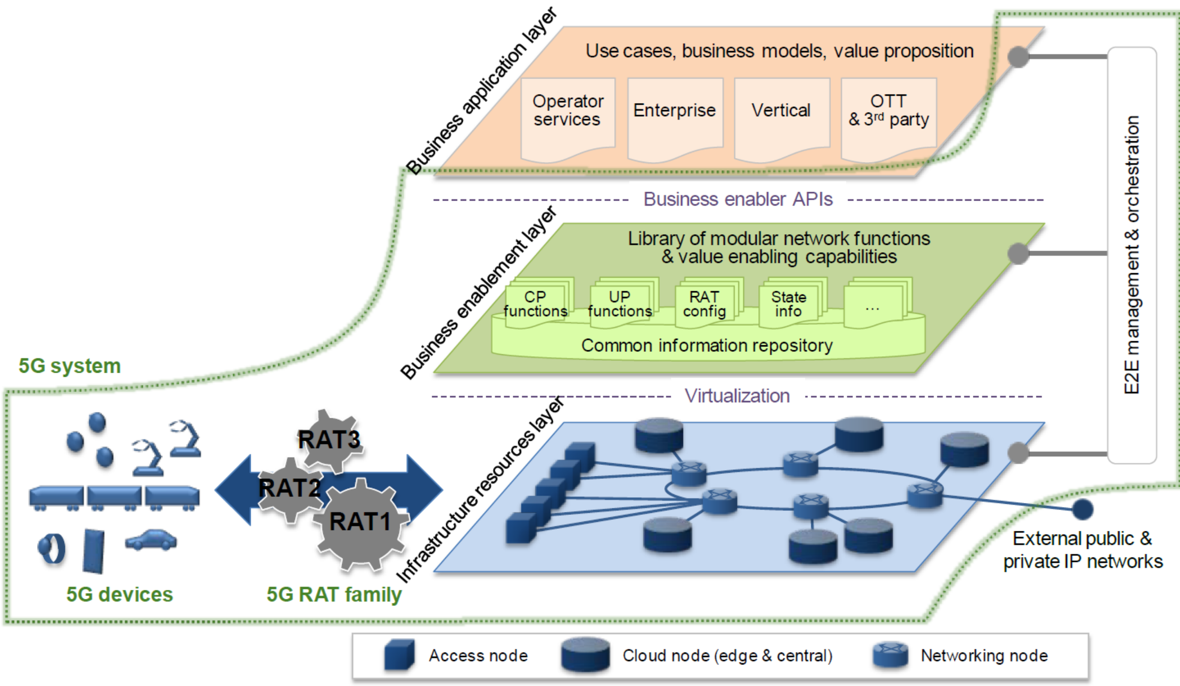


Figure 4-5: High level view on NGMN 5G architecture [NGM15].

NGMN envisions a native SDN/NFV-based architecture (Software Defined Networking / Network Function Virtualization) that is set up on 3 layers covering aspects ranging from devices, (mobile/fixed) infrastructure, network functions (NFs) for Control-Plane and User-Plane (CP/UP), value enabling capabilities etc., up to all the management functions needed to orchestrate the 5G system. Application Programming Interfaces (APIs) are provided on relevant reference points to flexibly support multiple use cases, value creation and business models. The E2E Management & Orchestration Entity is responsible for the translation of 5G use cases and business models into concrete services and slices. It determines relevant NFs, air interface variants and performance configurations, and finally maps them onto the available 5G infrastructure consisting of HW and SW parts including transport networks, computing and storage resources, RF units (incl. antennas) and cables. It also manages scaling of the capacity of individual NFs and their geographic distribution, as well as OSS (Operations Support Systems) and SON (Self-Organizing/Optimizing Networking) features.

As mentioned before, NW slicing is an important part of the NGMN vision for the overall 5G architecture, though it is required to point out that the concept itself is still under discussion. The creation of NW slices is mainly business driven and aims to address the needs of different 5G use cases with highly diverging requirements (see Figure 4-6). A NW slice is envisioned to support the communication services of a particular connection type with a specific way of handling CP and UP for these services. To this end, a "5G slice" could be composed of a collection of 5G NFs and specific RAT settings that are combined together for a specific use case or business model.

From an end customer perspective a NW slice is seen as an independent network. However, in contrast to deploying independent network infrastructures as it was the case in former mobile radio generations, it will be realized together with other slices on a common infrastructure layer (also referred to as "virtual network"), also including assets such as spectrum. In this way, the infrastructure and assets utilization is likely to be much more cost and energy efficient. The slicing concept is envisioned to further allow for a much faster set-up of new services and applications or modification of existing ones. Generally, a slice is an abstract network that has to be instantiated to address the infrastructure resources. Several instances of the same slice are possible, each of them being customized via a suitable allocation of NFs and/or their parameterization out of a number of potential alternative NFs. Note that a slice may be statically configured, or dynamically instantiated or re-configured over time. A slice finally describes an end-to-end relation, i.e. its functionalities also cover the 5G device part. In principle, third parties (e.g. verticals, MVNOs, OTT service providers) can create and manage their own networks via the corresponding APIs (known as "anything as a service", XaaS).

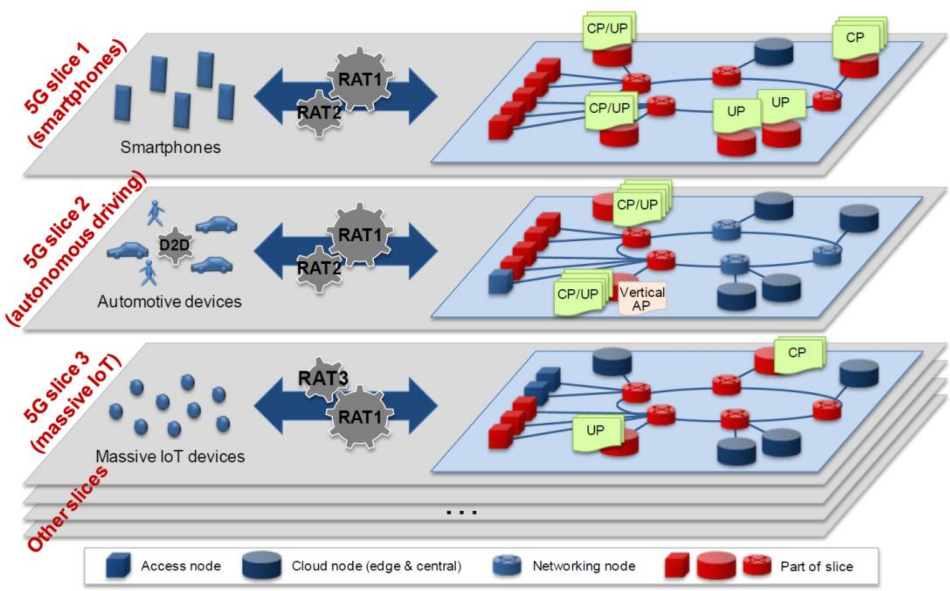


Figure 4-6: Examples for 5G network slices [NGM15].

Even if NW slices are seen as separated NWs (only on logical level) it is still required to efficiently use common resources such as radio spectrum, radio infrastructure, and transport between the slices. Only in special cases (based e.g. on regulatory and/or legal requirements) it is assumed that dedicated resources are statically assigned to a single slice. The detailed realization of the NW slicing concept in the 5G RAN is one of the research fields in METIS-II (visibility of "radio slices", resource and QoS management, slice isolation e.g. for security purposes, etc.).

According to Figure 4-6, CP and UP NFs of a slice can be flexibly placed according to the needs of service characteristics (latency, throughput, QoS, etc.) on the underlying infrastructure layer nodes considering the capabilities of those nodes w.r.t. transport, processing and storage capacity. One example is the support of low-latency applications where some NFs may be placed at the mobile edge, e.g. directly on access nodes or alternatively in a Cloud-RAN node (see also [MET15-64]).

Even if the SDN/NFV concept is softening the separation between RAN and CN in a future 5G system, METIS-II still assumes a logical split between the 2 parts as a starting point (see Figure 4-7).

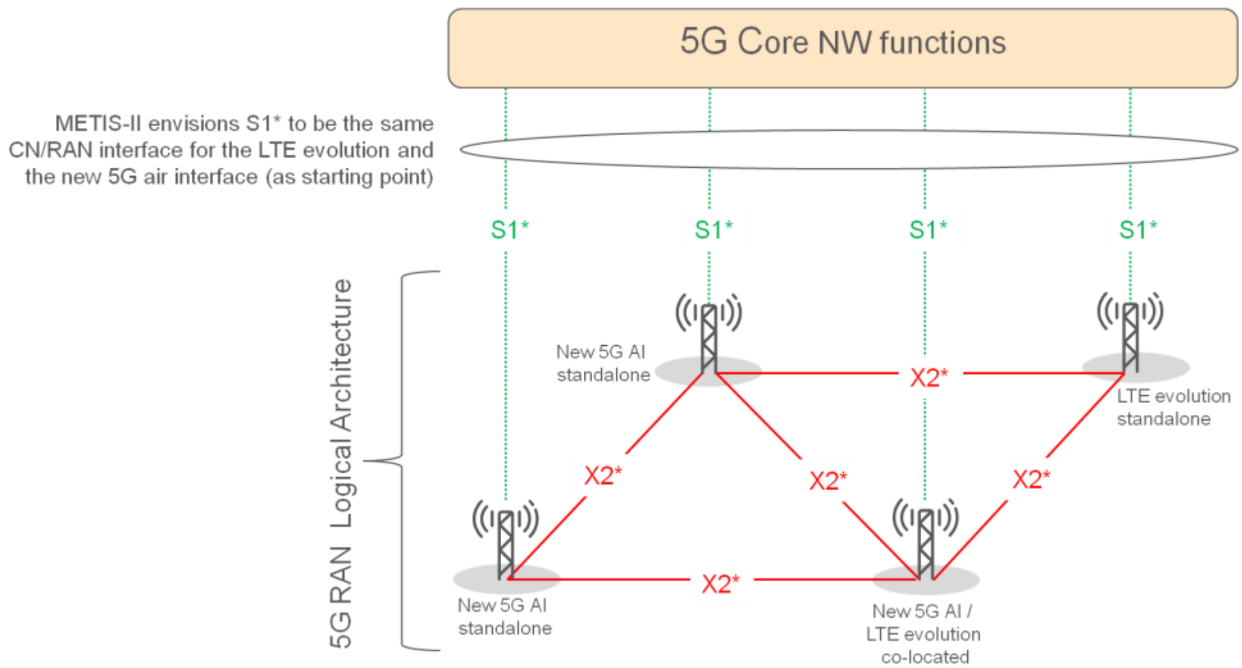


Figure 4-7: Possible logical 5G RAN architecture (serves as starting point for the investigations in METIS-II).

This logical split is seen as beneficial for the following reasons:

- It allows for an independent evolution of RAN and CN functionality;
- It enables to make the CN functions or at least a subset of them access agnostic (e.g. common UP processing);
- It facilitates mobility since some CN functions (CP and/or UP) can be kept (anchored) when UEs move to a new RAN node;
- A logical separation does not forbid cross-layer optimizations in some deployments when the functions are co-deployed;
- A logical separation also allows multi-vendor CN/RAN interoperability.

METIS-II initially assumes that the new CN/RAN interface, called herein S1*, will have the S1 interface [3GPP15-36300] as starting point but without necessarily backward compatibility requirements.

W.r.t. the CN, the following functionalities are assumed to be covered:

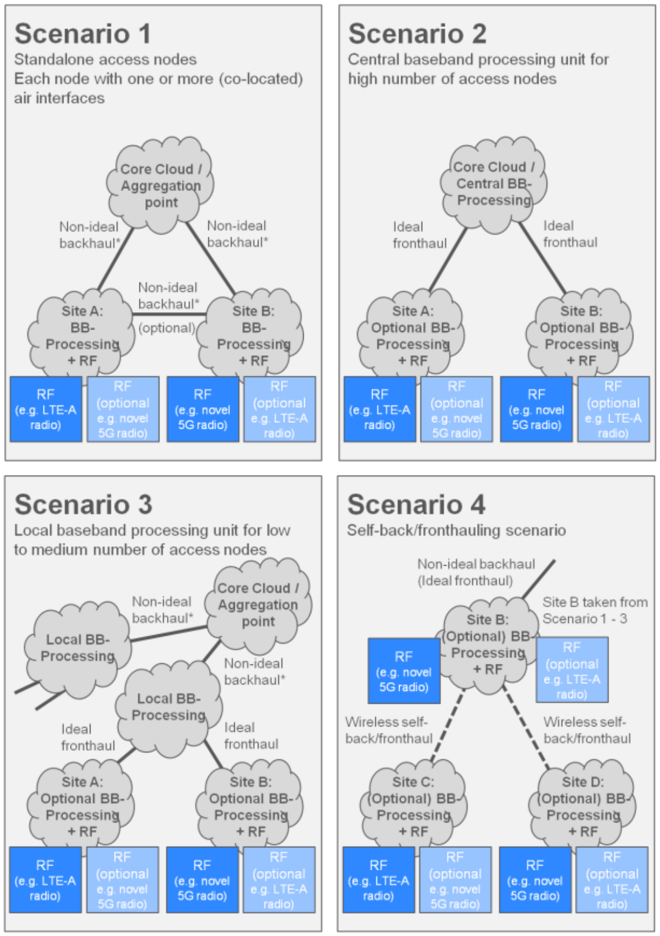
- Mobility anchoring (e.g. for inter-RAN node mobility, including inter-RAT mobility), addressing, roaming functionality;

- QoS control, charging, policy enforcement, context awareness;
- Attach and authentication signaling including security key generation.

An important aspect in 5G will be the enhanced integration of access technologies on lower layers of the radio protocol stack resulting in optimized joint resource management and increased performance and reliability e.g. by applying multi-connectivity links on UP and/or CP across different 5G air interface variants. Whereas the integration of evolved LTE-A (which is seen as part of the 5G air interface family) with novel 5G air interface variants is expected to happen on PDCP/RRC layer (or 5G equivalent), a tight integration of novel variants may go down to the MAC layer.

The finally achievable performance will be also strongly dependent on the device capabilities, as e.g. mMTC devices like sensors will – in contrast to future-proofed smart phones for xMBB purposes – probably only support single air interface variants due to cost reasons (partly also additional restriction to a single frequency band). More sophisticated 5G devices will be able to flexibly act as an infrastructure network node as well, e.g. a self-backhauled, possibly nomadic access node [MET15-64]).

W.r.t. infrastructure deployment aspects, the key assumptions on the physical RAN architecture are stated in the form of four representative scenarios depicted in Figure 4-8. These scenarios have been chosen and defined such that they reflect in a simplified form the corner cases of deployment that can be expected in the 5G time frame (e.g. deployment of novel 5G radio sites in addition to existing LTE-A sites, co-deployment of LTE-A and novel 5G radio, wide-spread usage of self-backhauling, stand-alone sites and baseband (BB) hostelling etc.)



* Non-ideal backhaul could be modeled as in TR 36.932

Figure 4-8: Physical RAN architecture scenarios considered.

The scenarios are detailed in the following:

- **Scenario 1** depicts a case where the same or different air interface variants are served from two geographically separated sites, and where the connection between the sites and from the sites to the next aggregation point are prone to non-ideal backhaul, which could for instance be modeled as in [3GPP14-36932]. For simplicity, it is assumed that CN functionality also resides at the aggregation point, hence there is no further latency involved beyond the aggregation point. As an option, multiple air interface variants (e.g. LTE-A and a novel 5G air interface variant) could be served in a co-located way.
- **Scenario 2** depicts the case where centralized processing is applied to all cells, and different spatially separated access nodes are served with ideal or non-ideal fronthaul, depending on the RAN functional split that is deployed.
- **Scenario 3** is similar to Scenario 2, but considers multiple clusters of centralized processing, each serving multiple radio sites that are assumed to be connected via ideal fronthaul. The connections between the centralized processing clusters, however, are assumed to be prone to non-ideal backhaul.

- **Scenario 4** builds upon Scenarios 1-3, but now depicts a case where two additional access nodes establish wireless backhaul links to sites with wired backhaul.

4.2.2 Evolutions of the positioning of current players with 5G

MNOs & MVNOs players:

- Both players are traditional mobile operators. They currently provide a mobile service to customers and manage this end customer relationship.
- A mobile virtual network operator (MVNO) does not possess any spectrum allocation or mobile access infrastructure, whatever the technology used. MVNOs sign a contract with a mobile network operator (MNO) that holds a frequency license and a mobile network infrastructure.

Table 4-1: Mobile operators & MVNOs positioning.

Player	Current positioning	Possible evolution
MNO	Builds and operates the mobile network Manages subscriber relationships for both retail and wholesale markets	Content provision Generalization of the fixed radio access provision More focus on IoT and vertical markets (to counter declining revenues on the consumer market) Getting higher in the value chain by proposing IT / big data services
MVNO	Buys capacity to MNOs and manages subscriber relationships. In some cases MVNO operates part of core network May own SIM cards	May operate more elements of the core network

Other access networks:

- WiFi access providers use unlicensed spectrum and are usually located in large-scale venues where people are likely to use high-speed internet (airports, coffee shops, hotels, universities...).For a mobile operator, a higher density of WiFi hotspots also means more possibilities to offload traffic on the fixed network and thus reduce the traffic load on the radio access network.
- LPWA (Low Power Wide Area) players use dedicated technology for low power and low experienced user throughput in unlicensed spectrum. Unsurprisingly, many different players are stepping in the Low Power Wide Area/IoT field. LPWA pure providers are

operators managing a network infrastructure (SigFox). Other players (LoRa, Neul) provide access connectivity (not the backhaul connectivity as a traditional player).

- Satellite operators use telecommunications satellites which are usually placed in Geostationary Earth Orbit and Low Earth Orbit with a number of specific technical requirements for telecom systems to operate (notably large constellations of small satellites, frequency coordination).

Table 4-2: WiFi, LPWA, satellite players role.

Player	Current positioning	Possible evolution
WiFi access provider	Operate WiFi access points Sells wholesale and retail services Manages subscriber relationships	Small cells operation mainly on unlicenced spectrum, with possible integration with 5G networks. Small cell as a service (SCaaS)
LPWA (Low Power Wide Area) operators	Deploy and operate dedicated networks for IoT	Possible integration with 5G networks (cell site sharing, RAN integration? integration of unlicensed bands?)
Satellite operator	Limited provision of narrowband mobile services with LEO constellations (e.g. Iridium, Inmarsat)	Possible offering in fronthaul/backhaul integration with terrestrial networks. Use of non-GEO constellations with reduced latency. Multicast approach in combination with terrestrial networks. Use for MTC in rural areas

RAN Outsourcing players:

- Tower companies are in position to go further than their current role of renting space for MNOs' base stations and could operate part of the RAN.
- Facility managers such as building or stadium managers are generally involved in mobile coverage/capacity through DAS (Distributed Antenna Systems) operation. They usually pay a specialized company for DAS installation.
- Urban furniture managers: Today, small cells are being deployed on urban street furniture such as street lamps, utility poles, bus stops, benches or billboards through

partnerships between equipment vendors and advertising companies. Deployment of small cells in street furniture is expected to enhance coverage and network capacity in highly populated areas to meet the future customer demand.

- Equipment manufacturers: A few years ago, telecom operators acknowledged that they could not be present in every segment of the value chain and create more value by setting up partnerships with large-scale players. This leads to innovations or changes in model or management such as, for example, outsourcing passive or active infrastructure or sharing fixed or mobile networks. Equipment manufacturers are well positioned for the RAN outsourcing role due to their expertise in that domain.

Table 4-3: RAN Outsourcing players role.

Player	Current positioning	Possible evolution
Tower company	Build, own, operate, maintain tower assets Build customized/green sites Rent towers to MNO (fixed power and fuel cost/traditional pass-through cost)	Could operate the RAN / parts of RANs
Facility manager	Operate DAS (mainly indoor environment)	Could operate small cells (SCaaS) Could offer telecoms access in a building using mobile infrastructure with backhauling via a fiber optic at the bottom of the building
Urban furniture manager	Build, own and operate urban furniture Rent resources on a pay-as-you-go model	Could install base stations, operate parts of RAN (small cells)
Equipment manufacturers	Outsourcing and service management	Operation of wholesale mobile network

IoT/MTC players:

- Integrators & IT companies: System integrators or software companies have strong capabilities in data and in software, especially in analytics. As the value chain is disassembling in many markets and as hardware is now commoditized, integrators re-assemble certain functions and provide packaged services in a “softwarization” move. IT companies are mainly positioned on the professional markets (Machine-to-Machine (M2M) and Internet of Objects) on the IT side and data management through their cloud services (based on their data center farms).

- Vertical market players encompass car manufacturers in the automotive business, hospitals/doctors in the health industry…, that will be part of the enlarged telecom ecosystem in the near term as telecom is spreading in many verticals. The verticals will develop new services, new processes and new business models, thanks to offered robust, affordable transmission and automated collection of data.

Table 4-4: IoT/MTC players positioning.

Player	Current positioning	Possible evolution
Integrators	Strong capabilities in data and software	Connectivity provision
IT companies	Provide Cloud services	Leverage on data to provide better services and solutions
Vertical market players	Buy connectivity from MNOs	Play a role in service creation & operation

Public Safety and Public Protection and Disaster Relief players (PPDR):

- Current non-broadband dedicated public safety systems mainly use the 400 MHz and the 700-800 MHz bands worldwide. Spectrum above 1 GHz supports also a variety of PPDR operations for temporary use only. A number of these PPDR networks have been deployed all over the world.

Table 4-5: Public safety players positioning.

Player	Current positioning	Possible evolution
Dedicated Public Safety	Build, own and operate Public Safety / PPDR networks	Provide unused capacity during non-critical hours of operation to 5G operators
Public Safety MVNO	Sell mobile services to end-users	Rent capacity to 5G operators

Content owners, OTTs:

- Content owners are specifically involved in content creation and adaptation to mobile devices. They are responsible for the accuracy of the content. The consumption of content has gradually evolved from a model mainly based on ownership of content (physical media or a digital copy) to a model based on access to a free (ad-supported) and/or subscription service.

- The well-known Over-The-Top (OTT) players are serving their customers over the Internet (voice through VoIP and messaging are the two first services provided). They are providing an integrated product over the Internet and bypassing traditional distribution. Services that come over the top are, if not always, lower in cost than the traditional method of delivery. However, they have lower QoS than services provided by MNOs.

Table 4-6: Content owners and OTT positioning.

Player	Current positioning	Possible evolution
Content owners	Creation of the content, adaptation to multiple devices	No role expected in radio access
OTTs	Provision of services through the internet free of charge	MVNO providing mobile communications services

Other players

- Obviously, device manufacturers are designing and marketing devices directly to users and to telecom operators. Devices are still central to the telecom market and are continuing to develop in term of better performances.
- Today, in-flight connectivity on commercial airlines is provided through air-to-ground and satellite networks. In-flight connectivity is provided on a wholesale basis and on a retail basis.

Table 4-7: Other players positioning.

Player	Current positioning	Possible evolution
Device manufacturers	Sell handsets to customers and mobile operators	With virtualized SIM card, device manufacturers could manage customers relationship
In-flight connectivity providers	Sell in-flight connectivity directly to the user or through the airline	In-flight connectivity providers could manage the user relationship widely

4.2.3 Identification of new players in the 5G field

In its 5G White Paper [NGM15], NGMN describes new business models expected with 5G. New business roles described in this document make reference to asset provider, connectivity provider and partner service provider. In this section, we use the previous section on the identification of the current players and NGMN's input as a basis to identify new players/roles in the 5G field.

Connectivity providers

The business models associated to connectivity providers can be differentiated between "basic" and "enriched" models and are the following:

- Basic connectivity providers: in this model, only best effort IP connectivity is provided. This is the « dumb pipe » model for mobile operator and we can include WiFi access providers in the same model. In the years to come, we might see new players such as satellite service providers, LPWA players, loons' players… Wi-Fi first players such as Google with its Google-Fi offer, which use WiFi as the primary connection option and switch to mobile network only as a "backup solution" could play a bigger role in bundling other access networks as well (satellite, LPWA, loons…).
  In the energy sector, an example of basic connectivity provider is an evolution of the MVNO concept called PVNO (Private Virtual Network Operator). The energy grids long-term needs are not fulfilled by existing mobile networks leading the players of this sector to become MVNOs and to take full or partial control of a wireless network. The PVNO could control elements of the core network such as customer database and the SIM cards. In countries like the Netherlands and France, utilities have built cellular networks and were awarded spectrum (in the 450 MHz band) for their own needs.
- Enhanced connectivity providers could increase operator differentiation through network quality/reliability/mobility/configurability. Public Safety players, new MVNOs providing M2M enriched services (for vertical sectors, for security purposes…) could appear in this field. The broadcasting sector could also propose a new model called TOo5G for 'Tower Overlay over 5G' in which the broadcast operator would use its HTHP (high tower high power) infrastructure; the latter being already in place and serves for digital terrestrial television (DTT) services. This dedicated broadcasting infrastructure would provide broadcast and multicast services (such as video streaming) with lower transmission costs than in unicast mode, but the viability of this solution will depend on the 5G design choices (integration of DVB-like air interfaces in 5G) and on the development of evolved MBMS (Multimedia Broadcast Multicast Services) solutions.

Asset providers

The asset provider role covers both network sharing models and XaaS models. As explained in Section 4.2.1, XaaS is a collective term that refers to everything as a service (or anything as a service). With XaaS, everything can be accessed on demand via the cloud. XaaS gives a first sight at what would be the future of cloud services. Users have access to services remotely, whatever the device.

In addition to SCaaS, XaaS asset provider models identified in the NGMN white paper are IaaS (Infrastructure as a Service), PaaS (Platform as a Service) and NaaS (Network as a Service). They should bring completely new business models in the 5G field.

In the IaaS model, hardware (servers, routers…) and software elements, maintenance and backup means are managed by a third-party provider. These providers are able to provide dynamic scaling and policy-based services. They charge their customers on a subscription basis and can also take into account the amount of virtual machine space used. In the IaaS model, it is expected that Internet or traditional IT companies such as IBM, HP, Google, etc., could become important players with 5G.

As of SCaas, other parties can also provide it and vendors are already entering this market. Municipalities or real estate owners can also jump in the business and monetize access to small cells. For example, located in street furniture, small cells can be deployed almost everywhere very close from the user.

In the PaaS model, applications are delivered over the Internet. Hardware and software tools are hosted by the infrastructure provider which provides applications to its customers. Internet and IT companies (Salesforce, Google, Microsoft…) and telecom players will play a role.

In the NaaS business model, network services are virtually delivered over the Internet thanks to virtualization of network functions. This can be done on a monthly subscription or on a pay-per-use basis.

Network sharing represents another dimension for asset providers with real-time network sharing. We could see dynamic network sharing between commercial mobile networks and public safety networks. Capacity would be made available to commercial operators in absence of emergency. Spectrum brokers could also play a role in the future and manage spectrum resources on behalf of mobile network operators in order to allow real-time management of the spectrum.

New players in relation with RAN evolution

With the expected development of Cloud-RAN architectures, new players such as CDN (Content Delivery Network) providers or data centers players could play a role:

- Data centers players could operate BBU (Baseband Unit) in a centralized infrastructure, i.e. data centers under the form of a large concentration of servers/databases. A limit to their possible investment in this field is the limited number of data centers which are only present in large cities.
- CDN players could provide services to mobile operators in supporting content hosting closer to the edge of the network. Today, Akamai dominates the market, followed by LimeLight and Jetstream.

- New players could offer both BBU hosting/management and CDN capabilities (and play a role in RAN sharing agreements).
- Relay owners propose relays to extend coverage of a wireless network or to increase the area spectral efficiency, by means of shortening the radio path distance among end users and access nodes. The actor running and maintaining the relay could be a MNO, an end user that wants to provide enhanced performance in its specific area or a third party interested in providing coverage enhancement due to a specific agreement with MNO (since it is using radio resource assigned to the MNO) like a restaurant owner.

Partner service provider

Disintermediation of the value chain creates opportunities to create innovative services. With its network, the MNO provides bandwidth to customers and evolves from the former pricing model (per minute, per volume, per data rate) to a value pricing model (various QoS, availability, prioritization, latency…).

In the partner service provider model, the MNO offer can be enriched by partners or the other way round, the partner offer would be enriched by MNO' capabilities and services.

- MNO capabilities/offers enriched by partners: In this model, the mobile operator still provides the service to the end user. As an example, collaboration with OTTs enables MNOs to differentiate their offers. In the coming years, payment solutions, content or integrated streaming solutions could be added by partners. In the vertical "industry" (e.g. Factories of the future), new players could provide data analysis on top of sensing & communications provided by the 5G operator.
- In the second model, third party or OTTs are using MNO's network and have direct relationship with customers. A product such as a smart body analyzer devices or connected clothes could use health monitoring feature and connectivity provided by the MNO.

Table 4-8: Possible new players in the RAN.

Group	Player	Possible role	Who?
Spectrum	Spectrum brokers	Allow spectrum sharing on a dynamic basis between MNOs and other access network providers	?
Access	WiFi	WiFi-First service enriched with other access networks	Google, Facebook
	LPWA	Possible integration with 5G networks (cell site sharing, RAN integration?)	Sigfox, LoRa operators
	Satellite	Possible offering in fronthaul/backhaul integration with terrestrial networks. Use of non-GEO constellations with reduced latency. Multicast approach in combination with terrestrial networks.	Eutelsat, Inmarsat, OneWeb, Facebook…

		Use for MTC in rural areas	
	Loons	Additional access network offering coverage in rural areas	Google
	Tower company	Could operate the RAN / parts of RANs TOo5G (Tower Overlay over 5G)	Arqiva, TDF, Crown Castle
	Facility/Mall/Stadium manager	Could operate small cells and/or provide SCaaS Could offer telecoms access in a building using mobile infrastructure with backhauling provided via a fiber optic at the bottom of the building	Malls, stadiums
	Urban furniture managers	Could install base stations, operate parts of RAN (small cells) and/or provide SCaaS	JC Decaux
Access + core	Dedicated Public Safety operator	Provide unused capacity during non-critical hours of operation to 5G operators	FirstNet (USA)
Manufacturers	Equipment manufacturers	Operation of wholesale mobile network: add core network operation to current outsourcing services (radio access network)	Ericsson, Nokia, Samsung…
	Device manufacturers	Becoming service provider and manage customers relationship with virtualized SIM card	Samsung, Apple…
Other players	MTC system integrators	Connectivity provision	Mobile Wisdom, AWS…
	Web and e-commerce giants	Bundle access provision	Amazon…
	Data centers players	Operate BBU	IBM, Cogent, Equinix
	CDN players	Could provide content hosting closer to the edge of the network	Akamai, LimeLight, Jetstream
	Vertical players: transport	Networks (small cells) on-board trains, cruise ships, planes	Airlines, train… companies
	Vertical players: utilities	PVNO (Private Virtual Network Operator).	Electricity distributors

4.2.4 New value chains

The Private Virtual Network Operator value chain

The PVNO model is a model where a utility provider (for instance) would decide to rely on frequencies and radio infrastructures of a commercial MNO but would still own and operate all or part of the elements of the core network. The utility could own parts of the network (parts of core network or parts of access network)

A utility such as an electricity provider would thus buy capacity from an operator through a wholesale agreement. The MNO would keep control on frequencies and radio network but the electricity provider would provision communication devices themselves and customize part of the core network and information system (such as the customer database for instance).

This model is very similar to a MVNO but with the differences of ownership/control on network elements and those users would only be either employees or customers of the utility only. The service provided to the customer could be completely transparent to the MNO such as in the B2B2C model.

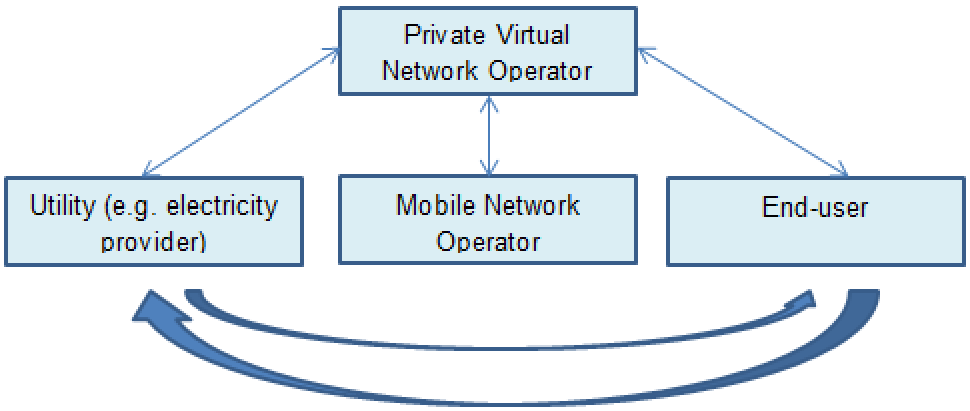


Figure 4-9: PVNO value chain.

Enhanced connectivity provider value chain

An example of enhanced connectivity could be provided through partnership between MNOs and broadcast tower operators. Indeed, the High Tower High Power (HTHP) model used by broadcast players enables to have a wide coverage at low cost and could be especially interesting to broadcast content/applications/updates over 5G network. This would be complementary to the Low Tower Low Power model (LTLP) currently used by mobile operators where the higher capillarity of the network is aimed at providing enough capacity to the users, something that is not necessary in broadcast or multicast mode. This concept of collaboration is called Tower Overlay over 5G (TOo5G).

The traditional broadcast network would be used for the broadcasting or multicasting of popular content/software. 5G architecture would enable this collaboration and integration of a different technology with 5G. In this model, broadcast operator would partner with telecom operator but end-users devices would have to support an additional RAT.

This model could also be suitable for public safety players where the broadcast network would provide critical services over the broadcast network with the insurance of being covered and reaching the appropriate (group of) people. Less critical applications would be run in unicast on the regular network. Note that this model would require a very high availability of the broadcast network as a stand-alone network. Only in combination with a feedback channel via the mobile network, the received quality level might be sufficiently high.

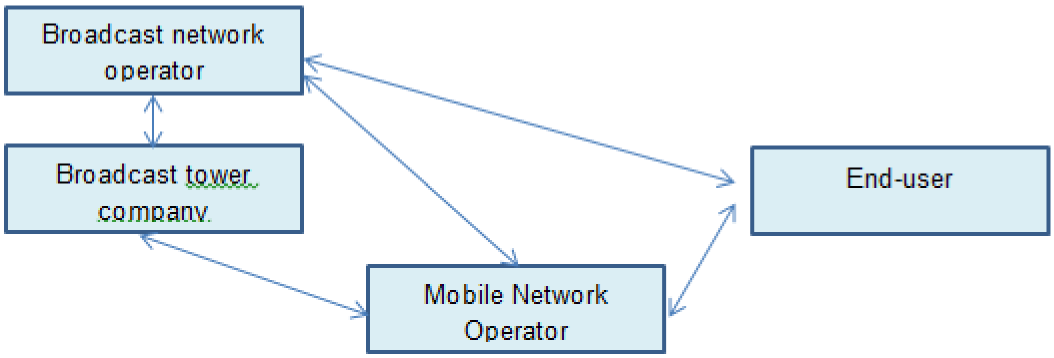


Figure 4-10: Tower overlay over 5G value chain.

The Small Cell as a Service value chain

With SCaaS, the idea would be to have one or several players investing in the deployment of small cells in a particularly crowded place.

This “host” small cell network could be deployed by different players:

- A MNO which decides to do the initial investment because it believes bringing more capacity to a specific zone would definitely bring value to its own service. By proposing SCaaS to other (competing) carriers, initial investment would then be mitigated.
- A Joint Venture between several operators, similar to network sharing agreements already existing in the industry for the macro cell network.
- A third party such as an infrastructure vendor willing to offer additional managed services to either MNOs or MVNOs. Ericsson notably made an announcement at the Mobile World Congress related to its own SCaaS proposition. Other players such as municipalities or real estate owners could as well decide to make the investment to foster better capacity while monetizing the investment.
- Urban furniture managers may play this role, alone or in collaboration with one of the players mentioned above.

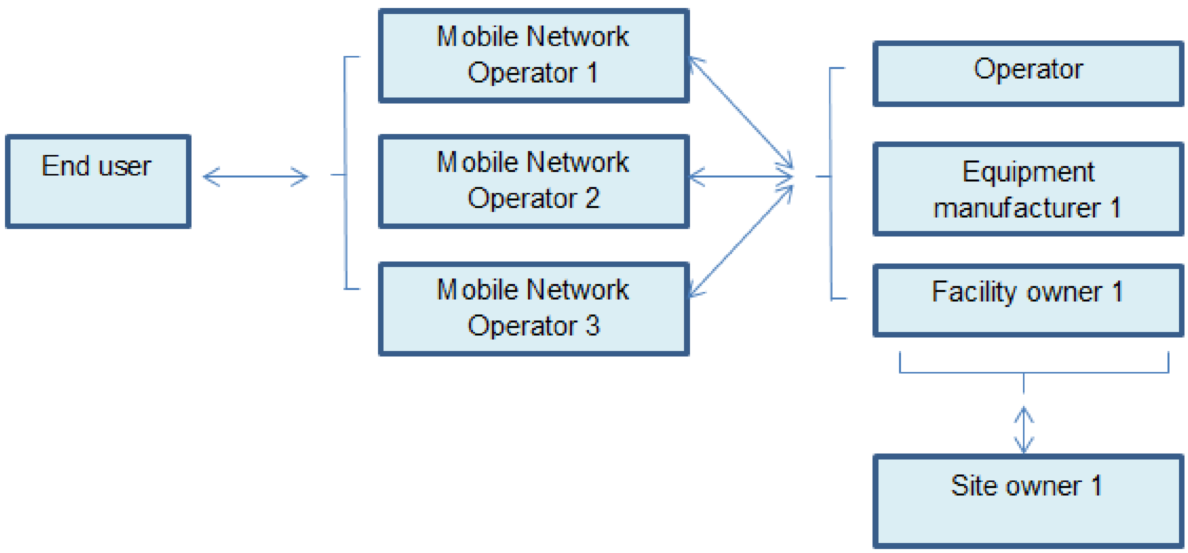


Figure 4-11: Small Cell as a Service value chain.

The partner service provider value chain

In this configuration, a device or object manufacturer would sell its product to the end-user. This product would include a service relying on a connectivity that could be provided in different ways:

- Either directly by contracting a MNO,
- Or indirectly through a partnership between the device manufacturer and a connectivity provider. This connectivity provider could be of course a MNO or a MVNO/PVNO that would be created by the device manufacturer to provide specific services.

Additionally, a player providing a platform to gather and analyze data would partner with the device/object manufacturer to provide service to the end user. This platform could be directly integrated in the network in the case where a PVNO would be created. Some device/object manufacturers could provide the platform themselves as some of them have developed the service competence internally or through the acquisition of specialized players.

The end user has regular relationship with the mobile operator (subscription) and the data analysis platform (sends periodic reports to the user.

In the same way, OTTs or verticals could replace the device/object manufacturer in the value chain below and manage the relationship with the end user. As an example, industry players could add data analysis services on top of connectivity provided by MNOs.

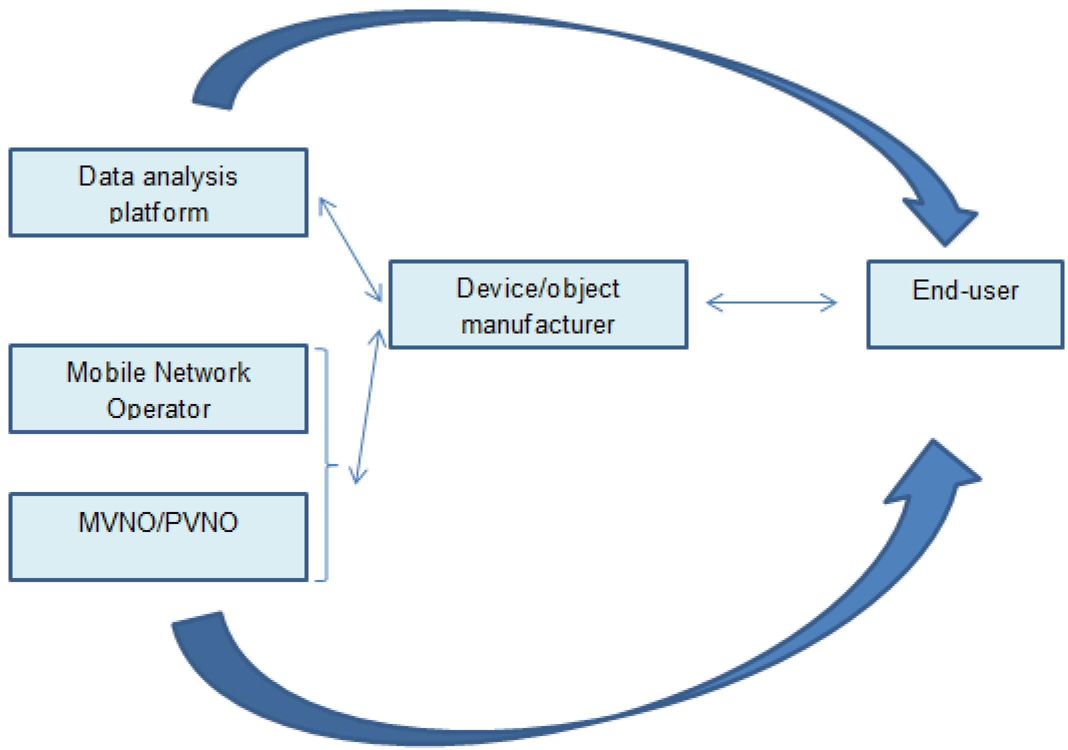


Figure 4-12: Partner service provider value chain.

4.2.5 MTC Actors in Smart City and the corresponding Value Network

A sustainable Smart City is often defined as an innovative city that uses Information and Communication Technology (ICT) 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 and environmental aspects [ITU-FGSSC-15]. Focusing on the communication part, the role of ICT on one hand is to collect information from the machines and send them to the applications; and on the other hand it should transfer the "smartness" from applications to machines.

Considering 5G as the paradigm shift in ICT that is supposed to enable Smart Cities, this system should include many high technical requirements that are highly integrative with other industries. This integration then happens via Machine to Machine (M2M) communication solutions. The role of M2M solutions is then to sense, analyze and integrate the key information of core systems in cities. As a result, the relevance of ICT in Smart Cities is twofold: first, how to enable a Horizontalization platform for other industry verticals and second, integrating ICT infrastructure in other industries involved.

Looking into the Smart City ecosystem, the network of suppliers [LGM-15] includes ICT providers and subsequently M2M providers. Considering M2M technologies as the enabling ICT tool for cities to become smart, then MTC would be the part where Cellular Telecommunication Networks come into the play. This highlights the role of Telecom actors in Smart Cities. At the same time, these changes may not occur unless the new value chain and value network can host specific demands and new actors of Smart City [GAM-15].

Since MTC corresponds to utilizing cellular technologies as the access network for M2M services, traditional actors in the mobile telephony value network are viably active here as well. Mobile Network Operators (MNO) as the typical carriers that control and operate cellular networks are capable of operating the MTC network. Telecom Equipment Vendors (TEV) as the traditional manufacturers of the telecommunication equipment, typically provision the technical procurement for the MNOs. But, according to the shift in the value chain, the TEVs have recently participated in different roles that historically have been assigned or taken care of by others; such as MNOs. Even roles like provisioning new demands such as Connectivity Platforms are now being provisioned by some TEVs.

Figure 4-13 illustrates the major business relations for MNOs and TEVs in the Mobile Telephony case. A Managed Service Provider (MSP) is typically an entity that offers end-to-end solutions; such as network operation management in this case. Based on proposed MTC Activities, Resources, Actors, and most importantly the framework introduced in Figure D-10 (in Appendix D1.2), five major groups of actors can be identified in the MTC value network. Besides the End Users (EU), these actors are the most likely entities who can own either of the resources mentioned earlier in order to perform MTC activities. These actors are:

a) End User,

b) Service Provider,

c) MTC network operator,

d) Device Provider, and

e) MSP.

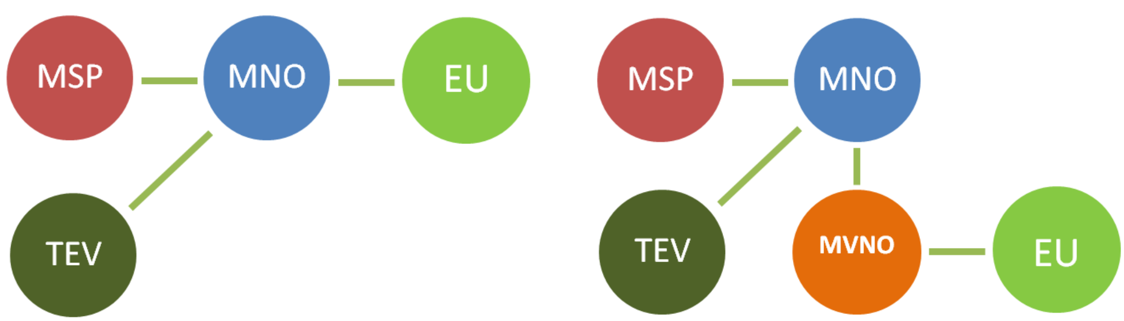


Figure 4-13 Two traditional Value Networks of Mobile Telephony.

According to the cases studied earlier, we showed that rather than traditional Telecom actors (i.e. MNOs and TEVs), there are other actors who might be even more competent in provisioning any of the activity blocks of MTC. For instance, a specialized M2M cellular network operator (MTC network operator) can be considered a better option to provision MTC network. Service Providers of M2M solutions also in some cases take control of the entire value chain by handling the EU; a previously dominant position for MNOs in Mobile Telephony (Figure 4-13 - Right). On the other hand, TEVs and MNOs have shown interest in different activity blocks.

Another major actor in this setup is then an entity which performs the role of provisioning CDP. It can be seen that this activity is mainly performed by the firms who have a history in provisioning connectivity in the sense of automating connected devices. Some examples can be either outsourcees of network operations for MNOs (MSPs) or the ones which have been active in automation of industry verticals (e.g. General Electrics, Siemens, etc.).

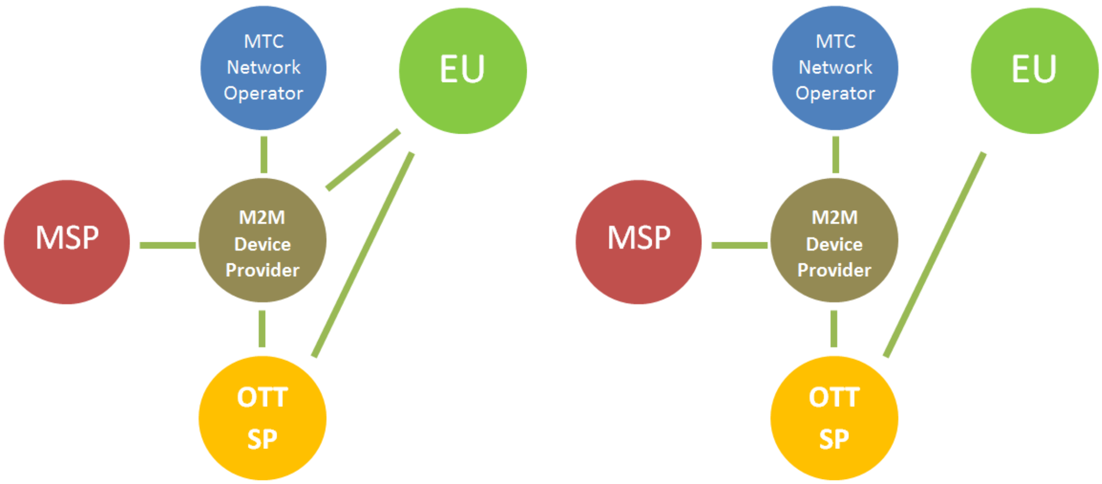


Figure 4-14 Two major setups of MTC Value Network.

Figure 4-14 illustrates two major setups of the MTC value network in Smart Cities. According to our description of the MTC activities, telecom actors are capable of performing multitude of activities in MTC value network in Smart Cities, but based on their resources. This directly concerns the competences they can acquire and/or have. Considering "connectivity domain" as their main playground, provisioning AEP is also an activity being performed by some TEVs in recent years. This way, telecom actors mainly correspond to either MTC network operators and/or MSPs (supporting role for provisioning AEP, CDP). An interesting observation here is the absence of MNOs on "owning" the End User. In terms of resources, it is important to consider that the actor/s who owns the end user -as a resource- is the most likely to have control over this value network. This value network should be considered when deploying and developing 5G systems, as it should allow collaborative setups to happen. Finally, it could be concluded that 5G and ICT will play the enabler-support role for making Smart Cities happen and not much more; so would the telecom actors.

4.2.6 Evolutions of the MNO-centric value Net

Having identified, in the previous section, the main actors and the interactions between them, we focus in this section on the MNOs. We construct the value net of these MNOs and its evolution with 5G; the aim being to identify their coopetition relations with the other actors.

The value net model has been elaborated by [BRAN96]. This model is a complementary approach to the value chain framework. The objective of value chain and value net models is nearly the same, i.e. identify the main players on market and the main activities they conduct.

They give a general overview of an industry during a specific period of time. But the logic is quite different between the two models. In the case of value net, the analysis is more comprehensive as the main players have to be integrated in four categories: customers, suppliers, competitors and complementors following a vertical and horizontal dimension. The horizontal axis is related to competition and cooperation issues. Figure 4-15 shows a generic value chain centered on a given company. Note that players can cover – and often do cover - more than one role in the value net.

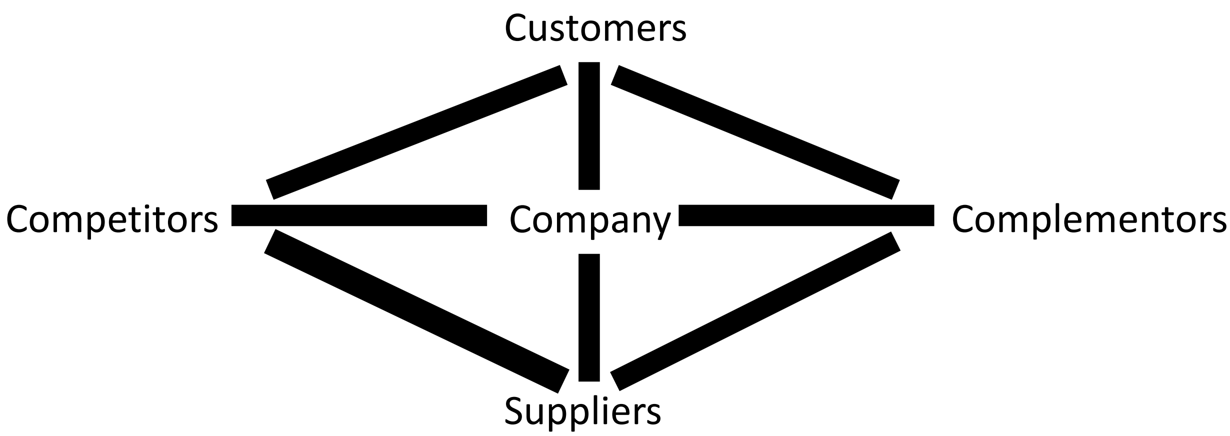


Figure 4-15: A generic value net.

Figure 4-16 gives the current value net of MNOs. We first begin by defining customers as this will give us a clear view about the positioning of the MNO. Two kinds of customers are identified:

- End users, be they in the mass market (individuals), or other business customers (private companies or public administrations). Clearly, these customers are contracting with the MNO as a *service provider*.
- MVNOs: they are customers of the MNO as they buy the right to use his network in order to serve their customers. When the MNO sells network access rights to MVNOs, he is behaving as a *network operator*.

Based on this analysis, we can see that customers groups can be classified into two groups: customers of the MNO as a service provider and customers of the MNO as a network operator. We will keep this classification for the rest of our analysis of the value net.

Next, we stay in the vertical dimension and identify suppliers. As a *network operator*, the MNO has the following suppliers:

- Infrastructure vendors that supply him with base stations, network controllers, etc. Examples of such vendors are Ericsson, Alcatel Lucent, Huawei, etc.

- Infrastructure suppliers that provide access to towers, backhaul capacity and other resources required for network operation. These resources are often shared resources and rented or even provided “as a Service”.
- Network operation & management software makers from whom the MNO can buy network monitoring and management tools allowing him to preserve quality of its network. Note that infrastructure vendors have also their own software solutions, but operators whose networks are multi-vendor need third party software solutions.

On the other hand, as a *service provider*, the MNO has as suppliers device manufacturers (Apple, Samsung, Nokia, etc.). Indeed, service providers usually buy devices from manufacturers and sell them at lower prices to end users.

Let us now move to the horizontal dimension and identify competitors. As a service provider, each MNO has as obvious competitors all other service providers, be they MNOs or MVNOs. Over the top (OTT) players, like Skype and Viber, are also seen as competitors of the MNO as a service provider as they propose substitution services (voice, video conferences). As a network operator, the considered MNO has as competitors the other MNOs as they offer the same services for MVNOs.

The most difficult task is to identify complementors whose presence incites customers to buy more services from the MNO. Obviously, content providers (online game developers, Google maps, TV channels) act as complementors as people are willing more to buy mobile data access in order to benefit from their favorite contents everywhere. Device manufacturers are also complementors as end users consider smartphones and tablets as valuable devices by themselves, and a smartphone or a tablet will be more useful with a wireless Internet connection. Device application developing industry is also a complementor as the multitude of smartphone applications incites users to buy a smartphone and to subscribe to a mobile data connection. Note that we do not make a distinction between complementors of the MNO as service provider or as network operator as they are generally the same (they stimulate the need of a network access).

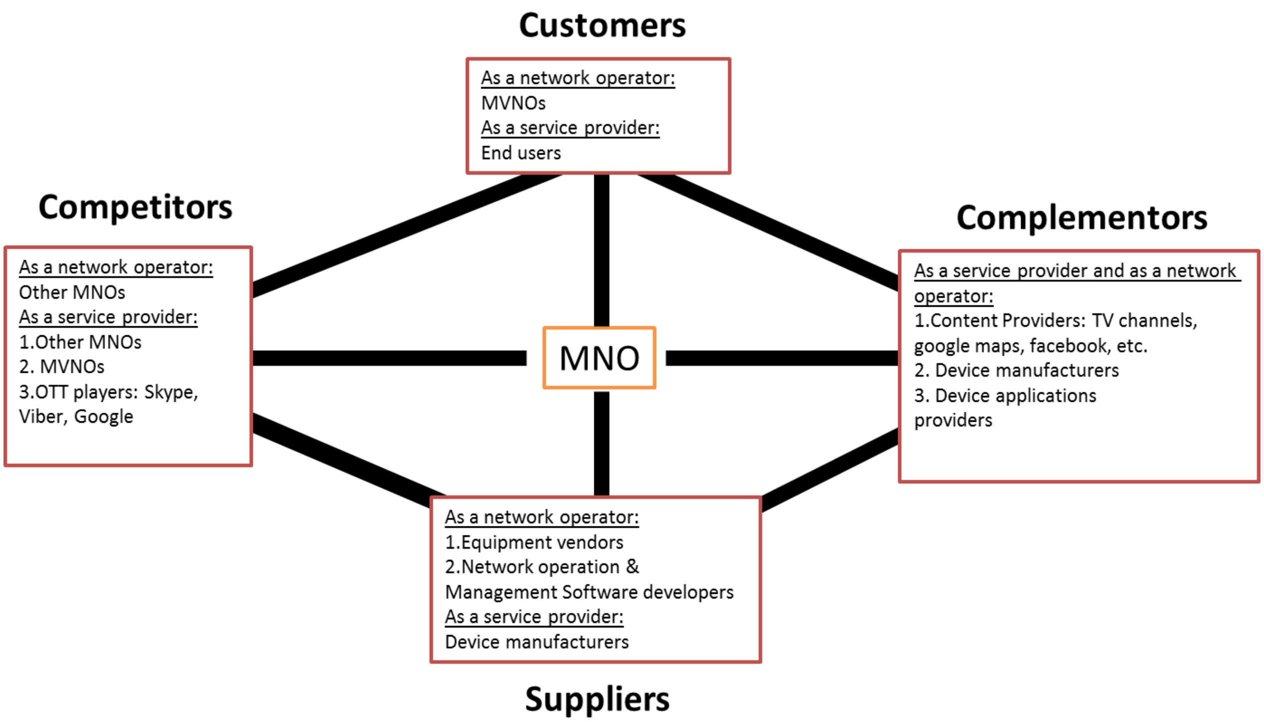


Figure 4-16: Current value net of MNOs.

Figure 4-17 shows the evolution of the value net of MNOs with 5G, based on the 5G players identification in the previous sections. We start with the evolution of the group of customers where PVNOs join MVNOs as customers of the MNO as a network operator, and where verticals, when they buy directly connectivity to their customers, become customers of the MNO as a service provider. The same verticals become complementors as, by moving towards more connectivity, they provide needs for people (individuals and professionals) for 5G services.

As for the suppliers of the MNO, the increased heterogeneity and the virtualization of networks are expected to diversify their list. The lists of equipment vendors and of network operation and management software suppliers are joined by classical IT companies like IBM, HP, etc., which provide processing servers and virtual network software (e.g. based on SDN/NFV). Data center players may play a role in managing hostels of BBUs in this context, especially for Cloud-RAN architectures. Asset providers like facility managers, urban furniture managers and tower companies are expected to have a larger role in the deployment and the management of parts of the access network, reinforcing their position as suppliers of the MNO as a network operator. With the evolution of spectrum regulation and the allocation of new bands under innovative authorization schemes (e.g. LSA and LAA), spectrum brokers could play a role in the future and manage spectrum resources on behalf of mobile network operators in order to allow real-time management of the spectrum. Finally, as a service provider, the MNO can make deals with

CDN players for content hosting near end users at the network edge, making them suppliers with regards to his role as a service provider.

Finally, in the group of competitors, the advent of new LPWA networks and of various access networks based on satellites and loons in addition to the increased integration of WiFi evolutions within the 5G network introduce a variety of players as competitors of the MNO in the RAN. A possible scenario, as discussed previously, is the emergence of large WiFi players in the bundling of these various access networks. Regarding the service provider role of the MNO, PVNOs and MTC operators join MVNOs as competitors for offering services to end users.

5G is targeting to open up the ecosystems. One of the main tools allowing to support PVNOs is the concept of Network Slicing brought forward by NGMN. It allows PVNOs to operate and manage a “network slice” as an independent virtual network allowing them to introduce their domain specific business cases and to follow domain specific regulation.

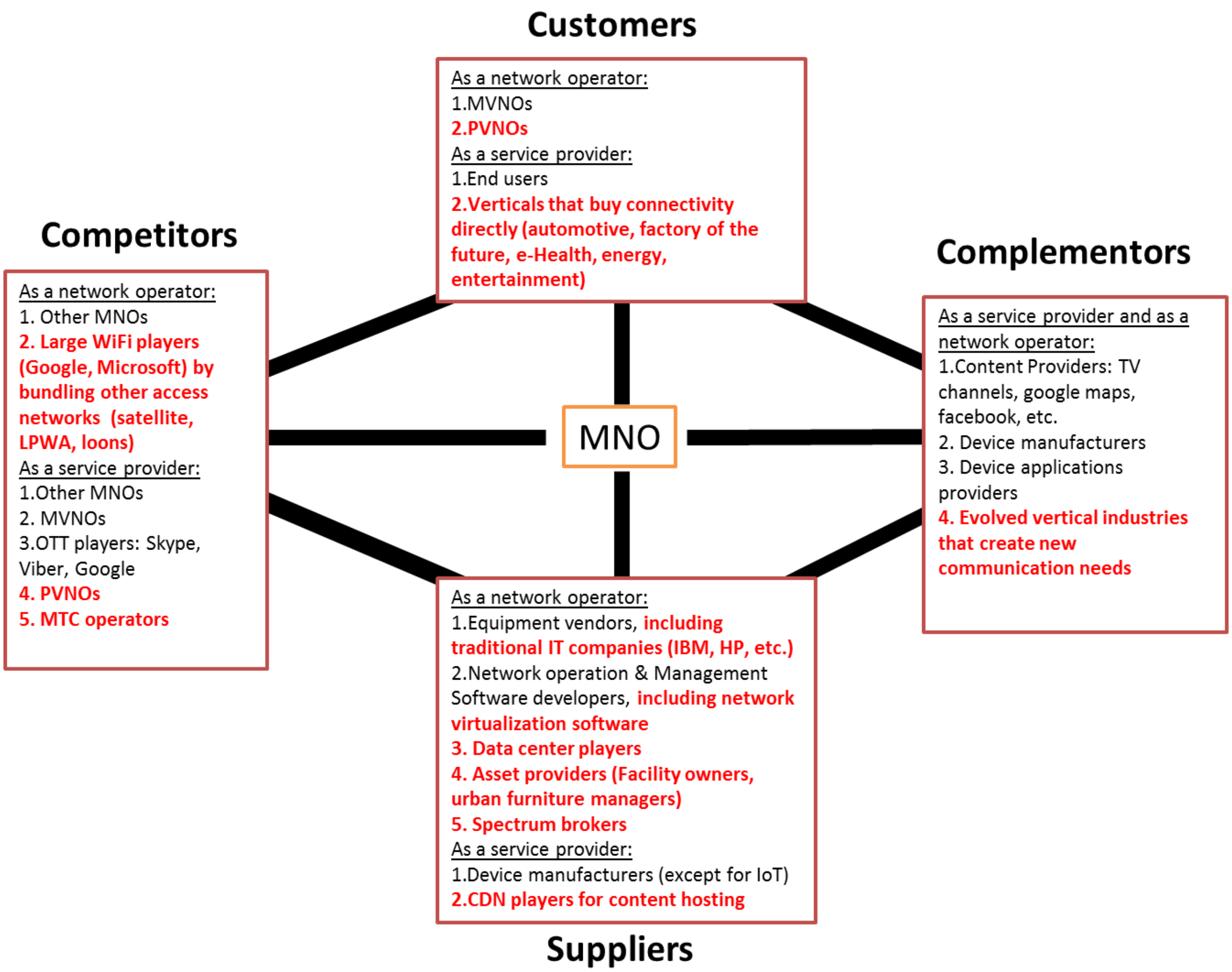


Figure 4-17: Evolution of the value net of MNOs with 5G.

4.3 Focus on the dense urban information society use case

The aim in this section is to identify the possible value networks for the provisioning of the targeted mobile services in the future dense urban information society, as described in Section 2.1.1. In the first part we will focus on deconstructing mobile services provisioning into a number of business roles in view of the discussed evolution path of the radio access network (RAN) Architecture in section 4.2.1, while the second part is dedicated to identify the possible business relationships and cooperation models between the actors in the xMBB ecosystem.

4.3.1 Evolution in RAN architecture and deployment options

The Radio Access Network (RAN) architecture is the shift towards more flexible, dynamic and heterogeneous architecture as described scenarios in Section 4.2.1 and Figure 4-8. In these scenarios, the provision strategy of the future mobile service can be based as a set of relatively autonomous resources that can be owned by different actors. In this context, number deployment strategies are to be considered for the provisioning of the mobile services in future dense urban information society. In this section, four deployment strategies have been chosen based on the RAN architecture scenarios in Figure 4-8 and considering different combinations of outdoor and indoor networks deployments as follows:

- **Strategy A (macrocells with no or limited number of outdoor small cells)**: the deployment of a dense layer of traditional macro cell sites and outdoor small cells based on exclusive spectrum use below 6 GHz along with use of shared spectrum resources below 6 GHz (i.e. based on different authorization and access options such as LSA and/or common authorization). In other words, the RAN architecture can be depicted as number of standalone macrocell radio sites that may be complemented by a number of outdoor small cells for coverage and capacity - As an option, multiple radio air interface variants (e.g. LTE-A and a novel 5G air interface variant) could be served in a co-located way. Referring to Section 4.2.1, all physical RAN architecture scenarios (1 to 4) are suitable for this deployment strategy. -

- **Strategy B (macrocells with massive deployment of indoor small cells)**: the deployment of heterogeneous RAN architecture based on the described macrocell infrastructure in Strategy A along with massive number of indoor small cells in public areas. These indoor small cells may be operated in the shared spectrum resources below 6 GHz (i.e. based on different authorization and access option such as LSA and/or common authorization).

- **Strategy C (massive deployment of outdoor small cells):** the deployment of a dense layer of outdoor small cell sites based in multiple frequency bands and authorization options. In other words, the outdoor small cells may be operated based on exclusive and shared spectrum use considering frequency bands below and above 6 GHz. Here, the

RAN architecture can be depicted as massive number of low-cost and low-power nodes that are supported with a centralized processing capability in the cloud. In other words, all the signals are sent back via ideal or non-ideal backhaul links from these outdoor small cells to the cloud.

- **Strategy D (massive deployment of indoor and outdoor small cells):** the deployment of a dense layer of small cell sites everywhere (both indoor and outdoor in public areas). In other words, the RAN architecture can be depicted as massive number of standalone outdoor small cell sites as described in Strategy C along with the deployment of massive number of indoor small cells. Here, the outdoor and indoor small cells may be operated based on exclusive and shared spectrum use considering higher frequency bands above 6 GHz.

With move towards more flexible, dynamic and heterogeneous RAN architectures, the provisioning of the mobile services is gradually separated from the ownership of the physical network infrastructure as well as from the necessary activities to operate and maintain the different network elements. Hence, the future RAN architectures can be depicted as a set of relatively autonomous roles that can be performed by different actors. Yet, these autonomous roles need to be managed based on a framework of common principles and SLAs to provision the targeted mobile service which open the door for new business role. In this respect, five key business roles can be identified in the future mobile services ecosystem considering the discussed evolution path of the radio access network (RAN) Architecture in sections 4.2.2 and 4.2.3; namely:

- **Service Provider:** example MVNO can use sub-set of the connectivity provider network capabilities based on certain SLA to provision over top services. Here the service provider can control and manage the relationship with end-customers.

- **Connectivity Provider:** offering only B2C connectivity: Basic connectivity involves best effort IP connectivity or B2B capacity wholesale. Here the connectivity provider can control and manage the relationship with end-customers (B2C).

- **Asset Providers:** Rent resources on a pay-as-you-go model, Infrastructure as services (indoor or outdoor radio base station, aggregation node, backhaul link etc.), Spectrum as a Service etc.

- **Resources Broker:** Support secure and seamless resources sharing among different Service providers, connectivity Service Providers, Asset Providers. In this context, the resources definitions can be extended to include different passive infrastructure along with different active hardware and software's resources. This may include the wireless network infrastructures such as fixed and nomadic radio access nodes and the processing capability of these nodes, backhauling links and the essential spectrum resources. Moreover, certain core and transport network operation and management functionalities can in a similar way be abstracted to a resource.

- **Managed Service Provider (MSP):** Wireless network planning, deployment and O&M activities. A third party such as an infrastructure vendor willing to offer additional managed services to either MNOs or MVNO. Ericsson notably made an announcement at the Mobile World Congress related to its own SCaaS proposition. Other players such as municipalities or real estate owners could as well decide to make the investment to foster better capacity while monetizing the investment. This player is expected to play a role in public areas typically, like shopping malls and airports.

4.3.2 Mapping actors to the roles: xMBB value network

Considering the identified deployment scenarios and business roles in section 4.3.1.1, an actor can play specific business roles based on his ability to control over assets and control over end-customers. Moreover, a player can perform more than one business role if clear strategic benefits can be identified as shown in Table **4-9**. In this context, assets such as the wireless network infrastructures and the essential spectrum resources can be owned with different players with different business traditions.

Table 4-9: Mapping actors to the roles.

Mobile Network Operator (MNO)			
Strategy A	**Strategy B**	**Strategy C**	**Strategy D**
Option 1: Act as Connectivity and Service Provider by building and operating the mobile network infrastructure. Here, the MNO will control all the business relationships with the end-subscribers (B2C). Moreover, the MNO may outsource the network O&M activities to a MSP. **Option 2:** Act as Connectivity Provider and Assets Providers by selling the network capacity to virtual Operators such as MVNOs and PVNOs.	**Option 1:** Act as Connectivity and Service Provider by building and operating the mobile network in both indoor and outdoor locations. Here, the MNO may outsource the network O&M activities to a MSP. **Option 2:** Act as Service Provider only in certain indoor locations and purchase network capacity from an Assets Provider who owns indoor network infrastructure.	**Option 1:** Act as Connectivity and Service Provider by building and operating the mobile network infrastructure. Here, the MNO will control all the business relationships with the end-subscribers (B2C). Here, the MNO may outsource the network O&M activities to a MSP. **Option 2:** Act as Connectivity Provider and Assets Providers by selling the network capacity to virtual Operators such as MVNOs. Here the MNO can have a B2B	**Option 1:** Act as Connectivity and Service Provider by building and operating the mobile network in both public indoor areas and outdoor locations. Here, the MNO may outsource the network O&M activities to a MSP. **Option 2:** Act as Service provider only in certain indoor locations and purchase network capacity from an Assets Provider who owns indoor network infrastructure.

Here the MNO can have a B2B relation with actors such as MVNOs, OTTs etc.		relation with actors such as MVNOs, OTTs etc.	
Mobile Virtual Network Operator (MVNO)			
Strategy A	**Strategy B**	**Strategy C**	**Strategy D**
Act as Service and Connectivity Provider by purchasing network capacity from an Assets Provider who owns mobile network infrastructure. Here the MVNO will have B2B relation with MNOs and will control all the business relationship with end-subscribers (B2C).	**Option 1:** Act as Service Provider and Connectivity Provider in outdoor locations by purchasing network capacity from an Assets Provider who owns mobile network infrastructure. **Option 2:** Act as MSP or Connectivity Provider in indoor locations: enter into different cooperation model with facility manager (small cell deployment and O&M).	Act as Service and Connectivity provider by purchasing network capacity from an Assets Provider who owns mobile network infrastructure. Here the MVNO will have B2B relation with MNOs. Here, the MVNO will control all the business relationships with end-subscribers (B2C), buys capacity to MNOs and manages subscriber relationships.	**Option 1:** Act as Service and Connectivity Provider in outdoor locations by purchasing network capacity from an Assets Provider who owns mobile network infrastructure. **Option 2:** Act as MSP or Connectivity Provider in indoor locations: enter into different cooperation model with facility manager (small cell deployment and O&M)
Network Equipment Provider (NEP)			
Strategy A	**Strategy B**	**Strategy C**	**Strategy D**
Option 1: Act as NEP only by selling equipment and solution to MNO. Here the NEP will have B2B relationship with MNOs. **Option 2:** Act as MSP. Here the NEP will have B2B relationship with MNOs.	**Option 1:** Act as NEP only by selling equipment and solution to MNO. Here the NEP will have B2B relationship with MNOs. **Option 2:** Act as MSP or Connectivity Provider in indoor locations: enter into different cooperation models with facility	**Option 1:** Act as NEP only by selling equipment and solution to MNO. Here the NEP will have B2B relationship with MNOs. **Option 2:** Act as MSP. Here the NEP will have B2B relationship with MNOs.	**Option 1:** Act as NEP only by selling equipment and solution to MNO. Here the NEP will have B2B relationship with MNOs **Option 2:** Act as MSP or Connectivity Provider in indoor locations: enter into different cooperation model with facility manager (small cell deployment and

	managers (small cell deployment and O&M). **Option 3:** Act as Resources Broker (possible). **Option 4:** Outdoor Assets Provider (High possibility).		O&M). **Option 3:** Act as Resources Broker (possible). **Option 4:** Outdoor Assets Provider (high possibility).
Tower Company (TC)			
Strategy A	**Strategy B**	**Strategy C**	**Strategy D**
Act as Assets Provider by building, and maintaining radio sites. Here the TC will have B2B relationship with MNOs centric around rent spaces in radio sites.	**Option 1:** Act as Assets Provider in both indoor and outdoor locations by deploying and running all outdoor macro cell and indoor small cell in public areas (such as in shopping malls and airports) for several MNOs. **Option 2:** Act as Connectivity and Service Provider in indoor locations. By building and operating the mobile network infrastructure based on shared spectrum use. Here, the TC will control all the business relationship with end-subscribers (B2C). **Option 3:** Act as MSP or Connectivity Provider in indoor locations: enter into different cooperation model with facility manager (small cell	Act as Assets Provider by building, and maintaining radio sites. Here the TC will have B2B relationship with MNOs centric around rent spaces in radio sites.	**Option 1:** Act as Assets Provider in both indoor and outdoor locations by deploying and running all outdoor macro cell and indoor small cell in public areas (such as in shopping malls and airports) for several MNOs. **Option 2:** Act as Connectivity and Service Provider in indoor location. By building and operating the mobile network infrastructure. Here, the TC will control all the business relationships with end-subscribers (B2C). **Option 3:** Act as MSP or Connectivity Provider in indoor locations: enter into different cooperation model with facility manager (small cell deployment and O&M).

	deployment and O&M).		
Facility Manager (FM)			
Strategy A	**Strategy B**	**Strategy C**	**Strategy D**
Option1: Act as Assets Provider by renting spaces to deploy the outdoor radio base stations. Here, the FM could have B2B with different MNOs.	**Option 1:** Act as Assets Provider in indoor locations by deploying and running indoor small cell for several MNOs. **Option 2:** Connectivity and Service Provider in indoor location. Here, the FM may outsource the network O&M activities to a MSP.	Act as Assets Provider by renting spaces to fix the outdoor radio base stations. Here, the FM could have B2B with different MNOs.	**Option1:** Act as Assets Provider in both of indoor locations by deploying and running indoor small cell for several MNOs. **Option 2:** Connectivity and Service Provider in indoor location. Here, the FM may outsource the network O&M activities to a MSP.
OTT			
Strategy A	**Strategy B**	**Strategy C**	**Strategy D**
Option 1: Act as Service Provider only based by providing OTT services to end subscribers (i.e. content and application). **Option 2:** Act as Service Provider and Connectivity Provider by purchasing network capacity from an assets provider who own mobile network infrastructure. Here the OTT may enter into B2B relation with MNOs and become MVNOs.	**Option 1:** Act as Service Provide only based by providing OTT services to end subscribers (i.e. content and application). **Option 2:** Connectivity and Service Provider in indoor location. Here, the FO may outsource the network O&M activities to a MSP. **Option 3:** Act as Resources Broker capitalize in the available cloud and IT infrastructure.	**Option 1:** Act as Service Provide only based by providing OTT services to end subscribers (i.e. content and application). **Option 2:** Act as Service and Connectivity Provider by purchasing network capacity from an Assets Provider who own mobile network infrastructure. Here the OTT will may enter into B2B relation with MNOs.	**Option 1:** Act as Service Provider only based by providing OTT services to end subscribers (i.e. content and application). **Option 2:** Connectivity and Service Provider in indoor location. Here, the FO may outsource the network O&M activities to a MSP. **Option 3:** Act as radio Resources Broker capitalize in the available cloud and IT infrastructure.

5 Summary

This document presented five refined 5G use cases from METIS-II project that cover different 5G service families, along with their requirements. It then summarized architectural design aspects and spectrum demand scenarios that would enable offering these services in different use cases. As a pre-requisite to the success of any 5G deployment there needs to be viable business models to guide such deployment, so a qualitative RAN business model analysis was performed where we:

- identified the new players that enter the RAN ecosystem with 5G,
- analyzed the positioning of the new players and the evolutions of the positions of current players,
- built the MNO-centric value net that identifies the evolutions of the relationships between MNOs and other players with 5G.

In order to be more specific, we presented detailed business model analyzes for 5G in dense urban environments.

Building further on this document, the plan is to continue working on 5G business models, with a quantitative techno-economic feasibility assessment and the proposal of cost and profit sharing strategies between the different 5G RAN actors.

6 References

[3GPP10-36814] 3GPP TR36.814, "Evolved Universal Terrestrial Radio Access (E-UTRA); Further advancements for E-UTRA physical layer aspects", 2010.

[3GPP14-36932] 3GPP TR 36.932, "Scenarios and requirements for small cell enhancements for E-UTRA and E-UTRAN", September 2014.

[3GPP15-22879] 3GPP TR 22.879, "Feasibility Study on Mission Critical Video Services over LTE (Release 14)", v0.2.0, Doc. S1-152339, August 2015.

[3GPP15-22880] 3GPP TR 22.880, "Feasibility Study on Mission Critical Data Communications (Release 14)", v0.2.0, Doc. S1-152340, August 2015.

[3GPP15-22885] 3GPP TR 22.885, "Study on LTE support for V2X services (Release 14)", v0.3.0, Doc. S1-152760, August 2015.

[3GPP15-22891] 3GPP TR 22.891, "Feasibility Study on New Services and Markets Technology Enablers; Stage 1 (Release 14)", v0.2.0, Doc. S1-152336, August 2015.

[3GPP15-36300] 3GPP TS 36.300, "Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2 (Release 13)", V13.0.0, June 2015.

[3GPP13-36888] 3GPP TR 36.888, "Study on provision of low-cost Machine-Type Communications (MTC) User Equipments (UEs) based on LTE (Release 12)", June 2013.

[3GPP14-LAA] 3GPP TR 36.889, "Study on Licensed-Assisted Access to Unlicensed Spectrum Release 13)", V13.0.0, June 2015.

[3GPP15-45820] 3GPP TR 45.820 V1.2.1 ," Cellular System Support for Ultra Low Complexity and Low Throughput Internet of Things" May 2015-05.

[3GPP15-MCDATA] 3GPP SA, New Work Item Description (WID) "Study on Mission Critical Data Communications (FS_MCDATA)", Doc. SP-150049, March 2015.

[3GPP15-MCVIDEO] 3GPP SA, New Work Item Description (WID) "Study on Mission Critical Video over LTE (FS_MVVIDEO)", Doc. SP-150048, March 2015.

[3GPP15-SMARTER] 3GPP SA, New Work Item Description (WID) "Study on New Services and Markets Technology Enablers (FS_SMARTER)", Doc. SP-150142, March 2015.

[3GPP15-V2XLTE] 3GPP SA, New Work Item Description (WID) "Study on LTE support for V2X services (FS_V2XLTE)", Doc. SP-150051, March 2015.

[5GN13-D21] ICT– GA 318555 "5G Cellular Communications Scenarios and System Requirements", March 2013.

[5GPPP15] 5G Infrastructure PPP Association, "5G Vision - The 5G Infrastructure Public Private Partnership: the next generation of communication networks and services", White Paper, February 2015.

[ARCEP] Autorité de Régulation des Communications et Postes, République Française, "La qualité des services de voix et de données des opérateurs mobiles (2G et 3G) en France métropolitaine", Les actes de l'ARCEP, November 2012, http://www.arcep.fr/uploads/tx_gspublication/cr-enquete-QoS-2g-3g-nov2012.pdf

[BRAN96] Brandenburger, A.M., and Nalebuff, B.J. (1996). Co-opetition. New York: Doubleday.

[CARE] CARE – EU road accidents data base: http://ec.europa.eu/idabc/en/document/2281/5926.html, Nov. 2010.

[CISCO] Cisco, "Cisco Visual Networking Index: Forecast and Methodology, 2014–2019", May 2015, http://www.cisco.com/c/en/us/solutions/collateral/service-provider/ip-ngn-ip-next-generation-network/white_paper_c11-481360.html

[EARTH12] EARTH project, "Most suitable efficiency metrics and utility functions", EARTH project deliverable D2.4, January 2012, https://bscw.ict-earth.eu/pub/bscw.cgi/d70454/EARTH_WP2_D2.4.pdf

[EC10-1] European Commission, General for Mobility and Transport 20/07/2010: EU road fatalities.

[EC10-2] European Commission, Road Safety: Commission outlines measures to halve road deaths by 2020 (IP/10/970), press release, July 2010.

[ECC08-DEC01] European Conference of Postal and Telecommunications Administrations (CEPT), ECC Decision on "The harmonised use of the 5875-5925 MHz frequency band for Intelligent Transport Systems (ITS)", March 2008/July 2015.

[ECC14-DEC02] European Conference of Postal and Telecommunications Administrations (CEPT), ECC Decision on the "Harmonised technical and regulatory conditions for the use of the band 2300-2400 MHz for Mobile/Fixed Communications Networks (MFCN)", June 2014.

[ECC14-REP205] European Conference of Postal and Telecommunications Administrations (CEPT), ECC Report 205, "Licensed Shared Access (LSA)", February 2014.

[FCC15-47] US Federal Communications Commission (FCC), "Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band", April 2015.

[GBF+14] S. Gosselin, J. De Biasio, M. Feknous, T Mamouni, J. Torrijos, L. Cucala, D. Breuer, E. Weis, F. Geilhardt, D. v. Hugo, E. Bogenfeld, A. Hamidian, N. Fonseca, Y. Liu, S. Kuehrer, A. Gravey, A. Mitcsenkov, J. v. Galan, E. Masgrau, L. Gomez, L. Alonso, S. Hoest, A. Magee, "Fixed and Mobile Convergence: Needs and Solutions", European Wireless 2014, 14-16 May 2014.

[GUV11] I. Guvenc, S. Gezici, Z. Sahinoglu, and U. C. Kozat, Reliable Communications for Short-Range Wireless Systems. Cambridge University Press, 2011.

[GAM-15] Amirhossein Ghanbari, Oscar Alvarez Alvarez, and Jan Markendahl, "MTC Value Network for Smart City Ecosystems", 2015.

[iJo14-D52] ICT-317941 iJOIN, "Final Definition of iJOIN Requirements and Scenarios", November 2014.

[ITU11] International Telecommunication Union – Radio (ITU-R), "Assessment of the global mobile broadband deployments and forecasts for International Mobile Telecommunications", ITU-R report M.2243, 2011.

[ITU11b] International Telecommunication Union – Radio (ITU-R), "The outcome of the evaluation, consensus building and decision of the IMT-Advanced process (Steps 4 to 7), including characteristics of IMT-Advanced radio interfaces", ITU-R Report M.2198, November 2011.

[ITU15] International Telecommunication Union – Radio (ITU-R) Working Party WP 5D: Draft New Recommendation "IMT Vision - Framework and overall objectives of the future development of IMT for 2020 and beyond", Doc. R12-SG05-C-0199 (approved by Study Group SG5), June 2015.

[ITU-2083] Recommendation ITU-R M.2083-0, IMT vision – framework and overall objectives of the future development of IMT for 2020 and beyond, Sept. 2015.

[ITU-2290] Report ITU-R M.2290, Future spectrum requirements estimate for terrestrial IMT, Dec. 2013.

[ITU-2730] Report ITU-R M.2730, "IMT traffic estimates for the years 2020 to 2030", July 2015.

[ITU-FGSSC-15] ITU-T Focus Group on Smart Sustainable Cities, "Setting the stage for stakeholders' engagement in smart sustainable cities" March 2015.

[KRB15] Chang Wook Kim, Jihoon Ryoo and Milind Madhav Buddhikot, "Design and Implementation of an End-to-End Architecture for 3.5 GHz Shared Spectrum," 7th IEEE Dynamic Spectrum Access Networks (DySPAN), Stockholm, Sweden, Sep29-Oct02 2015.

[LGM-15] Andres Laya, Amirhossein Ghanbari and Jan Markendahl "Tele-Economics in MTC: what numbers would not show" EAI Endorsed Transactions on IoT, October 2015.

[MAM15-D11] ICT- 619086, "System scenarios and requirements specifications", January 2015.

[MCN13-D21] ICT – 318109, "Reference Scenarios and Technical System Requirements Definition", April 2013.

[MM14] S.-S. Manfred and N. Dmitry, "On m2m software platforms", International Journal of Open Information Technologies, vol. 2, no. 8, 2014.

[MET13-D11] ICT-317669 METIS, Deliverable 1.1 Version 1, "Scenarios, requirements and KPIs for 5G mobile and wireless system", April 2013.

[MET15-D15] ICT-317669 METIS, Deliverable 1.5 Version 1, "Updated scenarios, requirements and KPIs for 5G mobile and wireless system with recommendations for future investigations", April 2015.

[MET14-D53] ICT-317669 METIS, Deliverable 5.3 Version 1, "Description of the spectrum needs and usage principles", August 2014.

[MET15-D54] ICT-317669 METIS, Deliverable 5.4 Version 1, "Future spectrum system concept", April 2015.

[MET15-D64] ICT-317669 METIS, Deliverable 6.4 Version 2, "Final report on architecture", January 2015.

[MET15-D66] ICT-317669 METIS, Deliverable 6.6 Version 1, "Final report on the METIS 5G system concept and technology roadmap", May 2015.

[MET15-R31] ICT-671680 METIS-II, Report 3.1 Version 1, "Preliminary spectrum scenarios and justification for WRC Agenda Item for 5G bands above 6 GHz", October 2015.

[MiW15-WP] "MiWaveS White Paper - Heterogeneous Wireless Network with mmWave Small Cell Access and Backhauling", January 2015.

[MiW13-D11] ICT-608637, "Definition of Scenarios and Use Cases", December 2013.

[MMK+11] C. F. Mecklenbräuker, A. F. Molisch, J. Karedal, F. Tufvesson, A. Paier, L. Bernado, T. Zemen, O. Klemp, and N. Czink., "Vehicular Channel Characterization and Its Implications for Wireless System Design and Performance", Proceedings of the IEEE, vol. 99, no. 7, pp. 1189-1212, July 2011.

[MOT13-D21] ICT- 317959, "Use Cases and Requirements", February 2013.

[NGM10] NGMN Alliance, "User data rates in mobile data networks", May 2010.

[NGM15] NGMN Alliance, "NGMN 5G White paper", February 2015.

[Str11] E. G. Ström, "On medium access and physical layer standards for cooperative intelligent transport systems in Europe.", Proceedings of the IEEE, vol. 99, no. 7, pp. 1183–1188, July 2011.

[Tro13-D21] ICT-318784, "Scenarios and Requirements", July 2013.

[Werner08] M. Werner, P. Moberg, and P. Skillermark. "Cost assessment of radio access network deployments with relay nodes", In ICT-MobileSummit, 10-12 June, Stockholm, Sweden, 2008.

A Key Performance Indicators (KPIs)

This Appendix is based on [MET13-D11] and provides an overview of the Key Performance Indicators (KPIs) identified to assess the performance of the technical solutions derived within METIS-II and the five use cases defined in Section 2. Due to the wide variation of the environmental conditions in the different use cases there is also a corresponding spread of the KPI values which has to be taken into account, i.e. a single KPI value does not usually fit all use cases.

The KPIs taken as basis for assessment of the radio link related requirements are as follows:

- Traffic volume density,
- Experienced end-user throughput,
- Latency,
- Reliability,
- Availability and retainability,
- Energy consumption (efficiency),
- Cost (CAPEX, OPEX).

The KPI definitions are given within this section. Each KPI has a qualitative definition, motivation, and mathematical definition.

The requirements on each of the QoS KPIs (e.g. experienced end-user throughput and latency) have to be ensured in space and time following the availability and reliability requirements of the corresponding use case.

A.1 Traffic volume density

Qualitative definition: The traffic volume density describes the total user data volume transferred to/from end-user devices (measured on the interface between Layer 2 and 3) during a predefined time span divided by the area size covered by the radio nodes belonging to the RAN(s). For multi-hop solutions each user data is only counted once.

Motivation: This KPI is directly related to the general 5G goal to support a 1000 times higher traffic volume density than today's networks [MET13-D11] [5GPPP15]. This target figure is expected due to strongly increasing number of mobile devices with high data rate capabilities and traffic demand of multimedia-based services with rising share of ultra-high-resolution video during next decade [CISCO] [ITU11] [ITU-2730]. Figure A-1 schematically shows the expected exponential growth of the mobile traffic volume over time for a given area.

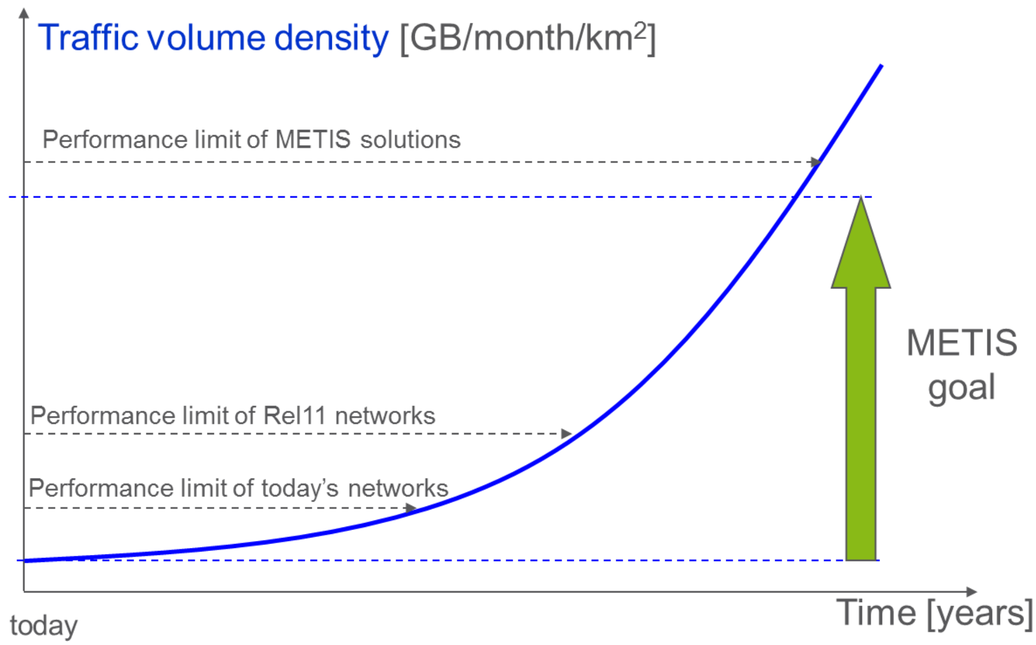


Figure A-1: Exemplary expected increase in traffic volume.

Today's legacy radio networks in Europe, based on a mixture of GSM, UMTS and LTE as well as of WiFi for hotspot scenarios, will not be able to cope with the expected traffic volume increase, even though further radio technology improvements will come with latest releases of 3GPP (known as LTE-Advanced Pro).

The traffic volume density is mostly interesting for the use cases which consider xMBB service types, i.e., taken into account high user densities as well as locations with high user data demands.

Mathematical definition: The traffic volume density in a network can be generally computed by the sum of traffic volumes each produced and consumed by an end-user device over a predefined time span, possibly differentiated between downlink and uplink direction, divided by the time span and by the overall service area covered by the corresponding radio nodes.

It has to be noted that the traffic volume density is usually strongly correlated with the environment and corresponding user densities. E.g. in dense urban areas with many large buildings and high user penetration the density will be much higher than in rural areas, see graphical illustration in Figure A-2 (left diagram). In addition, the instantaneous density will vary over the day with the traffic busy period being most important time slot for statistical evaluation, illustrated in Figure A-2 (right diagram). Therefore the variation in time and space has been taken into account at the definition of the KPI value for the different use cases.

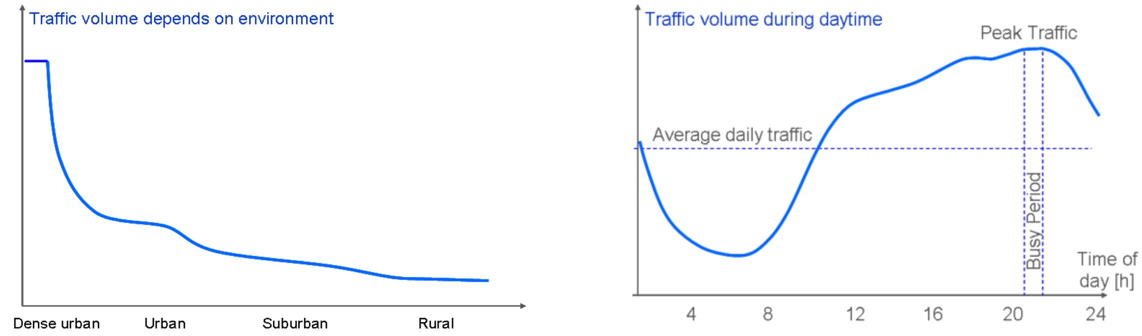


Figure A-2: Exemplary dependency of traffic volume on environment (left) and day time (right).

A.2 Experienced user throughput

Qualitative definition: The experienced user throughput is the data throughput an end-user device achieves on the interface between Layer 2 and 3 (user plane only) averaged during a predefined time span. This metric is one possible measure for the quality of experience (QoE) level a user experiences for the service applied. However, the data rate of the service application itself is lower than the experienced user throughput as additional protocol overhead and/or traffic control on higher layers, e.g., IP, TCP/UDP/SCTP. The experienced user throughput depends on the use case environment, but also on the number of users and the amount of data they generate, because they affect the cell load and interference from surrounding cells in a radio network.

Motivation: The KPI is directly related to the 5G goal to achieve a 10 to 100 times higher typical user data rate compared with today's systems [MET13-D11] [5GPPP15]. In principle it is relevant for all 5G use cases considering xMBB service types.

Mathematical definition: Let the k-th packet (at the interface between Layer 2 and 3) of the i-th user have a size $\mathrm{L_{ik}}$ bits. Its distribution depends on the application. Let $\mathrm{T_{ik}}$ be the E2E delay (one trip delay measured between the interfaces mentioned before) for delivering the packets to the destination. It depends on e.g. the RAN solution, user position (radio conditions), and scheduler load. The throughput for this packet is $\mathrm{R_{ik}} = \mathrm{L_{ik}}/\mathrm{T_{ik}}$. For instance, if a packet of 1.25 Mbyte is delivered in 1 s, then the packet throughput is 10 Mbps. The experienced user throughput is computed as the expected packet throughput:

$$Th_i = E_k[R_{ik}],$$

where the expectation is taken over a time span which is specific to the application or use case. For instance, it could refer to all packets belonging to a session or when the user is in a predefined location. A distribution of the experienced user throughput can be derived for each use case, based on assumed traffic volume and evaluated RAN solution (probably differentiated between DL and UL). Depending on final service availability (or coverage) defined in the use cases, the KPI value may be defined, e.g. as the 5th percentile of this distribution, i.e. 95% coverage for a certain data rate, or as the 1th-percentile, i.e. 99% coverage.

The experienced user throughput defined here is different to values known, e.g. from 3GPP and ITU-R evaluations on LTE-Advanced and IMT-Advanced systems where user throughput curves are usually derived for homogeneous hexagonal macro cell structures with fixed numbers of equally-distributed users in each cell based on a full buffer approach for each user queue, i.e. 100% network load.

In real mobile radio network scenarios the experienced user throughput is different due to typically lower network load taken into account the user's randomized access to shared radio resources according to their service applications. NGMN proposed in [NGM10] to apply file transfers as a basis for simulator evaluations. 3GPP proposed in [3GPP10-36814] a similar model to enable user throughput assessment at various network loads.

In contrast to those methods the more general approach applied in METIS-II can also be used in heterogeneous networks with unequal distribution of sites, users and traffic.

A.3 Latency

Qualitative definition: Different types of latency are relevant for different applications. E.g. the E2E latency, or one trip time (OTT) latency, refers to the time it takes from when a data packet is sent from the transmitting end to when it is received at the receiving end. Another latency measure is the round trip time (RTT) latency which refers to the time from when a data packet is sent from the transmitting end until acknowledgements are received from the receiving entity, e.g. internet server or other device. The measurement reference in both cases is the interface between Layer 2 and 3. Any processing time on higher layers, e.g. for audio and video encoding and decoding, on the application layer, is not considered here. The entire network (radio, core, and backhaul/aggregation) typically affects the latency, although this is use case dependent. Only the user data plane is considered in the evaluation.

Motivation: The KPI is directly related to the 5G goal to provide a 5 times reduced E2E latency compared to present systems [MET13-D11] [5GPPP15]. In principle all use cases considered in METIS-II would benefit from a latency reduction, but main challenges are with respect to ultra-reliable and/or safety-relevant services of type uMTC (e.g. for V2V communications) that require fast reactions of the involved parties.

With respect to the METIS-II goal it has to be noted that network entities like the mobile core, backhaul/aggregation links as well as internet connections might be included in the E2E transmission chain which are not in the main METIS-II focus. Latency improvements are to be expected mainly in the RAN area up to the core elements considering new features like D2D communication, local break-outs or content delivery network (CDN) functionalities.

Mathematical definition: The RTT latency TRTT is the time span measured between the start time TS1 of the transmission of a data packet from an end-user device (peer 1) to a remote station or device (peer 2) and the time instant TA1 when the acknowledgement, sent by peer 2, arrives at peer 1:

$$T_{RTT} = T_{A1} - T_{S1}.$$

The OTT latency is the time span measured between the start time T_{S1} of the transmission of a data packet from an end-user device (peer 1) to a remote station or device (peer 2) and the time instant T_{A2} when peer 2 receives the message:

$$T_{OTT} = T_{A2} - T_{S1}.$$

In the use cases a differentiation is required for latency KPI values depending on the availability of an already established radio communication data link. For example, for mMTC with only low data amounts and energy-efficiency requirements the change between a non-active to an active state has to be as short as possible, e.g. change from idle to connected mode in LTE, which requires a minimized signaling overhead.

A.4 Reliability

Qualitative definition: The reliability is an assessment criterion to describe the quality of a radio link connection for fulfilling a certain service level.

Motivation: The KPI is important for all considered use cases, but main challenge is seen with respect to those covering ultra-reliable services (uMTC), where very high reliability values are requested, e.g. for safety-relevant applications.

Mathematical definition: Reliability can be defined diversely, if different layers of the network or different applications are considered.

Generally, reliability is defined as the probability that a certain amount of data from an end user device is successfully transmitted to another peer (e.g. Internet server, mobile device, sensor) within a predefined time frame, i.e. before a certain deadline expires. The amount of data to be transmitted and the deadline are dependent on the service characteristics in the underlying use case. Typically, the deadline corresponds to the E2E latency requirement of the use case, as defined in Section A.3. Mathematically, the reliability R can be expressed as follows:

$$R = Pr(L \leq D),$$

where L is the measured E2E latency and D is the deadline, which characterizes the degree of real-time of the communication link. Specifically, if no retransmission is allowed to meet the deadline D, the reliability, R, is equivalent to probabilistic complement of packet loss rate.

Similar to the latency KPI, a differentiation for a second use case has to be required during evaluation dependent on the use case background. If a low data rate radio node, e.g. a sensor, is usually switching to inactive state after transmission of a small packet on the user plane due to energy saving reasons, it has to attach first to the network on the control plane before the next data transmission. The time needed for attachment and the corresponding success rate should be considered in the final reliability. Ideally the final METIS-II concept will provide a solution to minimize the attachment time and maximize the success rate.

A.5 Availability and retainability

Qualitative definition: When the reliability decreases below an acceptable level QoE, then the user may be so dissatisfied that it may regard the service as unavailable. The availability is an assessment criterion to describe inside a coverage area the percentage of places where a service is provided to the end user with the user's requested QoE level. Alternatively, availability is defined as the percentage of users or communication links for which the QoE requirements are fulfilled within a certain geographical area, e.g. in terms of reliability as defined in Section A.4. The latter definition is better suited to the case of D2D communications. Retainability is a special aspect of the above, by which a service has been made available as long as the user needs the service.

There is a strong correlation of availability and retainability to reliability in Section A.4. During final evaluation of both KPIs possible degradations have to be taken into account which might occur during handover processes between neighboring cells when the end-user is moving and between different radio access layers (different technologies and/or frequency layers) if the end-user data bearer is shifted to a different layer.

Motivation: The KPI is important for all considered use cases in METIS-II as it will provide a measure to identify the service availability for the end-users in the intended coverage area. Moreover, the KPI will contribute to the optimization of the network layout. It finally depends on the service types and criteria underlying the different use cases.

Mathematical definition: The availability in percentage is defined as the number of places (related to a predefined area unit or pixel size) where the QoE level requested by the end-user is achieved divided by the total coverage area of a single radio cell or multi-cell area (equal to the total number of pixels) times 100.

Alternatively, availability can be defined as the probability that the QoE requirements are fulfilled for a user or communication link within the service area. For the case when the QoE is expressed in reliability terms, the availability A is expressed as follows:

$$A = Pr(R \geq QoE),$$

where R is the measured reliability and QoE is the QoE requirements in terms of reliability of the underlying use case. Retainability can be defined as the probability for R to remain larger than the QoE-target, QoE, given that the service has already been made available. With other words, it is the probability for a user to satisfactory complete a session or a call, once it has been made available. It is the complement of drop-rate for a session, call or any other service.

A.6 Energy consumption/efficiency

Qualitative definition: Introduces an indicator to highlight the energy efficiency of any innovation introduced in METIS-II, including the whole METIS-II system architecture.

Motivation: The explosion of traffic demand foreseen beyond the 2020 horizon future and the intrinsic increase of resources to be deployed to tackle the METIS-II challenges casts severe requirements in terms of energy consumption of the corresponding system. It is quite straightforward and currently widely accepted that these demands have to be monitored not by metrics referring to energy consumption only, but rather to energy efficiency, i.e. including the increased provisioning of capacity that the new system will ensure.

Mathematical definition: An elaborate description of the metrics to be adopted for energy efficiency has been provided in the European FP7 project EARTH and it is taken as a reference also within METIS-II. Besides, in ITU-R, energy efficiency is also identified as one of the key capabilities of IMT-2020. Its definition is given in [ITU-2083].

The definition should be applied to three different environments: component level (for hardware innovative solutions), node level (for innovative solution in the transmitting nodes) and network level (for efficiency of the whole network). More insight is given here on the latter metric (the network one) due to the specific METIS-II goals, but all the details about component and node level metrics can be found in [EARTH12].

Regarding network energy efficiency three metrics are worth mentioning:

- Energy per information bit, expressed as follows

$$\lambda_I = \frac{E}{I} = \frac{P}{R}\, in\, [J / bit]\, or\, [W / bps]$$

  that is the most widely accepted metric for energy efficiency, especially in urban environments (*E* stands for consumed energy in a given observation period *T* with consumed power *P*, *I* is the information volume with rate *R,* measured at MAC layer).

- Information bit per energy, which refers to the quantity of information bits transmitted to and received from users, per unit of energy consumption of the RAN (e.g. in bit/J).

- Power per area unit

$$\lambda_A = \frac{P}{A}\, in\, \left[W / m^2\right]$$

  typically applicable in suburban or rural environments (*P* is the power consumed and *A* the area coverage).

In order to evaluate the METIS-II goal, the energy consumption must be modeled and analyzed both for the infrastructure and for the terminals. On the infrastructure side, models for analyzing and improving the energy efficiency of nowadays technologies have been proposed in the EARTH project [EARTH12].

It is possible that for many innovations in METIS-II no legacy reference will be available. As an example, consider the energy consumption of a car that could become a radio node in a future 5G network: of course there is no legacy reference for this case and it is also quite questionable if a reference to a car without any “mobile network related” facility could be reasonable. Whenever new network elements are introduced in the METIS-II network, the only reasonable reference is to the overall network energy efficiency, considering these new elements as further nodes in the network providing more capacity to the whole system.

So far no particular investigations have been considered with the due attention regarding energy efficiency of “devices”, i.e. for D2D, and “machines”, i.e. for M2M, at least within the framework of a mobile network perspective. It has to be analyzed case by case the efficiency of these solutions, making comparisons to the previous conditions, where the innovative METIS-II functionalities were not applied to these devices or machines.

A.7 Cost

Qualitative definition: Unless otherwise stated in the use cases, the cost refers to all the additional investments and expenses required by the new METIS-II solution. Hence, if the METIS-II solution reuses part of the legacy infrastructure or it is a complement for it, then the cost of the legacy network is not included into the cost of the METIS-II solution.

For a cellular network solution, the cost typically includes a part related to infrastructure, a part related to the end-user equipment, and a part related to spectrum licenses. Costs that are not related to the technical solution, such as customer care and marketing, are not considered. The infrastructure part is typically divided into the capital investment to acquire and deploy the network, called capital expenditure (CAPEX), and the costs to operate the network, called operational expenditure (OPEX). For instance, the CAPEX of a macro site covers the site acquisition and preparation; the equipment acquisition, installation, and configuration; the backhaul installation; the antenna systems; the power cables. Typically, CAPEX consists of one-time expenditures. However, for practical reasons these expenditures are spread over several years, i.e. annualized. The OPEX for such a site covers site rental; power consumption; maintenance, optimization, reparations, and replacements; backhaul transmission costs; software and operation services.

The METIS-II focus is on the radio access network and therefore the costs of the core network and service platforms are typically not included, unless otherwise stated in the use cases.

The costs with the end-user equipment may be significant too. Some new technical solutions may require changes both in the infrastructure and the end-user equipment. Thus an investment in the infrastructure might not bring the expected benefits unless a significant part of the user equipment has been replaced. Therefore the operator(s) may have an incentive to invest in speeding up the natural process of renewing the end-user equipment.

For new types of services, applications, and technical solutions, it might be harder to draw the line between the infrastructure and the end-user equipment, as is the case with small mobile base stations, or relays, mounted on vehicles. But similar principles may as well be applicable for most of the use cases.

Motivation: METIS-II has an explicit goal of providing solutions whose costs do not exceed the cost of today’s networks, although their performance is substantially better.

Mathematical definition: The mathematical definition is tightly connected to the model one chooses to use. A simple model can be based on the assumption that the total cost of ownership for an operator is proportional to the number of infrastructure nodes, to the number of end-user devices, and the spectrum.

Examples of cost of ownership for radio access networks can be found for instance in [Werner08]. In practice, the actual cost for different site types may vary between market and/or countries. Since the METIS-II goal related to cost is expressed in relative terms with respect to the cost of the legacy network, it might be enough for some solutions to analyze the relative cost without the need to specify the node, or site, costs in absolute terms.

B Analysis of SOTA 5G use cases

5G research has been quite active the past years. Thus, several EU funded projects have attempted to create pioneering scenarios for identifying the requirements of 5G. Similarly other initiatives like NGMN, and standardization bodies, like 3GPP and ITU-R, have captured the respective requirements so as to drive the research for handling the future demands. This process has resulted in a large number of scenarios and UCs focusing on diverse requirements. The purpose of METIS-II, which aims at driving 5G research, is to identify the most representative scenarios and use them for the evaluation of the proposed mechanisms. However, given the large number of UCs, it would be unrealistic to consider all the UCs proposed by the research community and the standardization bodies and fora for evaluation of the new METIS-II solutions. Thus, a detailed analysis has been performed, so as to identify the similarities and the gaps between the already proposed UCs. This section presents a thorough analysis of the UCs of METIS-I, and other European projects, as well as the ones considered by NMGM, 3GPP, and ITU. The analysis of the presented scenarios and UCs has resulted in the 5 UCs that will be considered in METIS-II.

B.1 Analysis of METIS-I use cases

This section attempts to analyze the description and the requirements of the use cases so that the commonalities can be identified and the number of considered UCs may be reduced for the simulation study, without losing the benefits of the thorough description of METIS-I UCs. Since the UCs of METIS-I have different purposes, the outcome of this effort will definitely lead to the extension of the aforementioned UCs, so as to include new aspects which were not captured in METIS-I.

Table B-1 summarizes the description of the METIS-I use cases [MET15-D15]. Additionally, each UC was mapped to its key 5G service so that the key requirement can be captured. Thus the following aspects have been considered:

- Device Density:
  - High : ≥ 10000 devices per km^2
  - Medium : 1000 – 10000 devices per km^2
  - Low : < 1000 devices per km^2
- Mobility:
  - No: Static users
  - Low: Pedestrians (0-3 km/h)
  - Medium: Slow moving vehicles (3 – 50 km/h)
  - High: Fast moving vehicles, e.g. cars and trains (> 50 km/h)
- Infrastructure

    - Limited: No infrastructure available or only macro cell coverage
    - Mediocre: Small amount of small cells
    - Highly available infrastructure: Big number of small cells available
- Traffic Type
    - Continuous
    - Bursty
    - Event Driven
    - Periodic
    - All types
- User Data Rate
    - Very high data rate : ≥ 1 Gbps
    - High : 100 Mbps – 1 Gbps
    - Medium : 50 – 100 Mbps
    - Low : < 50 Mbps
- Latency
    - High: > 50 ms
    - Medium: 10 – 50 ms
    - Low: 1 – 10 ms
- Reliability
    - Low: < 95%
    - Medium: 95 – 99%
    - High: > 99%
- Availability
    - Low: < 95%
    - Medium: 95 – 99%
    - High: > 99%
- 5G Service Type, comprising:
    - xMBB, where extreme Mobile Broadband is the key service requirement.
    - uMTC, where the reliability is the key service requirement of the UC.
    - mMTC, where the massive connectivity is the key service requirement of the UC.

Table B-1: METIS-I use case descriptions by considering each UC characteristics and the dominant 5G service.

		Use Case key characteristics								5G service type		
UC number	UC name	User Density	User Data Rate	Mobility	Infrastructure	Traffic Type	Latency	Reliability	Availability	xMBB	uMTC	mMTC
UC1	Virtual Reality Office	Low	Very High	No	High	Continuous	Low	Medium	Low	X	-	-
UC2	Dense Urban Information Society	High	High	Medium	High	All types	Low / Medium	Low	Low	X	-	-
UC3	Shopping Mall	High	High	Low	High	All types	Low / Medium	Low	Low	X	-	-
UC4	Stadium	High	Medium	Low	High	Bursty	Low / Medium	Low	Low	X	-	-
UC5	Tele-protection in smart grid network	Low	Low	No	High	Event driven	Low	High	High	-	X	-
UC6	Traffic Jam	Medium	High	Medium	Mediocre	All types	High	Low	Low	X	-	-
UC7	Blind spots	Low	High	Medium	Mediocre	All types	High	Low	Low	X	-	-
UC8	Real time remote computing for mobile terminals	Low	High	High	Limited	Continuous	Low	Low	Low	X	-	-
UC9	Open air festival	High	Medium	Low	Limited	Continuous	Low / Medium	Low	Low	X	-	-
UC10	Emergency communications	High	Low	No	Limited	Event driven	High	High	High	-	X	-
UC11	Massive deployment of sensors and actuators	High	Low	No	Limited	All types	High	Low	High	-	-	X
UC12	Traffic efficiency and safety	Low	Low	High	Limited	Periodic and Event Driven	Low	High	High	-	X	-
UC13	Gaming	Low	Low - Medium	No	High	Continuous	Medium	Low	Low	X	-	-
UC14	Marathon	High	Low	Medium	Limited	All types	Low	Low	Low	X	-	X
UC15	Media on demand	Medium	Low	No	High	Continuous	Medium	Low	Low	X	-	-
UC16	Unmanned aerial vehicles	-	-	-	-	-	-	-	-	X	-	-
UC17	Remote tactile interaction	Low	Low	No	High	Continuous	Low	High	High	-	X	-
UC18	eHealth	Low	Low	High	Mediocre					-	X	-
UC19	Ultra-low cost 5G network	Low	Low	Medium	Limited	Bursty	High	Low	Low	X	-	-
UC20	Remote car sensing and control	Medium	-	-	Mediocre	Bursty	-	-	-	-	-	X
UC21	Forest industry on remote control	High	High	-	-	-	Low	-	-	X	X	-

Here to mention that for some fields of the above table, dash is used (-) for the cases where a UC is not described in full detail. Having Table B-1 as reference, the similarities between the UCs can be easily identified and the UCs can be grouped in the following families (bottom up approach):

- UCs that mainly have static users with high data rate requirements and whose considered 5G service is xMBB.

- UCs that have moving users in indoor and outdoor environments, with high or relatively high user density, and whose considered 5G service is xMBB.
- UCs that focus on high reliability and availability, with relatively low user density and whose considered 5G service is uMTC.
- UCs that focus on the user density and the considered 5G service is mMTC.

The mapping of the UCs to the respective groups is provided in Table B-2. This table will be used as reference for the following sections, where the analysis of the UCs proposed by European projects and standardization bodies takes place.

Table B-2: METIS-I UC groups.

UC group description		UCs in the respective group
Group 1	Static users with high data rate requirements and xMBB service.	UC1, UC13, UC15
Group 2	Moving users, indoor/ outdoor environments, with high or relatively high user density, and xMBB service.	UC2, UC3, UC4, UC6, UC7, UC8, UC9, UC14, UC16, UC19
Group 3	Relatively low user density with high availability requirements, and uMTC service.	UC5, UC10, UC12, UC17, UC18, UC21
Group 4	High or relatively high user density and mMTC service.	UC11, UC20

B.2 Analysis of EU projects use cases

The European community has been very active towards the definition of 5G by funding several projects. So, in order to have a full view of the 5G trends and the corresponding 5G requirements identified by the research community, it is important to analyze the UCs, partly also named as Test Cases or Scenarios, defined by the European projects. In this section we attempt to map them to the description and the requirements of the METIS-I use case families identified in Section B.1, so as to identify potential use cases considered by the EU projects that should be part of the METIS-II analysis.

This analysis is not exhaustive, though most of the European projects with relevance for 5G have been considered. The following projects have been studied:

- 5GNOW [5GN13-D21],
- COMBO [GBF+14],
- MiWEBA [MiW13-D11],
- MAMMOET [MAM15-D11],
- MOTO [MOT13-D21],
- TROPIC [Tro13-D21],
- iJoin [iJo14-D52].

The UCs of the European projects are linked to the METIS-I UC groups described in Section B.1 so as to identify whether they could be included by the METIS-I UCs, or they focus on other 5 aspects. Table B-3 summarizes the findings of our analysis.

Table B-3: EU project mapping to the METIS-II UC groups.

	Test/Use Case title	TC family
5GNOW	Burst communication and sparse signal processing	Not User oriented TC
	M2M: sensing monitoring, collecting	Group 4
	Real time	Group 3
	Fragmented Spectrum	Not User oriented TC
	CoMP/HetNet - Time and frequency synchronization	Not User oriented TC
	CoMP/HetNet - Imperfect channel state information	Not User oriented TC
COMBO	UC01 – FMC access for mobile devices	Group 2
	UC02 – Enhanced FMC access for mobile devices	Group 2
	UC03 – Converged CDN for unified service delivery	Group 2
	UC04 – Reuse of infrastructure for indoor small cell deployment	Group 2
	UC05 – Effective wireless backhaul deployment for outdoor small cells	Group 2
	UC06 – Common fixed and mobile access termination in hybrid connectivity for fixed and mobile integrated customer services	Group 2
	UC07 – Support for large traffic variations between residential and business areas	Group 2
	UC08 – Universal Access Gateway for fixed and mobile aggregation network	Group 2
	UC09 – Convergent access and aggregation technology supporting fixed and mobile broadband services	Group 2
	UC10 – Network sharing	Group 2
MiWEBA	S1: Dense Hotspot in Shopping Mall	Group 2
	S2: Dense Hotspot in an Enterprise	Group 2
	S3: Dense Hotspot in Home Environment	Group 2
	S4: Dense Hotspot in a Square	Group 2
	S5: Dense Hot Spot in Urban areas	Group 2
	S6: Mobility in the city	Group 2
	S7 : Backhauling and Fronthauling in both dense Urban and Metropolitan areas	Group 2
MAMMOET	Scenario 1: Open exhibition	Group 2
	Scenario 2: Massive connectivity with crowded buildings	Group 2
	Scenario 3: Ubiquitous connectivity for the urban society beyond 2020	Group 2
	Scenario 4: Crowded auditorium	Group 2
	Scenario 5: Wide area with mobility	Group 2
MOTO	Scenario 1: Mobile customers accessing the web page of a shopping center	Group 2
	Scenario 2: Internet access proxing in a congested/no coverage mobile network	Group 2
	Scenario 3: Data dissemination with Offloading in Crowds for day-by-day uses	Group 2

	(Augmented reality application in a crowded museum)	
	Scenario 4: Data dissemination with Offloading in Crowds to handle peak of data traffic demands	Group 2
	Scenario 5: Expanded Coverage and Cellular Network Offloading	Group 2
	Scenario 6: Content dissemination based on payment system	Group 2
	Scenario 7: Vehicle Fleet Management	Group 2
	Scenario 8: Map-Based Advanced Driver Assistance Systems (ADAS)	Group 2
	Scenario 9: Enhancing Traffic Efficiency through Cooperative V2X Communication Systems	Group 2
Tropic	Generic Use case for small cells cloud services: Top down scenario – data distribution	Group 2
	Generic Use case for small cells cloud services: Bottom up scenario – processing/workload distribution	Group 1
	Application/radio mixed use cases: Downlink video streaming in infrastructure area	Group 2
	Application/radio mixed use cases: Downlink video streaming in infrastructure-less area	Group 2
	Application/radio mixed use cases: Uplink video streaming	Group 2
	Corporate applications over a femto cloud	Group 2
	Smart airport	Group 2
	Small cells cloud data tariff plans for multinational corporations	Group 2
	Corporate Virtual Desktop	Group 1
iJoin	Stadium	Group 2
	Square	Group 2
	Wide-area continuous coverage	Group 2
	Shopping Mall / Airport	Group 2

Apart from the ones included in the table, the MiWaveS and the MCN project have also been analyzed, though, since they do not have detailed public descriptions of the considered UCs, they have not been included in the Table B-3. However, for MiWaveS, the defined UCs are traditional xMBB UCs which are focusing on the small cell deployment (in urban and rural environments) and on the flexible spectrum usage of the mmW frequency bands at 57–86 GHz and we could consider that may be captured by the “number of Users and Mobility, focused on xMBB service” group (Group 2) [MiW15-WP]. Regarding MCN, the focus is on equipment sharing, network virtualization and context awareness for load prediction in cloud enabled xMBB and MTC scenarios, without having detailed description of the identified requirements [MCN13-D21].

The description of the UCs of the analyzed European projects is mainly based on the 5G service type, the number of users, their mobility, the latency requirements, and the infrastructure availability. The analysis of the UCs considered in the European projects leads to the following outcomes:

- mainly xMBB scenarios are being considered from the EU projects,

- in some EU projects mMTC UCs have been considered,
- no uMTC UC has been considered in the analyzed EU projects apart from METIS-I.

As a conclusion, it could be mentioned that based on the analysis of the EU projects, no additional UC group seems to be required, since all the UCs could be included in the identified UC groups presented in Section B.1.

B.3 Analysis of NGMN use cases

According to NGMN, [NGM15], the business context beyond 2020 will be notably different from today since it will have to handle the new UCs and business models driven by the customers' and operators' needs. 5G will have to support, based on the NGMN vision, apart from the support of the evolution of mobile broadband, new UCs ranging from delay-sensitive video applications to ultra-low latency, from high speed entertainment applications in a vehicle to mobility for connected objects, and from best effort applications to reliable and ultra-reliable ones such as health and safety.

Thus, NGNM has proceeded in a thorough analysis for capturing all the customers' and operators' needs. The analysis is based on twenty-five UCs for 5G grouped into eight UC families (Figure B-1). The UCs and UC families serve as an input for stipulating requirements and defining the building blocks of the 5G architecture.

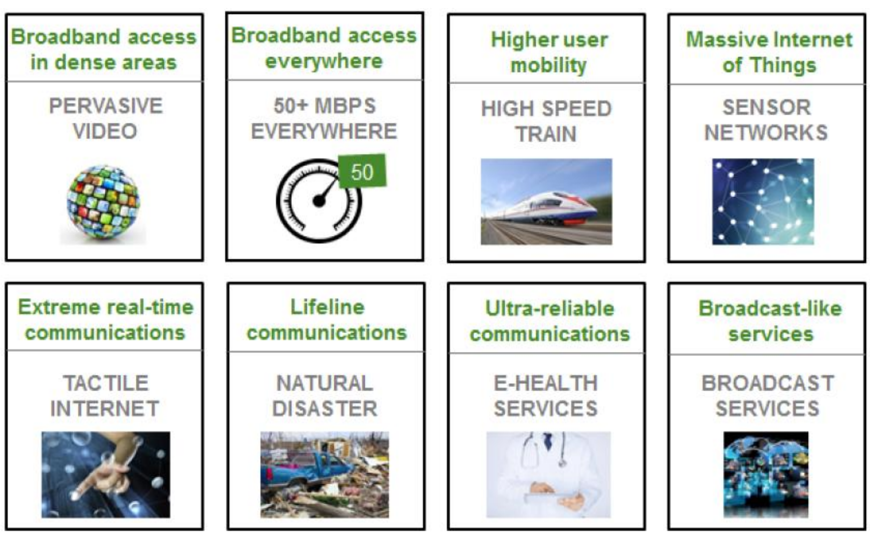


Figure B-1: UC families considered by NGMN with representative UCs [NGM15].

According to the NGMN 5G White Paper [NGM15], the UC analysis is not exhaustive, though it provides a thorough and comprehensive analysis of the requirements of 5G. Following the same analysis as in Section B.1 for the METIS-I UCs, we identify in this section the key requirements and characteristics of each UC proposed by NGMN and we attempt to map it in the UC groups identified using as reference METIS-I. The UC description provided in NGMN follows similar methodology to that of METIS-II, thus enabling a harmonized analysis (see Table B-4). The NGMN objective however is to incorporate the business aspects and the operators' views, thus capturing additional aspects on the one hand and posing slightly harder requirements for the network on the other hand.

Table B-4: NGMN UCs analysis by their characteristics and the dominant 5G service.

		Use Case key characteristics								5G service type		
UC number	UC name	Number of devices		Mobility	Infrastructure	Traffic Type	Latency Requirements	Reliability	Availability	xMBB	uMTC	mMTC
UC1	Pervasive Video	High	High	Limited	Yes	Continuous	Low	-	Low	X	-	-
UC2	Smart Office	High	High	No	Yes	Continuous	Low	-	Low	X	-	-
UC3	Operator Cloud Services	High	High	Yes	Yes	Continuous	Medium	-	Low	X	-	-
UC4	HD Video/Photo Sharing in Stadium/Open-Air Gathering	High	Medium	No	Yes	Continuous	Medium	-	High	X	-	-
UC5	50+ Mbps everywhere	Low	Medium	High	Limited	Continuous	High	-	High	X	-	-
UC6	Ultra-low Cost Networks	Low	Low	Medium	Limited	Continuous	Medium	-	Low	X	-	-
UC7	High Speed Train	Medium	Medium	High	Mediocre	All types	Low	-	Low	X	-	-
UC8	Remote Computing	Low	Medium	High	Mediocre	Continuous	Low	-	Low	X	-	-
UC9	Moving Hot Spots	Low	High	High	Mediocre	Bursty	Low	-	High	X	-	-
UC10	3D Connectivity - Aircraft	Low	Low	High	Mediocre	High	Low	-	High	X	-	-
UC11	Smart Wearables	High	Low	High	All types	Periodic	Low	-	High	-	-	X
UC12	Sensor Networks	High	Low	Low	All types	Periodic	Low	-	High	-	-	X
UC13	Mobile Video Surveillance	High	Medium	High	High	Continuous	Low	-	High	X	-	X
UC14	Tactile Internet	High	High	High	High	Various types	Low	High	High	-	X	-
UC15	Natural Disaster	High	Low	Low	Limited	Short messages	High	High	High	-	X	X
UC16	Automated Traffic Control and Driving	Low	High	High	High	All types	Low	High	High	-	X	-
UC17	Collaborative Robots: A Control Network for Robots	Low	Low	No	High	Continuous	Low	High	High	-	X	-
UC18	eHealth: Extreme Life Critical	High	Low	No/Low	High	Short messages	Low	High	High	-	X	-
UC19	Remote Object Manipulation: Remote Surgery	Low	Low	Low	High	Continuous	Low	High	High	-	X	-
UC20	3D connectivity: Drones	Low	Low	High	Limited	Continuous	Low	High	High	-	X	-
UC21	Public Safety	Low	Low	Low	High	Continuous	Low	High	High	-	X	-
UC22	News and Information	High	High	High	High	All types	High	-	-	X	-	-
UC23	Local Broadcast-	High	High	Low	High	All types	High	-	-	X	-	-

	like Services											
UC24	Regional Broadcast-like Services	High	High	High	High	All types	High	-	-	X	-	-
UC25	National Broadcast-like Services	High	High	High	High	All types	High	-	-	X	-	-

Table B-5 maps the NGMN UC to the UC groups, as they came up in Section B.1. As shown in Table B-5, the NGMN UCs can be grouped in the considered categories. However, some UCs either may not be included in the identified groups, or extensions are required. These identified use cases are the following ones:

- UC5: 50+ Mbps everywhere, which considers mobility combined with xMBB service, with lack of infrastructure. **It has been decided that the "50+ Mbps everywhere" use case will be used for the evaluation of the mechanisms of METIS-II.**
- UC16: Automated Traffic Control and Driving, which considers heavy moving users (i.e., cars) which have to exchange (a) information transfer with high reliability and with very low latency, and, (b) xMBB service among the cars. This use case may be seen as a mixture of METIS-I UCs 8 (Real-time remote computing for mobile terminals) and 12 (Traffic efficiency and safety). However, it focuses on the ultra-reliability nature, since it refers to automated driving, whereas METIS-I UC8 is related to remote computing, focusing on the xMBB nature. **It has been then decided that METIS-I UC "Traffic Safety and Efficiency" will be updated accordingly** so as to incorporate the corresponding requirements.

Table B-5: NGMN UCs grouping.

UC group description		**NGMN UCs in the respective group**
Group 1	Static users with high data rate requirements and xMBB service.	UC2, UC4
Group 2	Moving users, indoor/ outdoor environments, with high or relatively high user density, and xMBB service.	UC1, UC3, UC6, UC7, UC8, UC9, UC10, UC22, UC23, UC24, UC25
Group 3	Relatively low user density with high availability requirements, and uMTC service.	UC14, UC15, UC16, UC17, UC18, UC19, UC20, UC21
Group 4	High or relatively high user density and mMTC service.	UC11, UC12, UC13

B.4 Analysis of ITU-R usage scenarios

In its Draft New Recommendation "IMT Vision - Framework and overall objectives of the future development of IMT for 2020 and beyond" [ITU15], the ITU-R WP 5D defined the framework and overall objectives of the future development of International Mobile Telecommunications (IMT) for 2020 and beyond in light of the roles that IMT could play to better serve the needs of the networked society, for both developed and developing countries, in the future. IMT for 2020 and beyond is envisaged to expand and support diverse usage scenarios and applications that will continue beyond the current IMT:

- **Enhanced Mobile Broadband**: Human-centric use cases for enhanced access to multi-media content, services and data with improved performance and increasingly seamless user experience. This usage scenario covers a range of cases with different requirements, e.g., the hotspot case with high user density, very high traffic capacity and low user mobility, as well as the wide area coverage case with seamless radio coverage providing much improved user data rate compared to existing data rates with medium to high user mobility.
- **Ultra-reliable and low latency communications**: Stringent requirements for capabilities such as throughput, latency and availability. Examples: Wireless control of industrial manufacturing or production processes, remote medical surgery, distribution automation in a smart grid, transportation safety, etc.
- **Massive machine type communications**: Characterized by a very large number of connected devices typically transmitting a relatively low volume of non-delay-sensitive data. Devices are required to be low cost, and have a very long battery life.

These usage scenarios illustrated by some examples in Figure B-2 are in principle a one-to-one mapping of the 3 so-called generic 5G services xMBB, uMTC and mMTC stated in the METIS-I project [MET15-D66]. Due to that consensus there is no need in METIS-II to make any changes w.r.t. service types which are the basis for the final use case definition.

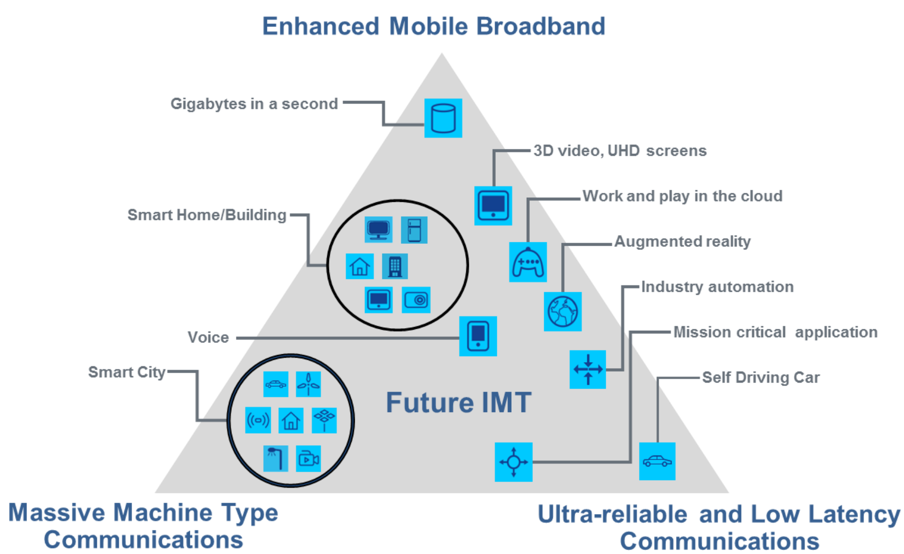


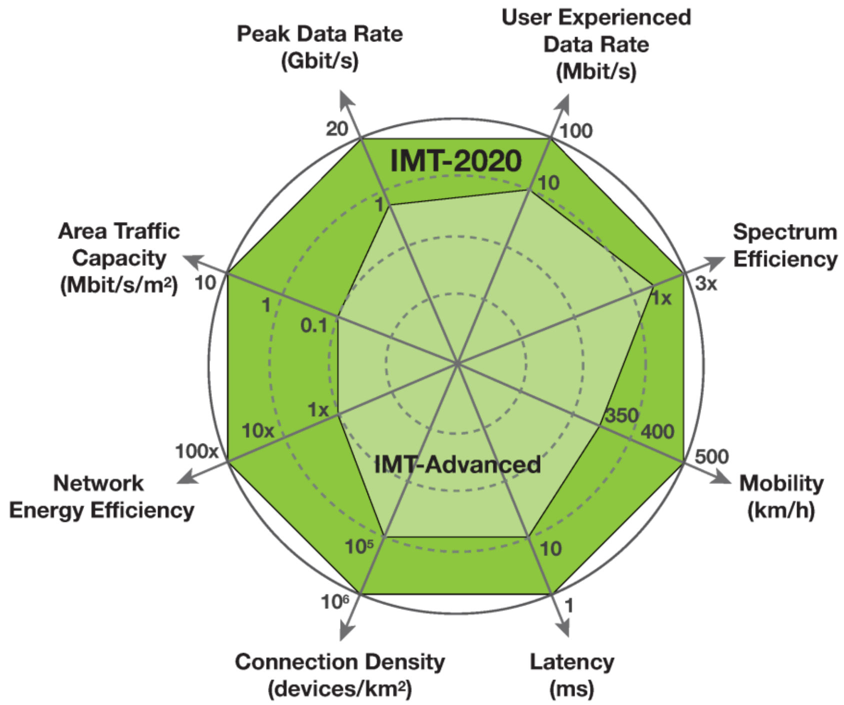
Figure B-2: Examples for usage scenarios considered by ITU-R for IMT beyond 2020 [ITU15].

The ITU-R has considered 8 parameters to be key capabilities of IMT-2020:

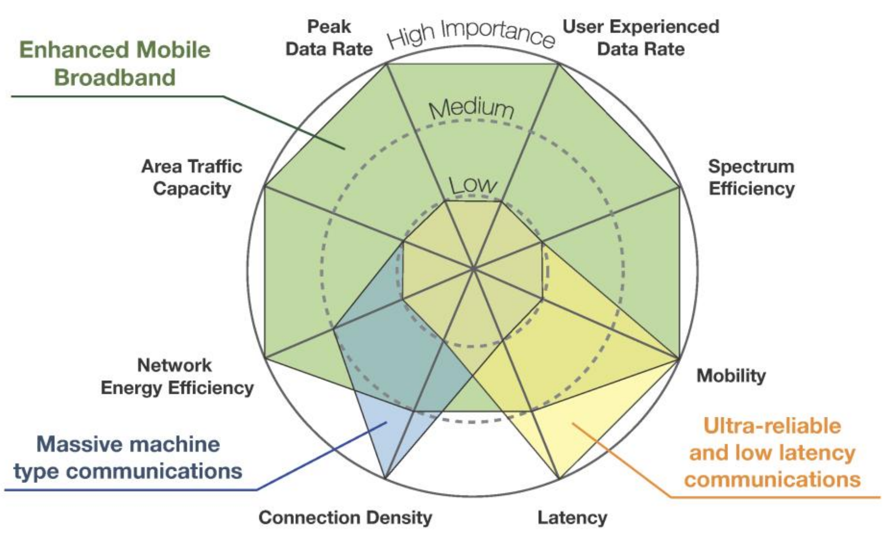
- **Peak data rate** (i.e., maximum achievable data rate under ideal conditions per user/device).

- **User experienced data rate** (i.e., achievable data rate that is available ubiquitously across the coverage area to a mobile user/device).
- **Latency** (i.e., the contribution by the radio network to the time from when the source sends a packet to when the destination receives it).
- **Mobility** (i.e., maximum speed at which a defined QoS and seamless transfer between radio nodes which may belong to different layers and/or radio access technologies (multi-layer/-RAT) can be achieved).
- **Connection density** (i.e., total number of connected and/or accessible devices per unit area).
- **Energy efficiency** (refers on the network side to the quantity of information bits transmitted to / received from users, per unit of energy consumption of the RAN, and on the device side to the quantity of information bits per unit of energy consumption of the communication module (in bit/Joule in both cases)).
- **Spectrum efficiency** (i.e., average data throughput per unit of spectrum resource and per cell (bit/s/Hz)).
- **Area traffic capacity** (i.e., total traffic throughput served per geographic area (in bit/s/m^2)).

The key capabilities expected for IMT-2020 are shown in Figure B-3(a) compared with those of IMT-Advanced, but due to different requirements the importance of the achieved capability values is not the same for all three usage scenarios. This is shown in Figure B-3(b). Nevertheless, dependent on the dedicated service or environment, the importance may also vary within one usage scenario (e.g. different mobility requirements for the hotspot and the wide area coverage case as mentioned before for enhanced MBB).



a) Expected enhancements versus IMT-Advanced.



b) Importance for different usage scenarios.

Figure B-3: Key capabilities of IMT beyond 2020 [ITU15].

The ITU-R noted also other capabilities with importance for the future IMT-2020 system:

- **Spectrum and bandwidth flexibility** (i.e., flexibility of the system design to handle different scenarios and in particular to the capability to operate at different frequency ranges, including higher frequencies and wider channel bandwidths than today).
- **Reliability** (i.e., capability to provide a given service with a very high level of availability).
- **Resilience** (i.e., ability of the network to continue operating correctly during and after a natural or man-made disturbance, such as the loss of mains power system).
- **Security and privacy** (refers to several areas such as encryption and integrity protection of user data and signaling, as well as end user privacy preventing unauthorized user tracking, and protection of network against hacking, fraud, denial of service, man in the middle attacks etc.).
- **Operational lifetime** (i.e., operation time per stored energy capacity which is particularly important for machine-type devices requiring a very long battery life (e.g., more than 10 years) whose regular maintenance is difficult due to physical or economic reasons).

In the use cases of the METIS-II project – and of the other 5G PPP projects as well – the capabilities recommended by ITU-R should be referenced as KPIs.

B.5 3GPP Study on New Services and Markets Technology Enablers

3GPP SA1 started in March 2015 a new Study Item called “Study on New Services and Markets Technology Enablers” (FS_SMARTER) [3GPP15-SMARTER]. The objective of this study is to identify new market segments and verticals the 3GPP system needs to address in the future to enable new business models and varying operational schemes to optimize the use of the operators' networks (e.g., faster network and service deployment, lower operational complexity and cost). The work will focus on use cases and requirements that cannot be met with today’s Evolved Packet System.

In a first step SA1 is developing use cases for various scenarios and identifying related high-level potential requirements. As second step/phase, it is working to group together use cases with common characteristics and agreed to group the different use cases in TR 22.891 into four building blocks. In order to accelerate this work, it held a dedicated ad-hoc meeting during 19-21 October, 2015. The current status of the FS_SMARTER output with descriptions of 74 different use cases is reflected in the Draft Technical Report TR 22.891 [3GPP15-22891] which was presented during SA meeting held in Dec 2015.

In the following meetings, SA1 will continue to work on the individual building block study items to further develop each selected use case (or group of use cases) and to capture desired system requirements and capabilities that apply across the different verticals. This essentially reflects a horizontal view on potential requirements to complement the vertical use cases. The target date for this final step with finalization of individual TRs is March 2016. The four agreed building block studies are: Study on New Services and Markets Technology Enablers – massive Internet of Things or FS_SMARTER-mIoT, Study on New Services and Markets Technology Enablers – Critical Communications or FS_SMARTER-CRIC, Study on New Services and

Markets Technology Enablers – enhanced Mobile Broadband or FS_SMARTER-eMBB and Study on New Services and Markets Technology Enablers – Network Operation or FS_SMARTER-NEO.

The list of use cases in current Draft TR 22.891 covers not only service-related use cases, but also use cases which are more related to future network set-up and operation. Examples for that are:

- Network slicing;
- On-demand networking;
- Multi-RAT connectivity incl. selection of best connectivity per traffic type;
- Coexistence with legacy systems;
- Flexible application traffic routing including optimizations in case of server changes;
- Network enhancements to support flexibility, scalability, and automation;
- Wireless backhauling.

Such kind of use cases were not reflected by the work in METIS-I and are also not intended in METIS-II, as the focus is a definition of end user service-related use cases.

The service-related use cases cover different xMBB usage scenarios, e.g. for indoor and hotspot scenarios (incl. virtual presence) as well as seamless wide-area coverage. In addition, use cases for low mobility as well as high mobility including connectivity to cars are listed. Also broadcasting is highlighted by use cases.

The typical mMTC service is reflected e.g. by “Wide area sensor monitoring and event driven alarms” as well as by use cases addressing the configuration of such low-cost devices.

Several use cases listed are related to uMTC scenarios, e.g.

- Tactile internet;
- Industrial control and factory/process automation;
- Robotics;
- Localized as well as wide-area remote control (e.g. connectivity for drones).

Further examples are on emergency and lifeline communications as well as on highly accurate user/device positioning and tracking.

These service-related use cases in Draft TR 22.891 are already considered to a large extent by the corresponding descriptions of METIS-I scenarios and test/use cases [MET13-D11] [MET15-D15], at least w.r.t. their challenging requirements. Nevertheless, as TR 22.891 is not finally approved, a cross-check with the requirements and KPIs taken for the selected use cases in METIS-II should be performed to achieve consistency between different activities.

Except of the feasibility study SMARTER 3GPP SA1 has also initiated 3 other Study Items which have some relevance for 5G, even if they are focused on LTE technology: the first one is on V2X use cases (FS_V2XLTE) [3GPP15-V2XLTE], the others on mission critical communications (FC_MCVIDEO [3GPP15-MCVIDEO] and FC_MCDATA [3GPP15-MCDATA]).

The Draft TR 22.885 for FS_V2XLTE [3GPP15-22885] is intended to be completed in Nov 2015. It describes use cases in a vehicular environment for V2V, V2I and V2P in the context of both safety and non-safety services. According to studies in METIS-I performed e.g. by BMW not all requirements especially for safety services can be efficiently fulfilled by current LTE releases. The work in METIS-I on 5G technology components already considered the most challenging parts of the FS_V2XLTE use cases via UC12 “Traffic efficiency and safety” (see Section 3.2 and [MET13-D11]), so it is not explicitly required to consider all listed use cases in detail for the work in METIS-II.

The work on mission critical video and data communication by SA1 is related e.g. to group communications systems, proximity based services, or isolated LTE operation for public safety. Different use cases which can be characterized to belong to the 5G uMTC scenario are listed in current Drafts TR 22.879 [3GPP15-22879] and TR 22.880 [3GPP15-22879] (intended to be approved by Nov 2015). In most cases the use cases do not provide dedicated values for KPIs which can be transferred to 5G, but functional requirements the wireless system has to fulfill. The main impact on 5G is that it is assumed that those mission critical services should run on a common platform (incl. the devices) together with other commercial services. The use cases are mainly related to group communications with different service types with and also without support of the network infrastructure, so e.g. extensions of D2D communication considered in METIS-I is required. Other service types, e.g. remote control features as well as video surveillance, are already covered by corresponding use cases in SMARTER.

C METIS-II 5G use cases

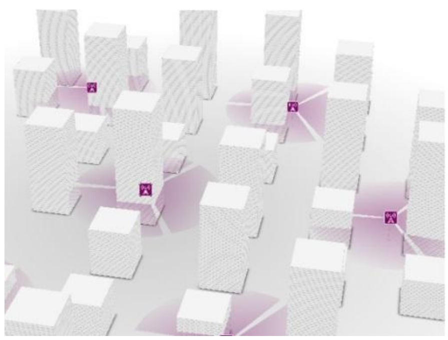
This appendix is a more in-depth presentation on each METIS-II use case and its requirements than what was provided in Section 2. The consolidated METIS-II use cases are described briefly in Section 2.1 and the main KPIs and requirements of each use case are presented in Section 2.2.

C.1 UC1: Dense urban information society

This use case is based mainly based on test case two of METIS-I (Dense urban information society), see [MET13-D11], and has been slightly updated following NGMN requirements [NGM15]. It mainly addresses the use case families xMBB and mMTC.

C.1.1 Background and motivation

The “Dense urban information society” use case is concerned with the connectivity required at any place and at any time by humans in dense urban environments, including both indoor and outdoor environments. We consider here both the traffic between humans and between human and the cloud, and also direct information exchange between humans or with their environment. D2D in dense urban environment provides opportunity to offload traffic as well as to cut-short traffic path by enabling proximity based discovery and communication.



Public cloud services

Besides classical services such as web browsing, file download, email, social networks, we will see a strong increase in high definition video streaming and video sharing, possibly also with higher requirements for image resolution, e.g. 4K standard. This trend will, for instance, be fostered through the availability of new user interface improvements like resizable portable screens, or screens embedded into watches or glasses. Besides a massive increase in the data volumes connected to the usage of public cloud services, a key challenge in communication systems beyond 2020 will lie in the fact that humans will expect the same reliable connectivity to the cloud anytime and anywhere.

Device-centric services

Also, augmented reality services will be essential in our daily life. For a full experience of the augmented reality, information could be fetched from various sources, such as sensors, smart phones, wirelessly connected cameras, databases, servers, and used locally in the device or sent to be processed in the cloud. Hence, the future mobile and wireless communication system should integrate both highly capable devices and other wireless devices in an efficient way. In an urban area, some of these devices may provide information about the surrounding of the users by measuring a certain phenomenon or by providing information about the presence of objects of interest. Based on the information harvested from surrounding devices and other sources, the UE could provide the user with contextual information so as to help the users to better understand and enjoy their environment. Also the information collected in or by the device can be uploaded to the cloud servers and shared with others through the cloud connectivity – a tight latency requirement will here be as important as a high experienced user throughput.

The challenge for mobile communication systems beyond 2020

The mobile technology, completely transparent for users, will allow network access at any location and any time with service quality comparable to current wired broadband access with optical fiber.

C.1.2 KPIs and requirements

In this use case, we consider both UEs exchanging information with cloud servers (i.e. for public cloud services) and also with other UEs, devices or sensors located in close vicinity (i.e. for device-centric services). The key requirements are described below and the KPIs are summarized in Table C-6.

For public cloud services, the requirement is to enable in **95% of locations and time an experienced user throughput of 300 Mbps and 50 Mbps in downlink and uplink, respectively.**

- For device-centric services, the experienced user throughput between UEs or sensors is required to be **10 Mbps or more**.
- The network is required to provide the above QoS levels while sustaining an average traffic volume of **500 Gbyte per device and per month**. Note that averaging is done over various types of users and devices.

Note that the above stated requirements will be connected to a mix of different traffic forms, e.g. bursty traffic and video streaming. If, as an example, only highly bursty downlink traffic is considered, the above experienced user throughput requirements and the traffic volume per subscriber could be translated into a traffic model foreseeing “1 downlink packet of size 30 Mbyte per user and minute, throughout 9 hours per day, to be delivered within 1s in 95% of time and area”. The exact split of the monthly user traffic volume among uplink and downlink, different times of the day, different areas (e.g. office, pedestrian sidewalks, residential areas, parks) and different forms of traffic (e.g. bursty and streaming) will be specified later by the METIS-II partners.

For the limited areas that will cover enterprises locations (e.g. complex of office buildings), universities (e.g. campus buildings) or any other managed public space, operators may provide cloud services at the quality level beyond the values stated above, i.e. **achieving experienced user throughputs up to 1 Gbps**.

The latency requirement from an end-user’s perspective depends on the service type:

- web browsing: less than 0.5 s for download of an average size web page. A latency of 0.5 s may not appear very challenging, but is has to be taken into account that typical web page sizes beyond 2020 will be much larger than today (in conjunction with the requirement of an experienced user throughput of 300 Mbps, web page sizes will be on the order of 20 Mbyte), and that from the human user perspective it will not make a difference if latency requirements are further tightened,

- video streaming: less than 0.5 s for video starting,
- augmented reality processed in the cloud and locally: less than 2 to 5 ms.

D2D related KPIs include D2D discovery time (synchronization scheme dependent), D2D link coverage (minimum 50 m), D2D setup latency (solution dependent, e.g. the level of network assistance), feedback latency, e.g. HARQ feedback latency (less than 1 ms), D2D link throughput and device battery consumption (total D2D radio power consumption should be lower than the cellular radio power consumption).

Table C-6: KPIs and requirements for UC1.

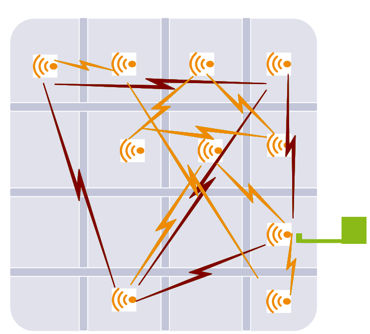
Variable/parameter	**Value**
Performance targets	
Experienced user throughput	300 Mbps in DL 50 Mbps in UL
Traffic volume density (busy hour)	750 Gbps/km^2 DL and 125 Gbps/km^2 UL
E2E RTT Latency	Web browsing: less than 0.5 s for download of an average size web page Video streaming: less than 0.5 s for video starting Augmented reality processed in the cloud and locally: less than 5 ms
Availability and reliability	95% in space and time
Constraints	
Energy consumption (infrastructure)	Low-energy consumption is preferred for cost and sustainability reasons. The consumed energy should be very low when not transmitting user data. Generally the network energy consumption should be comparable to the energy consumption of today's metropolitan deployments, despite the drastically increased amount of

	traffic
Energy consumption (UE or other devices)	Energy consumption should be similar to that of today's devices
Cost (infrastructure)	Infrastructure cost should be kept on the same level per area as today
Cost (UE or other devices)	Future mobile broadband UE cost should be similar to today's smartphones or 3G/4G modems (transceiver part). A sensor device must have a significantly lower cost than a regular handset devices, i.e. not more than a few euros for the radio part of the sensor
Use case definition	
User/device density	up to 200 000 users per km^2
Traffic volume/type	500 Gbyte/month/subscriber
User type	Primarily human generated and consumed traffic
User mobility	Most of the users, devices, have velocities up to 3 km/h, in some cases up to 50 km/h

C.2 UC2: Virtual reality office

This use case is based on test case one of METIS-I, see [MET13-D11]. This use case mainly addresses the use case family xMBB.

C.2.1 Background and motivation



In [MET13-D11] this use case was described as follows. A top-modern office space is located in a refurbished 19th century building classified as cultural heritage. The building is rented by a company working with 3D tele-presence and virtual reality. The work involves interaction with high resolution 3D scenes and is typically performed in teams of some 5 to 10 individuals simultaneously interacting with a scene. Some of the team members are sited within the building; others are working remotely from other office buildings. Each scene may include the virtual representation of the team members or computer generated characters and items. The high-resolution quality of the scene provides an as-if-you-were here feeling. Since each team member may affect the scene, all must continuously update the scene by streaming data to the others. In order to provide the real-time interaction, the work is supported by bi-directional streams with very high data-rates and low latencies.

Today's wireless technologies are not capable to provide, at reasonable costs, the high data-rate and capacity requirements posed by this type of applications on the access and the in-building backhaul to the wireless access points.

C.2.2 KPIs and requirements

The requirements that must be satisfied for this use case are described below and the key performance indicators are summarized in Table C-7.

End-users should be able to experience sustainable experienced user throughput of at least 1 Gbps to other team members and to the office cloud servers. The end-users may be located in different rooms or at different floors or even in other buildings. For purposes of synching large amounts of data (e.g. downloading large files from the office cloud to a local storage) even higher experienced user throughput, 5 Gbps, should be experienced, although a lower availability can be accepted for this use case. The average user density is one user per 10 m^2. To provide enough capacity one need to support a consumption of at least 0.1 Gbps/m^2.

End-users should be able to experience user throughputs of at least 1 Gbps in 95% of office locations (for cell-edge users) and at 99% of the busy period. Additionally, end-users should be able to experience user throughputs of at least 5 Gbps in 20% of the office locations, e.g. at the actual desks, at 99% of the busy period, which is equivalent to have this value in 80th percentile of the user-throughput CDF.

The round trip mean packet latency should be no more than 10 ms; i.e. the time from a packet is sent until an ACK is received should not exceed 10 ms in average. Moreover, less than 5% packet loss rate is expected.

Each end-user will generate an average traffic of at least 36 Tbyte per month in DL and UL. This corresponds to each user being active for 4 hours per day for 20 days a month and transferring data at a rate of 1 Gbps.

The installation of the building's communication network should be quick and smooth without troublesome configurations and with small impact on the building. A high speed connection (e.g. optical fiber) is available on each floor but it is desired, for reasons of flexibility and installation simplicity and cost, to reduce the amount of cabling, for instance for the transport backhaul.

The technologies should also be low cost, scalable and relatively easy to roll-out, configure and maintain.

Table C-7: KPIs and requirements for UC2.

Variable/parameter	Value
Performance targets	
Experienced user throughput	At least 1 (5) Gbps with 95% (20%) location reliability in DL as well as UL; see

	availability and reliability below
Traffic volume density (busy hour)	Average 0.1 Gbps/m^2 in both DL and UL; peaks can be 5 times higher
Average Latency	10 ms RTT
Availability	1 Gbps at 95%, 5 Gbps at 20% office space
Reliability	99% working hours
Constraints	
Energy consumption (infrastructure)	Low-energy operations are preferred mainly for cost and sustainability reasons. When not transmitting user data the consumed energy should be very low. Generally the network energy consumption should be comparable to the energy consumption of today's metropolitan deployments, despite the drastically increased amount of traffic
Energy consumption (UE or other devices)	UE should be able to operate on battery for several hours
Cost (infrastructure)	Network infrastructure should be cheap both in terms of hardware cost as well as installation and maintenance costs
Cost (UE or other devices)	UE cost should be similar to today's smartphones or 3G/4G modems
Use case definition	
User/device average density	1/10 m^2 per floor
Traffic volume/type	36 Tbyte/user/month, DL as well as UL; video dominates
User type	Mainly human
User mobility	Static or low mobility nomadic (less than 6

	km/h)

C.3 UC3: Broadband access everywhere

This is a new METIS use case built on elements of a NGMN use case [NGM15] combined with some aspects from the METIS-I test case seven (Blind spots) in [MET13-D11]. This use case mainly addresses the use case family xMBB.

C.3.1 Background and motivation

The demand for very high experienced user throughput Internet access at any time and at any place is constantly increasing. The ubiquitous capacity demands of future users will be challenging to satisfy in areas with sparse network infrastructure, such as scarcely populated areas, rural and even suburban areas. A consistent user experience with respect to throughput, needs a minimum experienced user throughput guaranteed everywhere. The target value of 50 Mbps everywhere should be understood as the minimum experienced user throughput and not a single user's theoretical peak rate. Furthermore, it is emphasized that this user rate has to be delivered consistently across the coverage area (i.e. even at cell edges). Furthermore, the battery consumption of smart phones and tablet terminals in areas with low coverage increases significantly due to higher propagation losses. A target of 50% energy consomption reduction compared with legacy network should be achieved both at network infrastructure and at end user level. While cell densification is promising for boosting capacity in future urban environment, wide coverage solutions as well as flexible, energy and cost efficient solutions must be developed in future wireless communication systems to provide ubiquitous coverage in suburban and more or less remote rural areas.

C.3.2 KPIs and requirements

The requirements and the key performance indicators are summarized in Table C-8, based on [NGM15].

High experienced user throughput coverage is expected at every location of the service area, even in remote rural areas. Mostly, video streaming and file downloads are required, corresponding to a high experienced throughput per user. In particular, each user should be able to experience a throughput of at least 50 Mbps in downlink and 25 Mbps in uplink.

User density and traffic volume density will vary according to environment types. In rural areas we assume a user density of 100 users per km2, which results in a total traffic volume of 7.5 Gbps/km2. Lower density values for more remote rural environments, representative of more scarcely populated areas, are provided. Suburban environments, representative of areas closer to urban cities are also addressed.

The end-to-end (one trip) RAN latency has to be maintained below 10 ms.

The service availability must be at least 99% (space domain). In addition, 50 Mbps DL and 25 Mbps UL should be achieved with 95% retainability where the service is available (time domain).

Reliability is not in the focus of this use case. Nevertheless, some level of reliability is required in order to ensure a seamless consumption of video services together with timely file delivery. For example, low reliability levels can lower the QoE of video services due to the presence of visual errors and can also delay the download time of file delivery services. As a result, a reliability value of 95% is assumed.

Both infrastructural and end user energy consumption should be minimized. In this regarding, operators associated infrastructure should have an energy consumption reduced by 50%, whereas the users need to spend less than half the energy they consume in legacy network.

Network cost including infrastructural equipment, site rental, energy consumption etc., is expected to be reduced by 50%. Solutions for low cost backhauling are thus to be developed.

Human users are generally the main target of this use case, while a large diversity of services should be supported, such as file downloading and video streaming.

Table C-8: KPIs and requirements for UC3.

Variable/parameter	Value (urban/rural/highway)
Performance targets	
Experienced user throughput	50 Mbps Mbps (DL) and 25 Mbps (UL)
Traffic volume density (busy hour)	Far remote rural : DL : 0.5 Gbps/km^2 Far remote rural : UL : 0.25 Gbps/km^2 Rural : DL : 5 Gbps/km^2 Rural : UL : 2.5 Gbps/km^2 Suburban : DL : 20 Gbps/km^2 Suburban : UL : 10 Gbps/km^2
End-to-end RAN latency (including connection setup and detection delay) for receivers within the target range	Less than 10 ms
Availability: percentage of area where transmissions meet the experienced user	99%

data rate requirement	
Retainability : percentage of time where transmissions meet the experienced user data rate	95%
Constraints	
Energy consumption (infrastructure)	Low-energy operations are preferred mainly for cost and sustainability reasons. When not transmitting user data the consumed energy should be very low. Generally the network energy consumption should be comparable to the energy consumption of today's metropolitan deployments, despite the drastically increased amount of traffic
Energy consumption (UE or other devices)	UE should be able to operate on battery for several hours
Cost (infrastructure)	Network infrastructure should be cheap both in terms of hardware cost as well as installation and maintenance costs
Cost (UE or other devices)	UE cost should be similar to today's smartphones or 3G/4G modems
Use case definition	
User/device density	Far remote rural: 11 users per km^2 Rural: 100 user per km^2 Suburban: 400 user per km^2
User type	Human
User mobility	A mix of static users and users in vehicles with velocity up to 120 km/h

C.4 UC4: Massive distribution of sensors and actuators

This use case is based on a test case eleven in [MET13-D11]. It mainly addresses the use case family mMTC.

C.4.1 Background and motivation

The importance of this use case will grow together with the massive deployment of these low cost and of low energy consumption devices. In order to get the maximum of information from these devices, so as to increase environmental awareness and better user experience, there is a need for these devices to be able to communicate with other devices and/or with the network. A range of examples are presented below.

Some examples of cases for the tracking of portable objects are listed in the sequel:

- **Tools (e.g. drills)**, where the purpose of the communication node in each tool is to measure in which environment and how the tool is used (e.g. in order to notify the user that he should rather be using a different tool or to develop tools which are better suited to their usage) and detect early signs of product failure.
- **Other products where the producer is interested in improving usability**. An example could be books (such as manuals), where sensors detect which pages are opened when and in which order. Another example could be related to a restaurant where it is measured which tables and chairs are occupied.
- **Products which require care (e.g. flower pots),** where the communication sensor/node would send a warning if watering or fertilization is needed.
- **Fragile products**, where the communication node could measure whether the product is handled with sufficient care (e.g. not too much acceleration, and right temperature), and send an alarm if this is not the case.
- **Potentially dangerous products**, such as knives, chemicals (or weapons), where the communication node could send an alarm if somebody unauthorized uses or moves these products.
- **Products that expire**, such as groceries and spices, where an alarm could be sent if product properties cross a certain threshold.
- **Products where statistics on the movement are to be collected**. For instance, a company may want to monitor a fleet of, e.g. bicycles. In an extreme case, one could imagine the European Central Bank tagging Euro notes in order to observe the flow of hard currency.
- **Products often subject to theft**, such as hand-bags or jewelry, where communication nodes could raise an alarm in case of unauthorized movement. Similarly if the customer places the products to a wrong location (shelf), the communication node can warn the customer and probably customer service.

Some other examples of cases for the monitoring of, e.g. environment, materials, may include:

- **Agricultural application**: A large number of sensors spread out over large agricultural areas to measure, e.g. fertility and humidity, to help the farmer optimize the right time for harvesting and fertilizing (approximately 10 sensors per km^2, it is acceptable if 50% of sensors manage to get a 20 byte uplink net payload through to the infrastructure once per day). It could also be imagined that such sensors are used indoors in, e.g. greenhouses.
- **Material monitoring (particular example: wind mill):** Sensors are placed every 5 m on the surface of the structure of a modern power-generating wind mill, reporting vibrations and other measures that may give an early indication of material damage or suboptimal usage (50 sensors per wind mill, all sensors should be able to get a 20 byte net uplink payload through to the infrastructure once per day). Note that in this particular case the sensors are moving, though this movement is highly predictable.
- **Material monitoring (particular example: high-speed train)**: Sensors are placed in each wheel of the train and are able to measure vibrations and early indications for track or wheel damage (4 sensors per carriage, all sensors should be able to get a 20 byte net payload through to the infrastructure per day). Such sensors – even at such a low duty cycle - would be able to prevent dangerous train accidents that have happened in the past due to unnoticed material faults.
- **Material monitoring (particular example: building)**: Sensors are placed in a building or on the surface of a building, again to monitor vibrations and other early indications for potential material failure. These sensors will also be useful to quickly assess the state of a building after a natural disaster, such as an earthquake or a hurricane (all sensors should be able to get a 20 byte net payload through to the Internet once per day).

C.4.2 KPIs and requirements

This use case targets the 5G goals related to the number of connected devices, energy consumption per device by maintaining the same energy consumption and cost at the network side.

The current state of requirements for these uses cases is reflected in [3GPP15-45820], for which the performance objectives are:

- Maximum Coupling Loss of 164.0 dB (with at least 160 bps data rate on both the uplink and downlink)
- 52547 devices within a cell site sector, based on: 40 devices per household, with 1517 household per km^2, and a Inter Site Distance of 1732 m
- 10 years durability of a 5Wh battery, for traffic based on 50 bytes TX with a 24 hours reporting interval in a 164.0 dB coupling loss scenario
- Reduced complexity (with reference on current GPRS modems) in order to enable cheaper devices, being measured based on:
  - Silicon area estimate, including on-chip memory.
  - Indication of required gate density should be given.
  - Relative area of RF and baseband functions.

- List of external components.
- Any special characteristics of external components specific to a system proposal.
- DSP cycles / second.

However, for 5G on 2020, it is foreseen that more ambitious targets are needs, as:

- Number of devices supported in the system 1 000 000 devices per km^2.
- Payload size is assumed to be very small, from 20 to 125 bytes per message, with a very large transmission cycle, which will depend on the specific application. As a reference, an experienced user throughput of 1 kbps is foreseen per device, which is equivalent to 1 message of 125 bytes per second.
- Long battery life (on the order of 10+ years) of the wireless device, implying the need for high energy efficiency. Battery life is directly related to energy efficiency.
- Minimum possible signaling overhead.
- Keeping the UE complexity in order to guarantee ultra-low cost devices.
- 99.9% availability.

Similar energy consumption and cost for the infrastructure as for the base systems of today. The requirements and the key performance indicators are summarized in Table C-9.

Table C-9: KPIs and requirements for UC4.

Variable/parameter	Value
Performance targets	
Battery life	At least 10 years (assuming 5 Watts-hour battery)
Device density	1 000 000 devices per km^2
Availability	99.9%
Traffic volume per device	From few bytes per day to 125 bytes per second
Constraints	
Energy efficiency (infrastructure)	In principle no specific constraints for the infrastructure
Energy efficiency (UE or other devices)	The power supply availability is limited, so low-energy operation is required. For sensor type devices with battery power supply only, the energy-optimized

	operation is required.
Cost (infrastructure)	Infrastructure cost should be kept on the same level per area as today.
Cost (UE or other devices)	For sensor type devices a significant cost reduction compared to normal handset devices is needed.

C.5 UC5: Connected cars

This use case is based on test cases eight and twelve of METIS-I [MET13-D11]. It mainly addresses the use case families uMTC and xMBB.

C.5.1 Background and motivation

The use of remote services is also applicable at higher user mobility, e.g. while driving cars or using public transportation, and not merely taking place in slow mobility or stationary settings. With higher user mobility enabled on-the-way workers as well as a leisured people can enjoy the benefits of real-time remote computing for mobile terminals. At the same time the connected car also provides a safe and efficient journey via the communication to its surrounding. This communication enables the car to avoid accidents, but it also enables other types of traffic planning such as avoiding traffic jam queues and minimizing fuel consumption. Thereby the connected car enables traffic safety, efficiency and real-time remote services.

C.5.2 KPIs and requirements

The connected car needs to be traffic efficient and alert in terms of safety as well as able to provide good real-time remote computing experience for the end-users.

Traffic efficiency and safety

The main challenges of this use case, when it comes to “traffic efficiency and safety” lie in the required reliability, availability, and latency of automotive safety services. The requirements are described below and the key performance indicators and constraints are summarized in Table C-10. A maximum wireless network end-to-end delay (including wireless device detection, connection setup and radio transmission but excluding the time needed from the vehicle to process and generate the information message) of 5 ms, with transmission reliability of 99.999% should be guaranteed to deliver the drive safety service. This is a major challenge.

- V2X communication needs to be established across different network operators with the same requirements in terms of latency and service guarantee as within a single network operator.
- ≈100% availability required such that the services are present at every point on the road.

Additional KPIs and constraints are the following:

- Relative positioning accuracy below 0.5 m is needed. GPS may not always be available and sufficient, and hence cellular based positioning techniques could be useful.
- Data traffic (inspired by current ETSI Technical Committee ITS and IEEE standardization work [MMK+11], [Str11], though, the parameter values are more challenging than what is discussed for today's systems):
    - Periodic broadcast traffic consisting of at least 1600 payload byte (for transmission of information related to 10 detected objects resulting from local environment perception and the information related to the actual vehicle) with repetition rate of at least 5-10 Hz. The update rate is chosen high enough such that the vehicle velocity vector does not change too much between updates. The traffic generated by each vehicle has to be delivered to all the neighboring vehicles within the specified range.
    - Event-driven broadcast traffic consisting of at least 1600 payload byte with repetition rate of at least 5-10 Hz (for transmission of information related to 10 detected objects resulting from local environment perception and the information related to the actual vehicle).
    - Both traffic types (periodic and event driven) can exist at the same time. Note that the repetition rate of both traffic types is determined by the need to track changes in the environment.
    - For communication between vehicles and other devices (e.g., smartphones) a payload of 500 byte may be sufficient (for transmission of the information from the actual consumer electronics device, such as current position and additional data from the device sensors).
- Four different mobility environments need to be distinguished: Urban, rural, and highway.
    - Urban: maximum absolute velocity of 60 km/h and 120 km/h relative velocity between vehicles.
    - Rural: maximum absolute velocity of 120 km/h and 240 km/h relative velocity between vehicles.
    - Highway: maximum absolute velocity of 250 km/h and 500 km/h relative velocity between vehicles.
    - Vulnerable road user velocities ranging from 3 km/h (pedestrian) up to 30 km/h (bicycle).
- User and device densities depend on the environment and scenario:
    - Vehicular devices:
        - In urban environments the user density can be up to 1000 users per km^2
        - In rural and highway environments the user density can be up to 100 users per km^2
    - Vulnerable road user devices:
        - In rural and highway environments the user density can be up to 150 relevant users per km^2.

- In urban environments the user density can be up to 5000 relevant users per km^2.

- The required communication range is different for the various environments:
  - Up to 1 km in highway scenarios.
  - Up to 500 m in rural scenarios.
  - Up to 50 m in urban scenarios.
- Additional spectrum constraints are:
  - Use of dedicated spectrum if available,
  - preferable frequencies below 5 GHz.

Real-time remote computing for mobile terminals

The main KPIs for this use case corresponding to xMBB aspects are

- High availability of 99%
- Low E2E latencies of less than 10 ms.

The requirements and key performance indicators for this use case are summarized in Table C-10 and described in more detail as follows:

- High data rate connectivity is expected for vehicles (or specifically, the on-board devices) and also for user devices inside of vehicles. Real-time interactive services (such as augmented reality and virtual office applications), location based services, and any service that requires to shift certain complex processing tasks (usually performed locally) to a remote server correspond to high data rate demands with real-time requirements. As a result we assume that every active device in the vehicle requires a data rate of 100 Mbps in downlink and 20 Mbps in uplink. Assuming at most 5 simultaneously active devices per vehicle (including the on-board devices) and a vehicle density of 100 vehicles per km^2 in motorways, this leads to a total traffic volume of 60 Gbps/km^2.
- Multi-operator solutions are required in order to serve users with different network operator contracts and thus make this KPIs available.
- The considered applications have real-time requirements. Therefore, E2E latencies lower than 10 [ms] with high reliability (i.e. 95% of the packets should be successfully transmitted within this time) needs to be achieved.
- The energy efficiency for the devices used in the vehicles and for Electronic Control Units (ECUs) using remote processing services should be high. Power consumption should be minimized in order extend the battery time and allow for high productivity of the users inside the vehicles.
- Device densities depend mainly on the means of transportation system. By 2020 and beyond people are expected to carry more than one cellular device. Moreover, the vehicle itself (through in-vehicle ECUs) may shift complex processing tasks to a remote

server in real-time. The number of active devices (passenger devices plus vehicle on-board devices) scales with the size of the vehicle:

- At most 5 simultaneously active devices per car
- Up to 50 user devices simultaneously active per bus
- Up to 300 user devices simultaneously active per train

- The use case considers human-to-machine and machine-to-machine type communication with high mobility making use of real-time remote processing.
- User mobility equals the vehicle speed.

The car-to-car communication becomes highly relevant in e.g. automated driving.

Table C-10: KPIs and requirements for UC5.

Variable/parameter	**Value (urban/rural/highway)**
Performance targets for traffic efficiency and safety	
Experienced user throughput	1600 byte x 10 Hz, i.e., 128 kbps
Traffic volume density	0.1 / 0.01 / 0.01 Gbps/km^2
End-to-end latency (including connection setup and detection delay) for receivers within the target range	5 ms
Availability	≈ 100%
Reliability	99.999%
Number of delivered message	To be maximized
V2X Range	50 m, 500 m, 1 km
Positioning accuracy	Relative accuracy less than 0.5 m
Performance targets for real-time remote computing	
Experienced user throughput	100 [Mbps] in downlink 20 [Mbps] in uplink
Traffic volume density	60 [Gbps/km^2] (for cars on a highway)
Latency	Less than 10 [ms] E2E latency

Availability	99% in space and time; Multi-operator solutions are required in order to serve users with different network operator contracts
Reliability	High reliability for real-time processing services. 95% of the packets shall be transmitted successfully within a maximum E2E latency of 10 [ms]
Constraints	
Energy consumption (infrastructure)	In principle, no particular constraints are required. Nevertheless low-energy operation of all radio nodes including sensors is expected due to energy cost and EMF considerations, especially auto-configuration/operation including switch-on/off of radio nodes dependent on traffic load/day time is considered as an important implementation feature.
Energy consumption (UE or other devices)	Energy consumption should be minimized and should not exceed the energy consumption of conventional terminals (without V2X technology). Main reason is that V2X terminals will mainly depend on battery power supply.
Cost (infrastructure)	V2X communication needs to be established across different network operators with the same requirements in terms of latency and service guarantee as within a single network operator. Therefore agreements and consolidation between operators is required. The cost of deploying V2X in additional infrastructure (such as traffic lights) should not exceed the costs of traditional cellular modems in order to guarantee a high market penetration.
Cost (UE or other devices)	V2X terminal/chips should come at the

	cost of traditional terminal/chips in order to guarantee a high market penetration and thus ensure 100% availability of safety services.
Use case definition	
User/device density	More than 1000 per km^2 / 100 per km^2 / 100 per km^2 At most 5 simultaneously active devices per car
Traffic volume/type	**For traffic efficiency and safety:** 1600 (500) byte periodic broadcast with 10 Hz per user V2V (V2D) 1600 (500) byte event-driven broadcast **For real time remote computing:** 53 Gbyte/hour/device
User type	Machine or Human, V2V or V2D
User mobility	60 km/h, 120 km/h, 250 km/h vehicle speed; slow speed for VRUs: 3-30 km/h x2 for relative speed

D Detailed analysis of the current value chains in the mobile sector

D.1.1 Identification of the main players & description of their respective roles

This section presents the main players involved in the mobile service value chain and their respective roles. It identifies possible evolution of their role in the coming years. Possible new players in the mobile sector are presented in Section 4.2.3.

Mobile operators & MVNOs

Both players are traditional mobile operators. They currently provide a mobile service to customers and manage this end customer relationship.

A mobile virtual network operator (MVNO) does not possess any spectrum allocation or mobile access infrastructure, whatever the technology used. MVNOs sign a contract with a mobile network operator (MNO) that holds a frequencies licence and a mobile network infrastructure. They can be present at each level, except the access network part, which remains the domain of MNOs. Depending on the strategy adopted and target selected, an MVNO's level of involvement in seeking its own technical solutions may vary. A MVNO may also have an IT and infrastructure solution called an MVNE (Mobile Virtual Network Enabler) in order to share infrastructure costs with other MVNOs.

CAPEX and OPEX for MNOs are the following:

- CAPEX to buy spectrum;
- CAPEX to build the network (acquire sites, RAN/CN equipment, backhaul/transport, etc.);
- OPEX to operate /maintain the network;
- OPEX to manage customer relationships.

Obviously, MVNOs do not use CAPEX to buy spectrum or to build the network (CAPEX only for the network parts MVNO may own). They use OPEX to manage customer relationships and buy wholesale minutes/data from host MNOs.

Apart from MVNOs, MNOs sign wholesale agreements with other players such as Amazon (for the Kindle) or car manufacturers:

- As early as in 2007, Amazon sold both the Kindle device and the connectivity to download the content. The Kindle was the first device to be sold with lifetime cellular connectivity (at launch from Sprint's mobile network, later from AT&T). AT&T provides wireless service to Kindle tablets and e-readers. It does not manage the customer relationship. Amazon shares revenue with AT&T on a B2B2C model. AT&T remains hidden from the end user point of view.

- Today, all US car manufacturers and some high-end European manufacturers are offering connected on-board services. In the automotive industry, the business model of reference is again the wholesale-based model on a B2B2C basis. The user pays the manufacturer for the service rendered. The car manufacturer shares revenues with the service provider. This kind of business model was pioneered few years ago by the OnStar/GM deal. The automaker provides the SIM card and covers the connectivity charges. In an alternative model, the end user pays the MNO for the connection and buys the car from the automaker. An illustration of this business model is offered by AT&T and Audi for the A3 car. AT&T sells a specific LTE retail data plan.

In the future, MNOs will certainly try to tap into new revenue sources. They might consider evolving toward content provision through agreements with content providers. They could be more present in the apps business. Many MNOs are currently offering applications but apps developers and platform owners are reaping the benefits from the business of apps. The idea is to move beyond the network and search value from customer data monetization, IT propositions, provision of new services (fixed radio access…).

Table D-1: Mobile operators & MVNOs positioning.

Player	Current positioning	Possible evolution
MNO	Builds and operates the mobile network Fixed radio access provision Manages subscriber relationships for both retail and wholesale markets	Content provision Generalization of fixed radio access provision More focus on IoT and verticals (to counter declining revenues on the consumer market) Getting higher in the value chain by proposing IT / big data services
MVNO	Buys capacity to MNOs and manages subscriber relationships. In some cases MVNO operates part of core network May own SIM cards	May operate more elements of the core network

Other access networks: WiFi, LPWA, satellite

WiFi

WiFi access providers such as IPass, Boingo own and operate access points usually located in large-scale venues where people are likely to use high-speed internet (airports, coffee shops, hotels, universities...).

They sell connectivity directly to users in these areas where broadband internet demand is high and where they acquired long-term wireless rights. On this current B2C model where WiFi access is provided to the public, users are asked to pay before accessing the service, often on a pay-per-use basis (per month, day, per hour,…). Turnkey systems are often deployed at no costs for the venue owner. The venue owner and the WiFi provider share revenues. The WiFi provider manages the customer relationship. On the B2B2C side, cooperation between WiFi access providers and MNOs is fruitful on both sides. Access to WiFi networks means an improvement of coverage and available bandwidth for the Telco's subscribers. For a mobile operator, a higher density of WiFi hotspots also means more possibilities to offload traffic on the fixed network and thus reduce the traffic load on the radio access network. Finally, Telcos can also offer connectivity to their users outside their national borders across the WiFi operator's international footprint. For the WiFi operator, cooperation with a telecom operator means that it will have access to a significant customer base in a given market with virtually no subscriber acquisition cost or CAPEX.

WiFi access providers aggressively invested in building their networks to be able to capture more cellular data traffic (offloaded to their networks).

In the future, a move from WiFi access providers towards small cell operation is expected. WiFi access providers might evolve towards providing connectivity through small cells (SCaaS). As integration of WiFi and cellular into networks progresses, the two businesses appear quite close and complimentary.

CAPEX and OPEX for WiFi players are the following:

- CAPEX to acquire sites, CAPEX to build and upgrade the network;
- OPEX to maintain and operate hotspots;
- OPEX to be able to install on large-scale venues (long-term agreements with venue owners).

LPWA (Low Power Wide Area) – non 3GPP

LPWA players use dedicated technology for low power and low experienced user throughput in unlicensed spectrum. Unsurprisingly, many different players are stepping in the Low Power Wide Area/IoT field. They are the following:

- Specialized pure players (SigFox, Senaptic, On-Ramp Wireless) are developing or developed technologies and are licensing them (to chip vendors for example).

- MNO/Telecom players are rolling out and building dedicated networks often based on proprietary technologies.
- Specialized new entrants are emerging mixing many different technologies. They often are the result of partnerships involving MNO or telecom players (M2ocity, joint venture between Orange and Velio – Telefonica/Libelium,…).
- Equipment vendors: Huawei is a new player in the LPWA market with its acquisition of the UK specialized company Neul.
- Software companies, semi-conductor companies and global integrators (IBM…).

LPWA pure providers are operators managing a network infrastructure (SigFox,…). Other players (LoRa, Neul) provide access connectivity (not the backhaul connectivity as a traditional player).

CAPEX and OPEX for LPWA players are the following:

- OPEX to use or CAPEX to develop and own technologies;
- OPEX to maintain technology and equipment.

LPWA players are expected to stimulate the market in the future. The fact that LPWA technologies do not need licensed spectrum while NB-IoT solutions operate on licensed spectrum, but with better QoS raises a number of questions on the interaction between the different related players in 5G

Satellite

Today, telecommunications satellites are usually placed in Geostationary Earth Orbit (GEO). Low Earth Orbit (LEO) satellites operate at much lower altitudes. Telecommunication satellites can be placed in LEO with a number of specific technical requirements for telecom systems to operate (notably large constellations of small satellites, frequency coordination). Provision of communication services in LEO is consequently relatively limited so far.

In-flight communications services will develop because they match with the consumer willingness to remain connected anytime anywhere. Inmarsat and Deutsche Telekom signed a strategic agreement at the end of September 2015 for the use of the S-band (Inmarsat allocations of 2 x 15 MHz in the 2 GHz bands). Both companies will deploy the first hybrid S-band Air-To-Ground (ATG) LTE network to provide in-flight connectivity from 2017 onwards.

Other hybrid solutions exist in higher frequency bands (Hybrid ATG/Ku systems, Hybrid Ku/Ka systems). ATG operates in the 800 MHz band.

CAPEX and OPEX for satellite players are the following:

- High up-front CAPEX before operations to build a satellite and launch it (long-design and procurement cycle);
- Huge CAPEX to operate satellites;
- OPEX to maintain satellites;

- OPEX with high retransmission fees.

In the future, satellite operators might evolve towards providing backhaul/fronthaul services to terrestrial networks for broadband services. The backhaul of mobile networks is currently mostly achieved through fiber, terrestrial and microwave solutions. As more and more backhaul optimization technologies are required to support the growing traffic, satellite becomes more and more a viable option. With new satellites, the cost of satellite backhaul is expected to decrease significantly. The relatively high latency experienced in GEO satellite communications could also be reduced with LEO systems as this is a basic requirement for 5G. Otherwise the 5G latency targets cannot be achieved. Therefore there may be a differentiation in the business model (xMBB for remote areas without other infrastructure (probably not in main parts of Europe), but with limited set of all 5G features). In addition, availability could also be enhanced with these new LEO satellites.

Satellite operators could also move towards the right side of the satellite value chain and adopt a multicast approach in combination with terrestrial mobile networks.

Satellite networks (MEO, GEO and LEO) can be really helpful drive the market for MTC in remote, widespread, hostile or global areas (things can be aeronautical platforms including aircrafts, maritime platforms, vessels…).

Table D-2: WiFi, LPWA, satellite players role.

Player	Current positioning	Possible evolution
WiFi access provider	Operate WiFi access points Sells wholesale and retail services Manages subscriber relationships	Small cells operation mainly on unlicensed spectrum, with possible integration with 5G networks Small cell as a service (SCaaS)
LPWA (Low Power Wide Area) operators	Deploy and operate dedicated networks for IoT	Possible integration with 5G networks (cell site sharing, RAN integration? integration of unlicensed bands?)
Satellite operator	Limited provision of narrowband mobile services with LEO constellations (e.g. Iridium, Inmarsat)	Possible offering in fronthaul/backhaul integration with terrestrial networks. Use of non-GEO constellations with reduced latency. Multicast approach in combination with terrestrial networks. Use for MTC in rural areas

- **Private wireless network owner**. This player is a corporate running a close subscriber group (CSG) radio network, providing proprietary connectivity, services and applications, usually with additional access to public networks.

Tower companies, facility managers, urban furniture managers, equipment manufacturers (for RAN outsourcing)

In this section, we analyze players owning assets which can be useful for mobile network coverage and capacity extensions. Tower companies, facility managers, urban furniture managers and equipment manufacturers fall into this group.

Tower companies

Tower companies such as American Tower (USA), Crown Castle (USA), AT&T Towers (USA), China Tower Company (China) or Arqiva (United Kingdom) are in position to go further than their current role of renting space for MNOs' base stations and could operate part of the RAN. In the United Kingdom, Arqiva is able to provide MNOs with access to over 400,000 street assets, including lampposts and CCTV cameras.

CAPEX and OPEX for tower companies are the following:

- CAPEX to acquire sites, build towers;
- Minimal CAPEX to operate (lighting system and fence repair…), increase number of clients (height extension, multiple antennas integration, shared generator, strengthened foundation…);
- OPEX to maintain and operate towers (ground rent, insurance, real estate taxes…);

On the other hand, tower companies rent towers to MNO with long-term contracts (fixed power and fuel cost/traditional pass-through cost). Charges are based on location, vertical space, weight placed on tower…

In the future, some tower companies might consider operating the RAN for a MNO through an outsourcing arrangement in competition with equipment manufacturers. Tower companies could also bid for spectrum during forthcoming auctions and build RANs either to cover rural areas with low frequency bands or in order to provide capacity with higher frequency bands in urban areas.

Facility managers

Facility managers such as building or stadium managers are generally involved in mobile coverage/capacity through DAS (Distributed Antenna Systems) indoor operation. They usually pay a specialized company for DAS installation. Capacity is sold to telecom players.

DAS allows operators and facility managers to work closely. Facility managers will no doubt increase expertise and experience in dealing with DAS.

In the future, experienced and skilled facility managers might evolve towards deploying DAS networks and installing DAS in other facilities and venues. They can also operate small cells or offer access in a building using mobile infrastructure with backhauling via a fiber optic at the bottom of the building.

CAPEX and OPEX for facilities managers are the following:

- CAPEX to buy buildings;
- Minimal CAPEX to operate;
- OPEX to maintain buildings and properties and operate towers (ground rent, insurance, real estate taxes…).

In the future, facility managers can benefit from their strategic position and move from the provision of DAS to provision of small cell based connectivity. Facility managers are expected to be willing to expand their business and further monetize properties (provision of a dedicated mobile infrastructure in the building with complete backhauling network).

Urban furniture managers

Today, small cells are being deployed on urban street furniture such as street lamps, utility poles, bus stops, benches or billboards through partnerships between equipment vendors and advertising companies. Deployment of small cells in street furniture is expected to enhance coverage and network capacity in highly populated areas to meet the future customer demand. Urban furniture managers build, own and operate street furniture. They provide turnkey solutions to MNOs and operation & maintenance services. A number of agreements were signed in the last months 2015 between street furniture providers and small cells vendors and MNOs. JCDecaux is one of the first to invest in the small cell technology. It leases its street furniture to small cell manufacturers.

CAPEX and OPEX for urban furniture managers are the following:

- CAPEX to build street furniture;
- Minimal CAPEX to operate;
- OPEX to maintain and upgrade street furniture;
- OPEX to operate (change ads, clean…).

In the future, urban street furniture managers might be willing to move up in the value chain. They might evolve towards providing and operating base stations and small cells themselves.

Equipment manufacturers

A few years ago, telecom operators acknowledged that they could not be present in every segment of the value chain and create more value by setting up partnerships with large-scale players. This leads to innovations or changes in model or management such as, for example, outsourcing passive or active infrastructure or sharing fixed or mobile networks.

It was about finding the best way of optimizing and securing a return on their assets and, in particular, the network.

Operators continue today to outsource their network and field operations also known as managed services, to large telecom equipment manufacturers. As competition among telecom players is still increasing, operators may be tempted to outsource more parts of their networks or eventually to let equipment manufacturers operate their networks.

CAPEX and OPEX for equipment manufacturers are the following:

- CAPEX to develop, design and build equipment on a large scale;
- OPEX to maintain equipment;
- OPEX to provide managed services;
- OPEX to manage telecom networks;
- CAPEX to provide managed services.

In the future, equipment manufacturers could be in a position to fully operate mobile networks. They could be tempted to increase their value proposition and provide mobile services on a wholesale basis (MVNOs).

Table D-3: Other RAN players role.

Player	Current positioning	Possible evolution
Tower company	Build, own, operate, maintain tower assets Build customized/green sites Rent towers to MNO (fixed power and fuel cost/traditional pass-through cost)	Could operate the RAN/ parts of RANs
Facility manager	Operate DAS (mainly indoor environment)	Could operate small cells (SCaaS) Could offer telecoms access in a building using mobile infrastructure with backhauling via a fiber optic at the bottom of the building
Urban furniture manager	Build, own and operate urban furniture Rent resources on a pay-as-you-go model	Could install base stations, operate parts of RAN (small cells)
Equipment manufacturers	Outsourcing and service management	Operation of wholesale mobile network

IoT/MTC players

IoT (Internet of Things)/MTC (Machine Type Communications) players covered in this section are integrators, IT companies and vertical market players.

Integrators & IT companies

System integrators or software companies including SAP or IBM, have strong capabilities in data and in software, especially in analytics. As the value chain is disassembling in many markets and as hardware is now commoditized (more powerful and cheaper), integrators re-assemble certain functions and provide packaged services in a "softwarization" move.

IT companies are mainly positioned on the professional markets (M2M and Internet of Objects) on the IT side and data management through their cloud services (based on their data center farms). They aim to apply their expertise in cloud and big data to the different IoT markets they want to address. They also want to leverage their traditional industrial clientele to help them to evolve their business transformation, made possible through connected devices rollout.

Vertical market players

Vertical market players encompass car manufacturers in the automotive business, hospitals/doctors in the health industry…, that will be part of the enlarged telecom ecosystem in the near term as telecom is spreading in many verticals. The verticals will develop new services, new processes and new business models, thanks to robust, affordable transmission and automated collection of data.

In the future, vertical market players will have to adapt to these radical changes. They could jump into the telecom business and provide specific connectivity services associated with the vertical. In the car industry, the car could be considered as an additional – larger – device connected to the Internet.

Generally, products are expected to lose their place at the center of the value chain. The product will become a sensor in a larger value chain.

Table D-4: IoT/MTC players positioning.

Player	Current positioning	Possible evolution
Integrators	Strong capabilities in data and software	Connectivity provision
IT companies	Provide Cloud services	Leverage on data to provide better services and solutions
Vertical market players	Buy connectivity from MNOs	Play a role in service creation & operation

Public Safety and PPDR (Public Protection and Disaster Relief) players

Current non-broadband dedicated public safety systems mainly use the 400 MHz and the 700-800 bands worldwide. Spectrum above 1 GHz supports also a variety of PPDR operations for temporary use only. In terms of usage, harmonized allocations and technologies for existing

TETRA/TETRAPOL or similar systems (DMR, APCO 25) are suitable and reliable for narrowband data, and technical specifications have been extended to enable wideband data transmission. A number of these PPDR networks have been deployed all over the world. Virve in Finland and Airwave in the UK are among the oldest ones at European level. BDBOS in Germany is the widest public safety network in Europe and the newest one: it has been completed early 2015.

TETRA-like narrowband technologies have served PPDR issues through dedicated PPDR networks using PPDR spectrum extremely well over the past decade. As these networks are by nature narrowband, they only support low experienced user throughputs. They seem inadequate for public safety with growing high broadband data and video needs which require situational awareness and video live streaming.

There is now a clear global consensus that LTE will be the baseline technology for next-generation broadband public safety networks. LTE still needs to be adapted: as from Release 12 of 3GPP LTE standards, LTE will be enhanced to meet public safety applications requirements. Release 12 includes basic PPDR features. Its freeze, however, has been slightly postponed and some PPDR features formerly scheduled in Release 12 will be dealt with in Releases 13 and 14.

A number of examples in the world demonstrate the trend toward LTE in public safety. In the USA, FirstNet will be a large-scale public safety network using dedicated spectrum in the 700 MHz band which is expected to aggregate local public safety “FirstNet-compatible” networks. Canada announces a quite similar decision. In Europe, Belgium, Finland and the UK are the first ones to reinvent public safety networks. Various forms of co-operation between MNOs and public safety can be considered: the use of commercial networks, ad-hoc networks, secure-MVNO (as the Belgian ASTRID virtual broadband MVNO, Blue Light Mobile rents capacity from the three national commercial MNOs; priority is given by Proximus (a Belgian MNO) to Blue Light Mobile subscribers over private subscribers), and hybrid solutions at various stages. In terms of spectrum, the use of a dedicated portion of the 700 MHz band or the use of commercial spectrum has not been decided yet.

CAPEX and OPEX for public safety network operators are the following:

- CAPEX to build a secure network that meets high requirements of public safety;
- OPEX to operate the network;
- OPEX to rent capacity from other networks;
- OPEX to negotiate specific conditions (priority, SLA…).

In the future, dedicated public safety network operators might evolve towards “de-specialization” of their assets. They could provide in-excess capacity to commercial players during non-critical hours. Secure-MVNO could also sell in-excess capacity to commercial mobile operators.

Table 6D-5: Public safety players positioning.

Player	Current positioning	Possible evolution
Dedicated Public Safety	Build, own and operate Public Safety / PPDR networks	Provide unused capacity during non-critical hours of operation to 5G operators
Public safety MVNO	Sell mobile services to end-users	Rent capacity to 5G operators

OTTs, Content owners

OTTs

The well-known OTT players are serving their customers over the Internet (voice through VoIP and messaging are the two first services provided). They are providing an integrated product over the Internet and bypasses traditional distribution. Services that come over the top are, if not always, lower in cost than the traditional method of delivery. QoS offered by OTTs is generally lower than the one offered by MNOs.

They are also increasingly reliant on WiFi. Apple's iMessage can be routed over WiFi networks – free for the user and the company – while voice calls can be made over the Internet on WiFi data connections using services such as Skype. In addition, Apple unveiled the iPhone 6 in September 2014 which feature WiFi calling.

OTTs are aggregating the separate communication markets, providing various types of communication through their single platform. Such a trend means that in theory, users can subscribe to just one IP communication provider to cover all communications.

CAPEX and OPEX for OTTs are the following:

- CAPEX to buy, design, build servers. OTT investments are focused on servers mainly rather than network infrastructure.
- CAPEX to design services in some cases;
- OPEX to maintain servers.

Some OTTs, among them Google and Facebook, are clearly considering an entry into the cellular business. OTTs may evolve towards providing mobile services. They have a key strength: they do not rely on subscribers to see revenues grow. They are able to drive down prices for consumers and adopt practices that would be difficult to sustain by other carriers. Confirming the announcements made during the MWC 2015, Google presented on its blog the "exploratory" mobile test-service named "GoogleFi" in 2015. The new offer relies primarily on the availability of the +1m hotspots verified and validated. The "GoogleFi" user is able to use the

+1million Google hotspots verified and validated and have access to cellular services supplied by Sprint and T-Mobile.

Looking slightly ahead, OTTs are well positioned to act as intermediaries for future services. By taking the platform approach, allowing third parties to build their innovative applications on top of them, or through individual partnerships, they can act as the link between users and future innovation. As an example, Apple's Siri application combines speech recognition technologies with the users' personal information, answering questions and making recommendations suitable to the users' questions. Here, Siri acts as the intermediary between the user and other players' contents and services. Another example would be webRTC, enabling voice and video communication through any web browser; third parties will then be able to build applications on top of webRTC.

Content owners

Content owners are specifically involved in content creation and adaptation to mobile devices. They are responsible for the accuracy of the content. The consumption of content has gradually evolved from a model mainly based on ownership of content (physical media or a digital copy) to a model based on access to a free (ad-supported) and/or subscription service. Dematerialization had the effect of decreasing the unit price of content.

With dematerialization and virtualization, the technical building blocks of multi-network, multi-device distribution are steadily coming into place, thanks to program post-production, network control and interconnection, interface management and content storage functions being moved to the cloud. This makes operational management simpler, innovation faster and distribution costs that are better adjusted to a pay-as-you-go approach.

CAPEX and OPEX for content owners are the following:

- CAPEX to create, design content and services associated with the content;
- CAPEX to upgrade content to new devices/platforms;
- CAPEX & OPEX to distribute the content;
- OPEX to manage the content.

In the future, content owners might be tempted to cash in by jumping in the access side. TV owners are already jumping in the Internet side.

Table D-6: Content owners and OTT positioning.

Player	Current positioning	Possible evolution
Content owners	Creation of the content, adaptation to multiple devices	No expected role modification
OTTs	Provision of services through the	MVNO providing mobile

	internet free of charge	communications services

Other players

Device manufacturers

Obviously, device manufacturers are designing and marketing devices directly to users and to telecom operators. Devices are still central to the telecom market and are continuing to develop in terms of:

- size and screen resolution,
- memory capacity for storing content,
- chip integration for network sharing.

CAPEX and OPEX for device manufacturers are the following:

- CAPEX to create, design devices and adapt to specific needs;
- CAPEX to upgrade devices;
- OPEX to adapt to evolving needs;
- OPEX to manage the device environment (applications).

In the future, devices are expected to evolve in many aspects (size, form factor, function…) and will support many technologies (WiFi, Bluetooth, 3G/4G/5G …) and spectrum bands. Form factors will no doubt be very diverse, spanning from personal devices such as smartphones and tablets, machine devices, wearables…, mainly depend on usage.

Looking ahead, e-SIM cards built into the phone will become mainstream. Basically the principle of the embedded SIM refers to SIM cards welded into the modules at manufacturing. The possibility of changing operators in e-SIMs raises the question of subscription management in the device. The customer will no more be tied to a single telecom operator and will be able to easily switch providers. Telecom operators are thus expected to have minor control over the end-user.

Device manufacturers could directly sell a package with both device and connectivity, and as a consequence manage the customer relationship. Connectivity could be included partly (given data volume included in a period of time) or entirely (data volume is offered free of charge during the device lifetime).

From the telecom operator point of view, innovative data pricing schemes should also become popular in a near future, such as the on-demand connectivity based on embedded SIM technology, ideal for short-time journeys, weekending or vacationing abroad, for instance.

In-flight connectivity providers (on commercial airlines)

Today, in-flight connectivity is provided through air-to-ground and satellite networks. In-flight connectivity is provided on a wholesale basis (the airline charges or not passengers for the service and the service provider charges a set price per plane and a given number of connections), on a retail basis (both the service provider and the airline decide on the price to charge for the passenger and share revenues.), or on the Gogo model, an hybrid ATG/Ku in-flight connectivity provider.

Gogo installs equipment (and supports all installation charges) and the airline pays for the connectivity service (no up-front investments). Revenues are shared but Gogo gets the larger part.

CAPEX and OPEX for in-flight connectivity providers are the following:

- CAPEX to install equipment and build the network;
- CAPEX to upgrade devices (equipment on-board aircrafts);
- OPEX to adapt to evolving needs;
- OPEX to pay satellite connectivity and ATG segment;
- OPEX to manage customer relationship (in the Gogo example).

In the future, in-flight connectivity providers might manage the customer relationship for the service during the flight and might evolve towards managing it on the ground.

Table D-7: Other players positioning.

Player	Current positioning	Possible evolution
Device manufacturers	Sell handsets to customers and mobile operators	With virtualized SIM card, device manufacturers could manage customers relationship
In-flight connectivity providers	Sell in-flight connectivity directly to the user or through the airline	In-flight connectivity providers could manage the user relationship widely

- **National Regulatory Authority (NRA)**. Public authority or government dealing with administrative law, regulation rulemaking, in the context of this document in the area of radio communications.

D.1.2 Detailed value chains in the mobile sector

The urban street furniture value chain

Today, small cells are being deployed on urban street furniture such as street lamps, utility poles, bus stops, benches or billboards through partnerships between equipment vendors and advertising companies. The urban street furniture provider can lease its street furniture to small cell manufacturers.

Figure D-1: Urban street furniture value chain.

The satellite value chain for TV broadcasting

The figure below shows the value chain for the provision of TV services.

Figure D-2: satellite value chain for TV broadcasting.

Satellite operators could move towards the right side of the satellite value chain and adopt a multicast approach in combination with terrestrial mobile networks.

The content value chain

Content owners are specifically involved in content creation and adaptation to mobile devices.

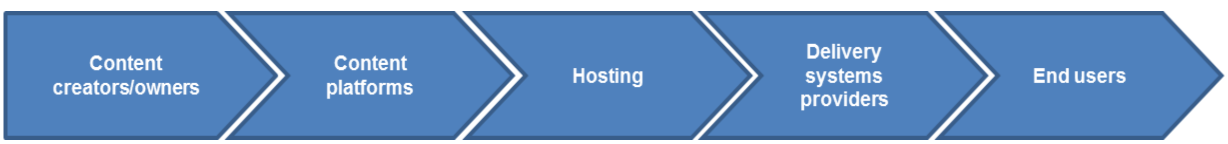


Figure D-3: The content value chain.

The OTT value chain

Telecommunication is not a closed ecosystem anymore but it is part of a larger digital ecosystem. Telecom players are facing up to OTTs which primarily focus on customer experience.

The type of today's environment when speaking of Telcos versus OTTs is the following: OTTs and Telcos are often viewed as competitors. They both want to sell services to customers and to act as primary contact.

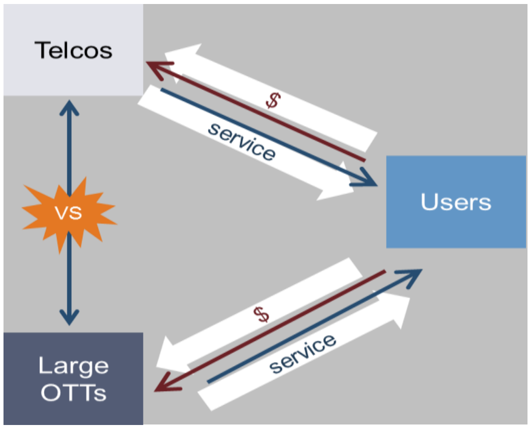


Figure D-4: Telcos/OTT value chain.

Content providers who are also part of the game are selling products to OTTs and/or Telcos but not directly to users. Some content providers also act as OTTs.

The M2M value chain

The M2M value chain is first presented in this section. The cellular devices and the Kindle value chains are shown to illustrate some specific developments.

The M2M value chain could be simplified as follows:

- Hardware (both objects and connectivity modules),
- Connectivity,
- Data management, including Big Data,
- Information system,
- Value-added services.

Figure D-5: M2M value chain.

M2M, IoO (Internet of Objects), connected devices and wearables & connected objects constitute the various components of the Internet of Things. IoO covers objects without connectivity and no active module. Connected devices are smartphones, tablets or PCs with cellular connectivity. Wearables & connected objects have connection capability using short range low power connection and use a connected device for connectivity.

The cellular devices value chain

The value chain of the connected cellular device is mainly composed of two groups of players: i) Connected cellular device manufacturers such as Samsung, Apple, Nexus, HP, Lenovo and

Dell ii) Mobile carriers providing innovative models such as subsidy-based and even on-demand connectivity. As a cellular module is required here, the module makers are also very involved in this segment. They provide specific modules and chiefly promote the embedded SIM-based module.

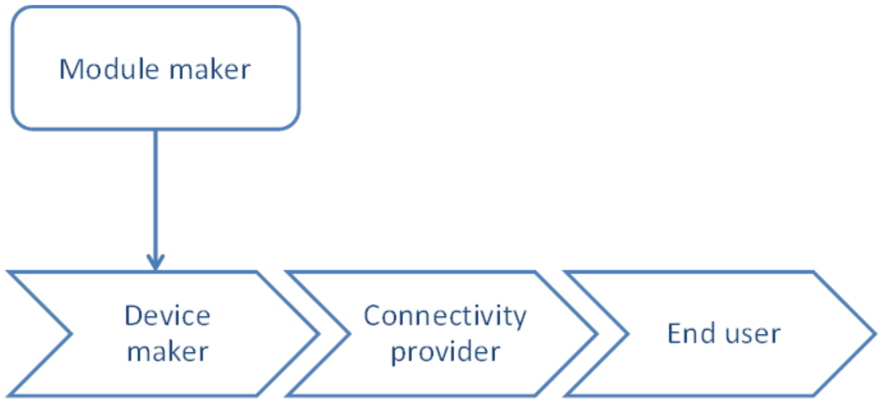


Figure D-6: Cellular devices value chain.

Kindle value chain

Amazon sold both the Kindle device and the connectivity to download the content. Amazon shares revenue with AT&T on a B2B2C model. AT&T remains hidden from the end user point of view.

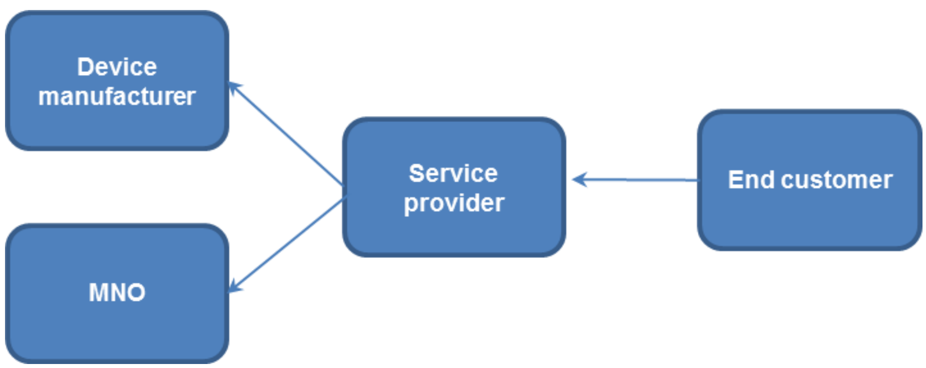


Figure D-7: Kindle value chain.

Automotive value chain

In the automotive industry, the business model of reference is the wholesale-based model on a B2B2C basis. The user pays the manufacturer for the service rendered. The car manufacturer shares revenues with the service provider.

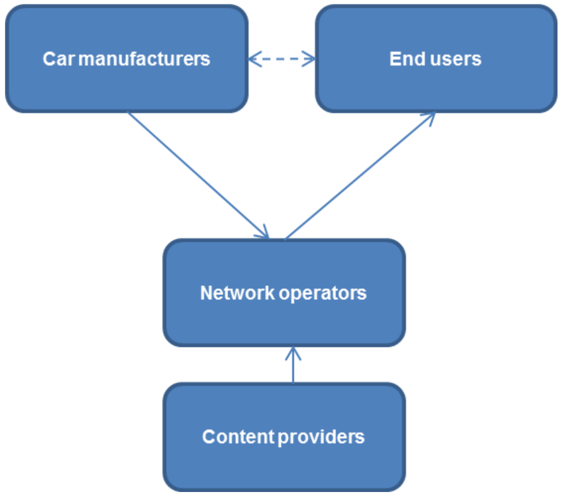


Figure D-8: Automotive value chain.

In-flight connectivity value chain

Today, in-flight connectivity is provided through air-to-ground and satellite networks. In-flight connectivity is provided on a wholesale basis, on a retail basis (both the service provider and the airline decide on the price to charge and share revenues.), or with the Gogo model, a hybrid ATG/Ku in-flight connectivity provider.

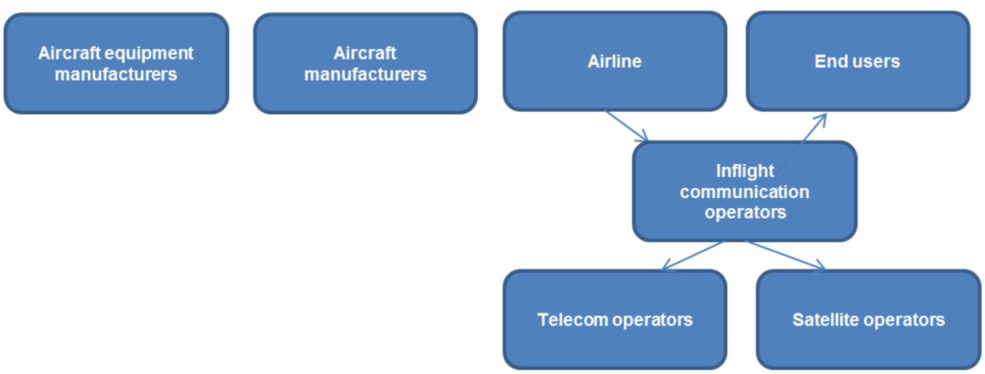


Figure D-9: In-flight connectivity value chain.

MTC Value Networks for Smart City

MTC in Smart Cities

M2M and MTC are at times considered synonyms. M2M is defined as a set of wireless and wired communication between mechanical or electric devices or the communication between remote machines and central management applications -. In a broader scope, M2M includes all the information and communication technologies able to measure, deliver, process and react upon information in an autonomous fashion. Since MTC is the working terminology by 3GPP, it is regarded as the segment of M2M carried over cellular networks [LGM-15]. MTC in Smart Cities then refers to the exchange of information over cellular networks between autonomous devices in control and monitoring applications without human intervention.

Figure D-10 Sample Smart City value chain.

An oversimplified Smart City value chain is illustrated in Figure D-10.. This chain mainly corresponds to ICT enabled Smart City solutions where the role of M2M and MTC is quite highlighted. The generic activities related to M2M and subsequently MTC are as follow:

1. Provision MTC network
2. Provision MTC device
3. Provide Connected Device Platform (CDP)
4. Provide Application Enablement Platform (AEP)
5. Provision M2M service
6. Manage Customer relation

Since it is impossible to map all performed M2M activities in this chain, we rather dig deeper into Smart City based M2M/MTC activities, find out related resources, and eventually identify the value networks for MTC in Smart Cities.

MTC Activities & Resources

In this section we introduce a set of generic activities associated with M2M solutions offered in the Smart City context. Afterwards, we discuss the “M2M resources” associated with these activities. These activities are based on studied use cases. The main idea is that these activities cover all major MTC activities performed in such setups. The constructed model for these roles has then the ability to map all different possible M2M solutions into it. This way we create a framework for analyzing the activities and identify which activity is being performed by its corresponding actor, based on the possessed resources.

The generic activities related to M2M and subsequently MTC are as follow:

1. Provision MTC network
2. Provision M2M device
3. Provide Connected Device Platform (CDP)
4. Provide Application Enablement Platform (AEP)
5. Provision M2M service

6. Manage Customer relation

This framework first categorizes the activities into three domains; a) Service, b) Connectivity, and c) Device. Since two major activities correspond to "M2M Platforms" first we discuss what is meant by M2M Platform.

An important part of the M2M ecosystem comprises the platforms, which includes CDP and AEP [MM14]. Correspondingly, provisioning these two platforms is considered as major roles in the value chain.

1) CDP: Connected Device Platform: CDPs are software elements that facilitate deployment and management of connected devices for M2M applications over cellular networks. CDP allows devices to connect to Cloud and should be compatible with different software platforms (e.g. Java, Android, etc.) in order to include as many devices as possible. CDP is usually a service portal that covers billing and policy control, bearer service, service ordering and subscription, and SIM-card management.

2) AEP: Application Enablement Platform: AEPs are designed to provide the core features for multiple M2M applications. They ease the data extraction and normalization activities, so M2M applications and enterprise systems can easily consume machine data. AEP also includes developing tools, enabling developers to create new M2M applications and services.

This way we create a framework (Figure D-11) for analyzing the activities and identify which activity is being performed by its corresponding players, based on the possessed resources.

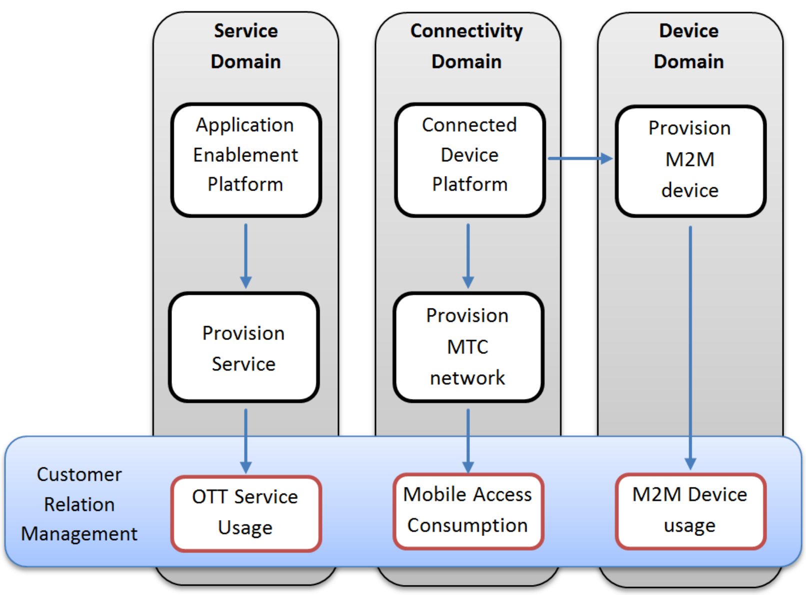


Figure D-11: Relation among MTC activities in Smart City [GAM-15].

This framework first categorizes the activities into three domains; a) Service, b) Connectivity, and c) Device. Since two major activities correspond to "M2M Platforms" first we discuss them.

MTC Resources in the context of Smart City

When it comes to the role of ICT in Smart City, a set of resources enables the MTC actors to participate and perform different sets of activities. The importance of these resources lies in the fact that possession of any of these resources enables players to perform a specific activity. By a resource it is meant anything which could be thought of as a strength or weakness of a given firm. More formally, a firm's resources at a given time could be defined as those (tangible and intangible) assets which are tied semi permanently to the firm. Examples of resources are: brand names, in-house knowledge of technology, employment of skilled personnel, trade contacts, machinery, efficient procedures, capital, etc. Defined pedagogically, resources can be categorized into six major categories: financial, physical, human, technological, organizational, and reputation.

- MTC Infrastructure

When providing communication services, the need of communications networks appears naturally. Within communication networks two different types can be identified: Core Network and Cellular Access Network. The core network is the central part of the communications network, facilitating the connection between different sub-networks. The cellular access network (also defined as radio access network) is the interface between the end-user and the core network, basically using wireless technology. The MTC Infrastructure is traditionally owned by a MNO, since it is the same as the mobile telephony cellular infrastructure. In the introduced cases, we also have seen emerging players who are specialized MTC Network Operators who own their own infrastructure.

- Connected Device Platform

CDPs are software elements that facilitate the deployment and management of connected devices for M2M applications over cellular networks. CDP allows devices to connect to Cloud and should be compatible with different software platforms (e.g. Java, Android, etc.) in order to include as many devices as possible. CDP is usually a service portal, which should cover billing and policy control, bearer service, service ordering and subscription, and SIM-card management.

- Application Enablement Platform

A software platform that acts as a common ground for development of services and applications on top of the physical infrastructure. AEP can also provide an open environment for collaboration between industries and support innovation in the context of smart sustainable cities.

- M2M Data

One very important resource when introducing Smart City and M2M services is the data originated for the End Users on the city. Data can be defined as all the information obtained from the usage of a number of services in the city environment; communication/Internet services, transportation services, energy consumption, car-sharing, parking or logistics. The added value in Smart City comes from obtaining a big amount of data, process the data and extract useful information for decision making in the city.

- End User

The final goal of these services is to provide useful information and services to the End User, which will be able to make better decisions on how to interact with the city. In the provisioning of services, a number of players are involved and it is not feasible that the End User has relation with them all. The usual relations with the user are with either the service provider or the M2M device provider (in some cases). In this sense, the different stakeholders are sharing this resource event though not all of them have direct relation with it. It could be concluded that customers are the economic resource which are subject to be cultivated by the producer

MTC players in Smart City

Since MTC refers to utilizing cellular technologies as the access network for M2M services, traditional players in the mobile telephony value network are still have key role in MTC value network. In this regard, the MNOs as the typical carriers that control and operate cellular networks are capable of operating the MTC network. Network Equipment Provider (NEP as the traditional manufacturers of the telecommunication equipment, typically provision the technical procurement for the MNOs. But, according to the shift in the value chain, the NEPs have recently participated in different roles that historically have been assigned or taken care of by others, such as MNOs. Or even roles like provisioning new demands such as Connectivity Platforms. Based on proposed descriptions of the cases and the general setup of offering any service to the End User (customer), five major groups of players can be identified in the MTC value network. Besides the End Users-these players are the most likely entities who can own either of the resources mentioned earlier in order to perform the activities. These players then are:

a) End User,

b) Service Provider,

c) MTC Network Operator,

d) Service Provider, and

e) Managed Service Provider.

According to the cases studied, we showed that there are other players rather than traditional Telecom players who might be even more competent in provisioning any of the activity blocks of MTC (besides MNOs and TEVs). For instance, a specialized M2M cellular network operator (MTC Network Operator) can be considered a better option to provision MTC network. Service Providers of M2M solutions also in some cases take control of the entire value chain by handling the End Users; a previously dominant position for MNOs (in Mobile Telephony). On the other hand, TEVs and MNOs have shown interest in different activity blocks. Another major player in this setup is then an entity which performs the role of provisioning CDPs. It can be seen that this activity is mainly performed by the firms who have a historic background in provisioning connectivity in the sense of automating connected devices. Some examples can be either outsourcees of network operations for MNOs or the ones which have been active in automation of industry verticals (e.g. General Electrics, Siemens, etc.).