



SUPERFLUIDITY

A SUPER-FLUID, CLOUD-NATIVE, CONVERGED EDGE SYSTEM

Research and Innovation Action GA 671566

DELIVERABLE I2.2

FIRST TECHNICAL AND BUSINESS REQUIREMENTS

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Abstract: This interim report presents the results from the initial requirements collection and analysis activities. The requirement definition methodology utilised is presented, where we use both partner input and our current understanding of pre-existing 5G requirements produced by SDOs (Standards Defining Organisations) and the 5G-PPP (5G Public-Private Partnership).

Keyword List: Technical requirements, business requirements, 5G-PPP



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Glossary

(TO BE FILLED OUT IN THE FINAL VERSION OF THE DELIVERABLE)

SUPERFLUIDITY DICTIONNARY	
TERM	DEFINITION

1 Introduction

1.1 Deliverable Rationale

This internal report is the result of the requirement analysis performed by Task 2.2. It develops the work on the use cases presented in I2.1 and represents a snapshot of the current evolution of the work that will be presented in Deliverable D2.1.

1.2 Quality Review

Review Team member responsible of the deliverable: _____

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1.3 Executive summary

1.3.1 Deliverable description

In this internal report, the new ecosystem that will be created by upcoming 5G technologies is analysed. Additionally, the use cases previously identified in I2.1 have undergone detailed analysis to derive the key business and technical requirements. Emerging standardisation trends in the ITU-



T, namely the IMT-2020 initiative, and the opportunities created in the framework of the 5G-PPP under the H2020 Framework Programme have been analysed. A methodology to extract an initial set of requirements from the individual use cases presented in I2.1 is also described. We use a questionnaire and cluster the results around major topics covered by the aforementioned standardization bodies and research activities. The results obtained will be used to define the use cases that will be adopted to be designed and implemented of the SUPERFLUIDITY system, which will be demonstrated at the end of the project.

1.3.2 Summary of results

(TO BE FILLED OUT IN THE FINAL VERSION OF THE DELIVERABLE)

2 Requirement selection

2.1 Introduction

This section reviews the challenges identified by the most relevant standardization bodies and the 5G-PPP initiative, and how they have been translated to technical requirements. Finally, we present our requirement identification methodology.

2.1.1 The 5G landscape, challenges and opportunities

As identified in [1], the main challenges for 5G are to create “interoperable, ubiquitous and dynamic” 5G communication systems and applications. These emerge from the need to meet user expectations with regard to mobility and quality of service, while coping with an ever-growing data volume. Wireless communication services will expand into new market segments, such as smart grids and smart cities, e-health, Intelligent Transportation Systems, traffic control and safety, just to name a few. This expansion is required to realise the vision for an intelligent, mobile and connected society based on social, political and technological drivers [2]. The key aspects of this vision are highlighted below:



- Final consumer – Mobile devices are ubiquitous in modern everyday life for a large and exponentially increasing set of users, accommodating new applications requiring very high data rates, low latency, security and reliability. People want to experience always-on mobile connectivity, with high quality, quick response and high reliability communication to interact seamlessly with the world around them. It is estimated that the global mobile data traffic will grow more than 200 fold from 2010 to 2020, and by nearly 20,000 times from 2010 to 2030.
- Machine to machine – Future wireless systems need to be designed with support for real-time machine-to-machine (M2M) communication in mind from the bottom-up. Some examples are driverless cars, real-time traffic control optimisation, emergency and disaster response, or efficient industrial communications, among others.
- High user density – Today, we are experiencing an ever-increasing mobile devices density per unit of area. Examples include large buildings with many employees, shopping centres, music festivals, sports events, etc.
- Enhanced multimedia services – User devices will have Ultra-High Definition (UHD) displays, including multi-view, mobile 3D projections, immersive video conferencing, augmented reality and mixed reality display, and interfaces enabling the provisioning of e-health, education and entertainment (as for instance gaming) applications. This will require considerably higher data rates.
- Internet of Things (IoT) – Every object can benefit from being connected through Internet technologies. These connected “things” can be smart phones, sensors, actuators, cameras, vehicles, etc., ranging from simple devices to highly complex and advanced devices. These connected devices are bound to have varying levels of energy consumption, transmission power, latency requirements, cost, etc. Smart cities, smart rural places will benefit from this level of ubiquitous connectivity. Examples include smart energy distribution grids, agriculture, healthcare, or vehicle-to-vehicle and vehicle-to-road infrastructure communications.

These drivers and other trends anticipate that global mobile traffic will grow and the technological systems will need to continuously evolve at an even faster rate to meet future demands.

Data forecasts

The following picture, taken from Cisco forecasts [5], provides predictions for several global population evolution indicators.

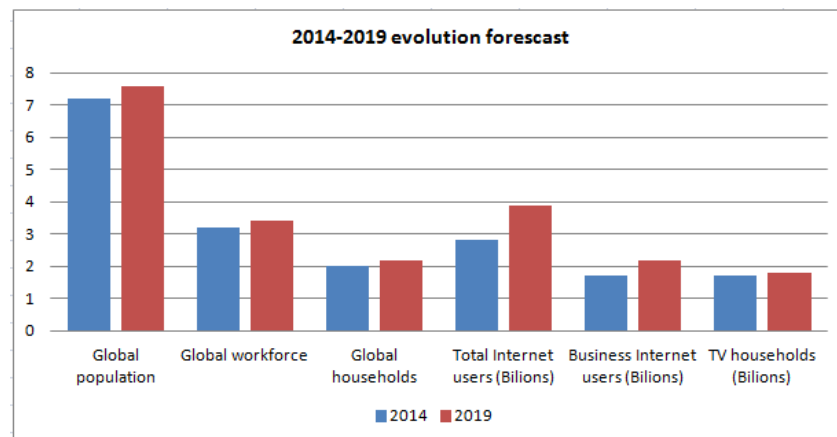


Figure 2-1 2014 → 2019 evolution forecast (source [5])

It can be seen from Figure 2-1 that the total number of Internet users will grow at a faster rate than the global population, while TV households will maintain relatively static. According to Cisco, mobile data traffic will:

- Grow 10-fold from 2014 to 2019, at a compound annual growth rate of 57%
- Reach 24.3 Exabytes per month by 2019, up from 2.5 Exabytes per month in 2014
- Reach an annual run rate of 291.8 Exabytes by 2019, up from 30.3 Exabytes in 2014
- Grow 3 times faster than global fixed IP traffic from 2014 to 2019
- Account for 15% of global fixed and mobile data traffic by 2019, up from 4% in 2014
- Be equivalent, in 2019, to 266x the volume of global mobile traffic 10 years earlier (in 2009)
- Be equivalent, in 2019, to 12x the volume of the entire Global Internet in 2005.

According to Cisco VNI, globally 47% of all networked devices will be mobile-connected in 2019. Figure 2-2 provides additional insights on the evolution of mobile traffic and of smartphone devices. Table 2.1 provides key indicators on the projected growth of connected devices between 2014 and 2019.

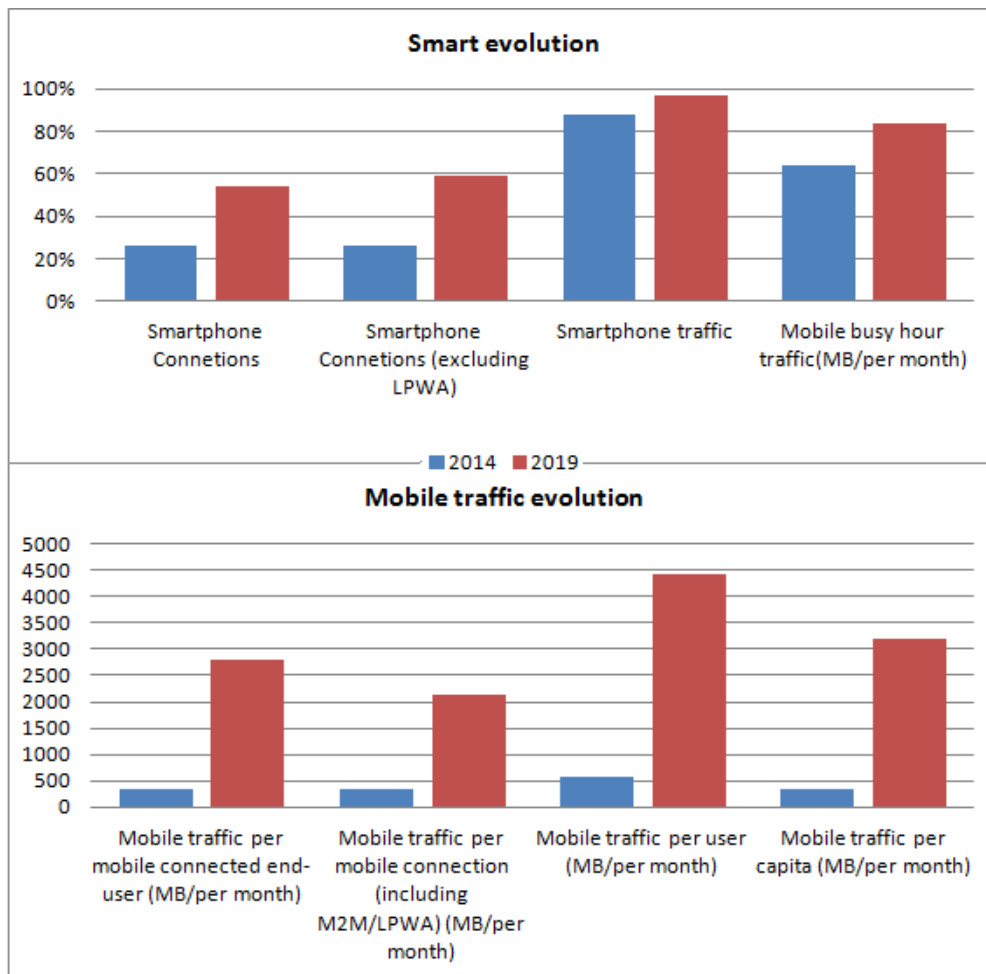


Figure 2-2 Mobile traffic and smartphone evolution



Table 2.1 Projected growth of connected devices 2014 to 2019

Devices evolution	2014	2019
Networked devices (billion)	14,2	24,2
Networked devices per capita	2	3,2
M2M modules	24% (3,3 billions)	43% (10,5 billions)
PCs	11% (1,5 billions)	6% (1,5 billions)
Tablets	4% (922,4 millions)	3% (419,2 millions)
Smartphones	19% (4,6 billions)	15% (2,1 billions)
Connected TVs	11% (1,5 billions)	12% (3,1 billions)
Non-smartphones	12,7% (3,1 billions)	32% (4,5 billions)
Other portables	4% (875,9 millions)	5% (693,1 millions)
Global IP Traffic from non-PC devices	39%	67%
IP Traffic from PCs	61%	33%
IP Traffic from TVs	29%	22%
IP Traffic from Portable devices (as smartphones and tablets)	10%	42%
IP Traffic from M2M	0,50%	2,70%
Consumer Internet Traffic from PCs	75%	33%
Consumer Internet Traffic from TVs	9%	10%
Total Internet Traffic from TVs	7%	8%

Timeline

According to [3], the expected timeline for 5G is based on the assumption that the standards in 3GPP Rel-14/15/16, the Spectrum Allocation in WRC-19 and ITU Approval will occur by 2020, as planned.

2.1.2 Financial Trends

While there are some key data enabling some operational projections, there are no detailed reports with potential revenue predictions currently available with the exception of Juniper Research [4]. This report forecasts the adoption for 5G, with service revenues set to exceed \$65 billion by 2025, compared to just \$100 million during its first year of commercial services in 2020. This figure would represent approximately 7% of all operator-billed service revenues.



2.1.3 5G Standardisation Activities

Currently, the ITU-T has established a focus group that is identifying the standardisation requirements for 5G networks, known as the International Mobile Telecommunications for 2020 and beyond (IMT-2020) study group. This group is focusing on the requirements of wired elements and interfaces in 5G networks. In parallel, the ITU-R has established an equivalent study group (that even shares the name with the ITU-T study group) to study the challenges and requirements for 5G system in the radio interface. This study group has produced a first report [2], which provides an analysis of trends and envisaged usage scenarios for IMT-2020.

The ETSI NFV ISG is in the midst of a change from stage 2, which focuses on the information model, to stage 3, that includes data models and interoperability tests. Being late, the ETSI NFV is looking for accelerators that would allow it to cope with open-source projects that have already implemented parts of its architecture, as well as with other standardisation bodies that have defined the data models for some of the ETSI NFV APIs. Specifically, in a recent poll among the operators, the majority voted in favour of adopting OpenStack APIs as the de-facto standard for the interfaces between VIM-VNFM and VIM-NFVO, which corresponds to the ETSI NFV IFA005 and IFA006, respectively.

There is still a need to adapt the OpenStack to comply with the requirements of ETSI NFV stage 2, or possibly, update the ETSI NFV in accordance to OpenStack's implementations. This gap analysis and the way to bridge is currently a discussion point for the ETSI NFV.

For orchestration, the TMForum ZOOM (Zero-time Orchestration, Operations and Management) project aims to define a vision of new virtualised operations with an architecture based on the seamless interaction between physical and virtual solutions. To that end, the TMForum published a framework technical report on information framework enhancements to support ZOOM [3]. This report defines 4 fundamental concepts for modelling NFV-based systems, namely, Virtual Resource, Network Function, Network Service, and Graph, as well as 2 general-purpose concepts, Catalogue and Event, which are also critical for realising SDN and NFV systems. Having already defined a set of APIs to OSSs, the TMForum is the leading candidate to be delegated by the ETSI NFV to define the data model for IFA012 and IFA013 (OSS-NFVO interfaces).

The 3GPP SA WG3 aims at specifying the requirements, architecture and solutions for provisioning and management of the network (RAN, CN, IMS) and its services. As such, it has requirements related to several ETSI NFV interfaces and architectural specifications, including network service life cycle management, VNF package management, virtual resource fault information, performance management information, and specifications of the Ve-Vnfm-em, Ve-Vnfm-vnf and Os-Ma-nfvo Reference Points with respect to 3GPP applications. The ETSI NFV IFA group cooperates in these areas with the 3GPP SA5 to align the specifications.



2.1.4 5G-PPP Initiative

The “Public Private Partnership on 5G” (5G-PPP) is the EU flagship initiative to accelerate research developments in 5G technology. Formally, it is an agreement between the EU commission and the “5G Infrastructure Partnership”, an industry association comprising the key European players in ICT. The European Commission will provide a public funding of €700 million to support this activity, in the context of the Horizon 2020 Programme. At the time of writing, the latest “vision” document produced by the 5G-Infrastructure PPP is [6] (February 2015).

2.2 Requirements definition methodology

We base our requirements definition methodology on three basic pillars:

1. The current view of the standardization bodies;
2. The initial consensus reached by the 5G-PPP community;
3. The requirements derived from each of the use cases described in I2.1 [I2.1].

2.2.1 General requirements from standards bodies

2.2.1.1 ITU-R

ITU-R has identified a set of ‘usage scenarios’ for ‘IMT for 2020 and beyond’. These were organised along three use cases’ categories, as shown in Figure 2-3, reflecting the supported requirements along those three axis:

- Enhanced Mobile Broadband (eMBB)
- Ultra-reliable and low latency communications, also known as critical MTC (cMTC)
- Massive machine type communications (mMTC)

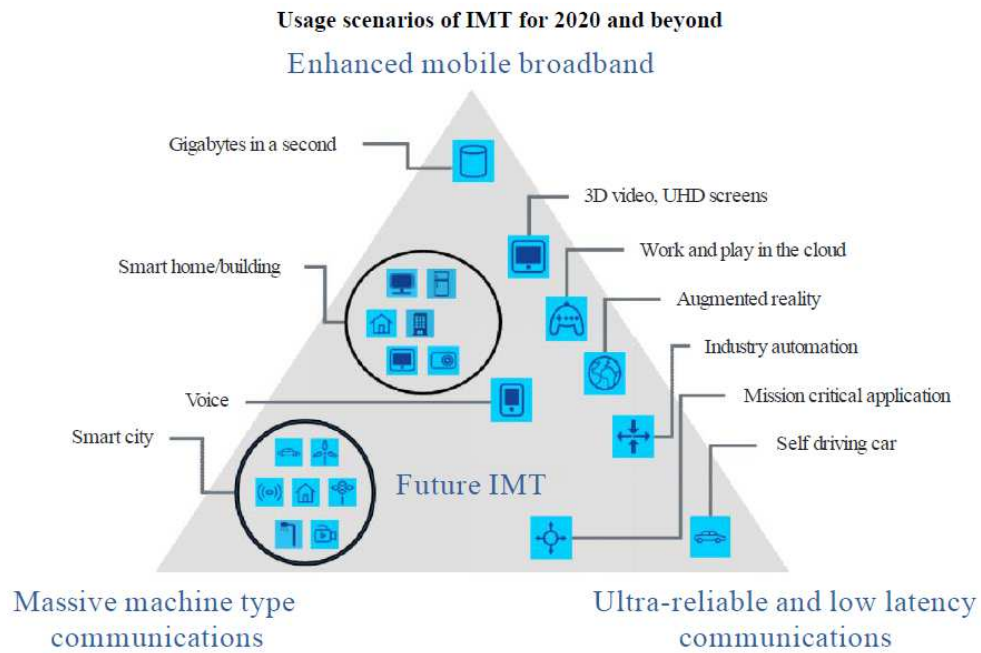


Figure 2-3 IMT 2020 and beyond usage scenarios [2]

(Source: ITU-R)

The target performance enhancements required to address those scenarios, are summarised by ITU-R into eight 'key capabilities', as shown in Figure 2-4.

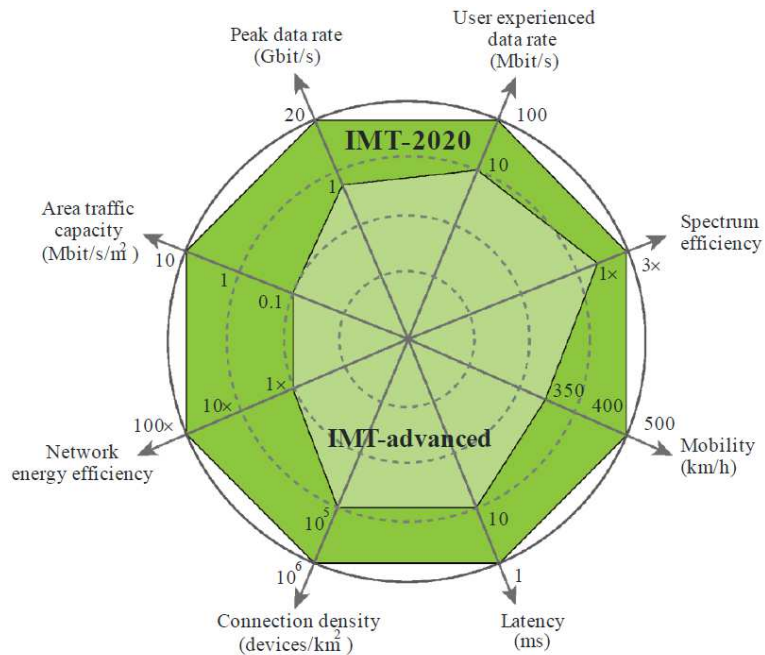


Figure 2-4 Enhancement of key capabilities from IMT-Advanced to IMT-2020 [2]

(Source: ITU-R)



These eight capabilities can be grouped into the following five categories:

1. Capacity (global area traffic and connections)
2. Throughput (peak and experienced data rates)
3. Latency
4. Mobility
5. Efficiency (Spectrum and energy)

The established target values for these KPIs face significant challenges, to be solved over the coming the years, with some requiring enhancements with factors of up to 100x.

Other organisations and vendors present slightly different numbers and add other KPIs, such as:

- Reduction to 20% in network management OPEX (5G-PPP)
- Services' deployment time below 90 minutes (5G-PPP)
- Cell spectral efficiency of 30 bps/Hz (Samsung)
- Cell edge data rate of 1 Gbps (Samsung)

Figure 2-5, Figure 2-5 Importance of key capabilities in different usage scenarios [2]

also from ITU-R, identifies the relative importance ('high/medium/low') of the key capabilities relevant to the usage scenarios.

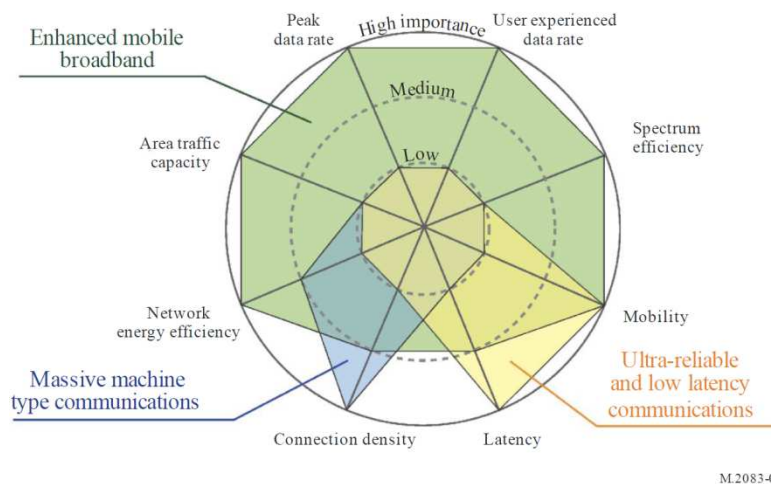


Figure 2-5 Importance of key capabilities in different usage scenarios [2]

(Source: ITU-R)

It is clear that the *enhanced mobile broadband* (eMBB) usage scenario represents the widest range of requirements, even if the focus is only on capacity, efficiency and mobility. *Massive machine type communications* (mMTC) and *ultra-reliable and low latency communications* have very specific requirements, the former focusing in efficiency, to cope with finite battery duration, and connection density (large number of devices per area unit), and the later focusing on mobility and latency.



2.2.1.2 3GPP

3GPP, via its SMARTER (*Study on New Services and Markets Technology Enablers*) Study Item, is elaborating the TR 22.891, currently encompassing seventy-two ‘use cases’, extracting functional requirements to be realised in future 3GPP Releases’ features. This work in progress, is complemented by results coming from *NexGen* (SA2 Architecture) and RAN (Radio Access Network) activities. From these and among many other requirements identified, we can extract the following as being directly relevant for Superfluidity:

- Ultra-reliable communications
- High availability
- Very low data error rate
- Network slicing
- On-demand networking
- Mobility between 3GPP and non-3GPP RATs
- Multiple simultaneous connections to several RATs
- Content caching capabilities at the edge of the network
- Services mobility to follow the user, with routing optimization
- Network capabilities exposure
- Broadcast/multicast services in a dedicated bearer

2.2.1.3 ETSI MEC WG

Mobile Edge Computing (MEC) is recognised by the 5G-PPP as one of the key emerging technologies for 5G systems (along with NFV and SDN). It will offer application developers and content providers cloud computing and an IT service environment at the edge of the mobile network (eventually on fixed environments in the future). The MEC environment will be characterised by:

- Proximity
- Ultra Low Latency
- High Bandwidth
- Real-time access to network information
- Location Awareness

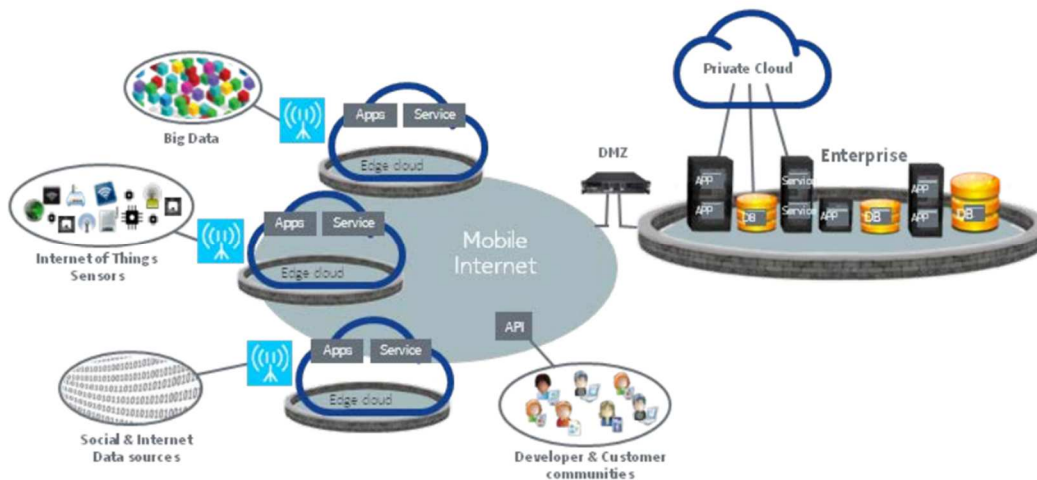


Figure 2-6 MEC provides IT and Telecoms Networking Convergence (source ETSI)

The ETSI Industry Specification Group (ISG) on Mobile Edge Computing (MEC) produces normative Group Specifications that will enable the hosting of third-party applications in a multi-vendor MEC environment. Launched in December 2014, the group plans to deliver the first set of specifications within 2 years.

The initial scope of the ISG MEC focuses on use cases, requirements and the reference architecture, including the components and functional elements that are the key enablers for MEC solutions.

When the first documents reach the required maturity level, work on platform services, APIs and interfaces will commence. The ETSI whitepaper on MEC [8] provides an initial overview of the MEC platform as shown in Figure 2-6. The MEC platform is described as a hosting infrastructure, comprising hardware resources and a virtualization layer. The details of the actual implementation of the MEC hosting infrastructure (including the actual hardware components) are abstracted from the applications hosted on the platform. The MEC platform API [9] will be application-agnostic and will foster the smooth portability of value-creating applications on every mobile-edge server with guaranteed SLA (see Figure 2-7).

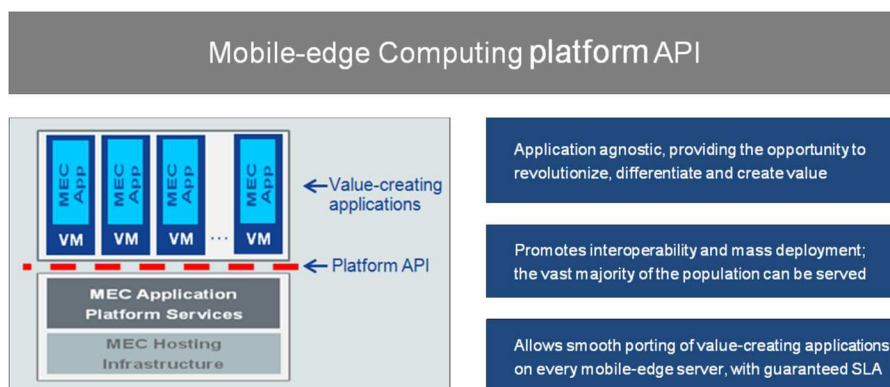


Figure 2-7 MEC Platform API (Source ETSI)



According to the work-in-progress Group Specification “ETSI GS MEC 002: Mobile-Edge Computing (MEC); Technical Requirements”, MEC technical requirements are organised/outlined in Table 2.2.

Table 2.2 ETSI MEC Technical Requirements

I. Generic principles		III. Services		
1	NFV alignment	<u>Platform service requirements</u>		<u>Features</u>
2	Mobility support	1	Services registry	1 Feature <i>UserApps</i>
3	Deployment independence	2	Connectivity	2 Feature <i>SmartRelocation</i>
4	Simple and controllable APIs	3	Storage	3 Feature <i>RadioNetworkInformation</i>
5	Smart application location	4	Traffic routing	4 Feature <i>LocationService</i>
6	Representation of features	5	DNS support	5 Feature <i>BandwidthManager</i>
		6	Timing	6 Feature <i>UEIdentity</i>
II. Generic requirements		IV. Operation and management requirements		V. Security, regulation, charging requirements
1	Requirements on the framework			
2	Application lifecycle			
3	Applications environment			
4	Support of mobility			

2.2.1.4 GSMA

The GSMA (GSM Association) represents all the mobile industry sector, organising events such as the Mobile World Congress. Through GSM Intelligence, it provides “mobile operator data, analysis and forecasts”. Figure 2-8 Figure 2-8 Bandwidth and latency requirements of identified 5G use cases [4]

taken from GSMA Intelligence¹, identifies some other use cases, which are slightly different, but complementary to the ITU-R use cases. The GSMA go into more detail and shows the dependency between the identified use cases and delay vs. bandwidth parameters.

The most demanding use cases are related to augmented/virtual reality and Tactile Internet, requiring simultaneously data rates above 1Gbps and delays in the order of a few milliseconds, which are in alignment with the ITU-R capabilities. In fact, those are the ones identified as not being enabled by today’s networks (grey area).

¹ <https://gsmaintelligence.com>

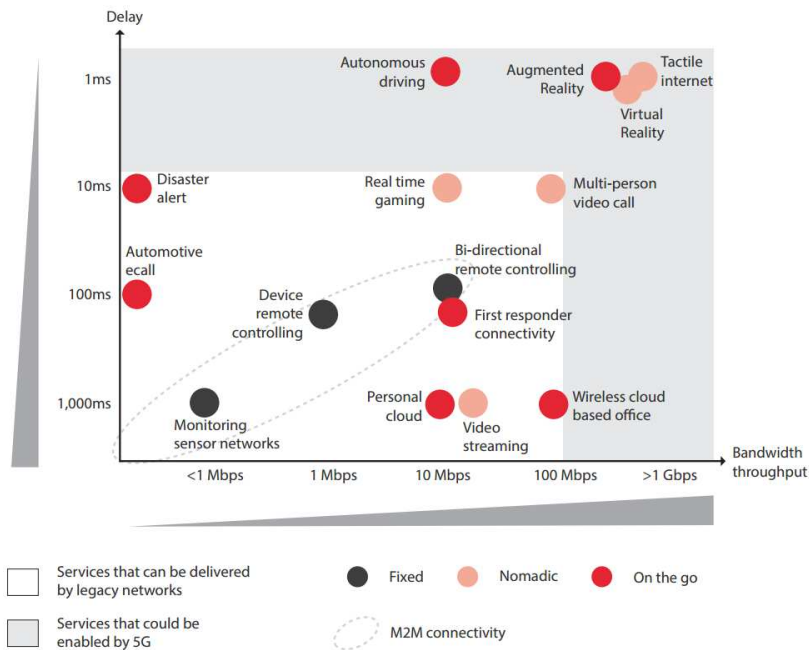


Figure 2-8 Bandwidth and latency requirements of identified 5G use cases [4]

(Source: GSMA Intelligence)

2.2.1.5 NGMN

The NGMN (*Next Generation Mobile Networks*) Alliance comprises Mobile Operators, Technology Vendors and Universities/Research Institutes, with the main objective of producing requirements, solutions and guidelines published in the form of as White Papers and Liaison Statements.

In its ‘5G White Paper’ [7], NGMN identifies a large number of requirements, organised according to the ‘dimensions’ depicted in Figure 2-9.

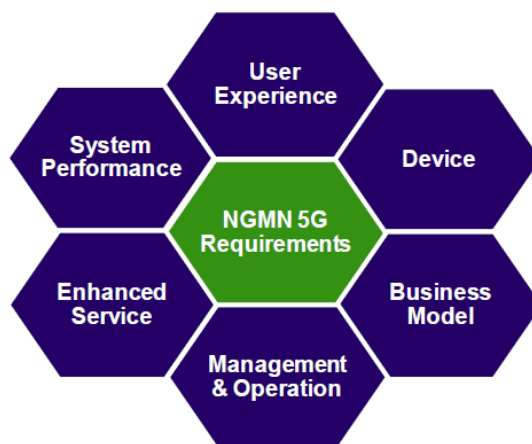


Figure 2-9 NGMN Requirements Dimensions

In detail, the identified requirements are the ones reproduced in Table 2.3.

Table 2.3 NGMN Requirements



User Experience		System Performance		Device Requirements	
1	Consistent User Experience	1	Connection Density	1	Operator Control Capabilities on Devices
2	User Experienced Data Rate	2	Traffic Density	2	Multi-Band-Multi-Mode Support in Devices
3	Latency	3	Spectrum Efficiency	3	Device Power Efficiency
4	Mobility	4	Coverage	4	Resource and Signalling Efficiency
5		5	Resource and Signalling Efficiency		

Enhanced Services		New Business Models		Network Deployment, Operation and Management	
1	Connectivity Transparency	1	Connectivity Providers	1	Cost Efficiency
2	Location	2	Partner Service Provider and XaaS Asset Provider	2	Energy Efficiency
3	Security			3	Ease of Innovation and Upgrade
4	Resilience and High Availability	3	Network Sharing Model	4	Ease of Deployment
5	Reliability			5	Flexibility and Scalability
				6	Fixed-Mobile Convergence
				7	Operations Awareness
				8	Operation Efficiency
				9	Ultra Low-cost Networks for Very Low-ARPU Areas
				10	Ultra Low-Cost Networks for Very Low-ARPU MTC Services

NGMN also provides a number of use cases, organised in families and categories, giving an overview on the relationships between requirements and use cases, as shown in Figure 2-10.

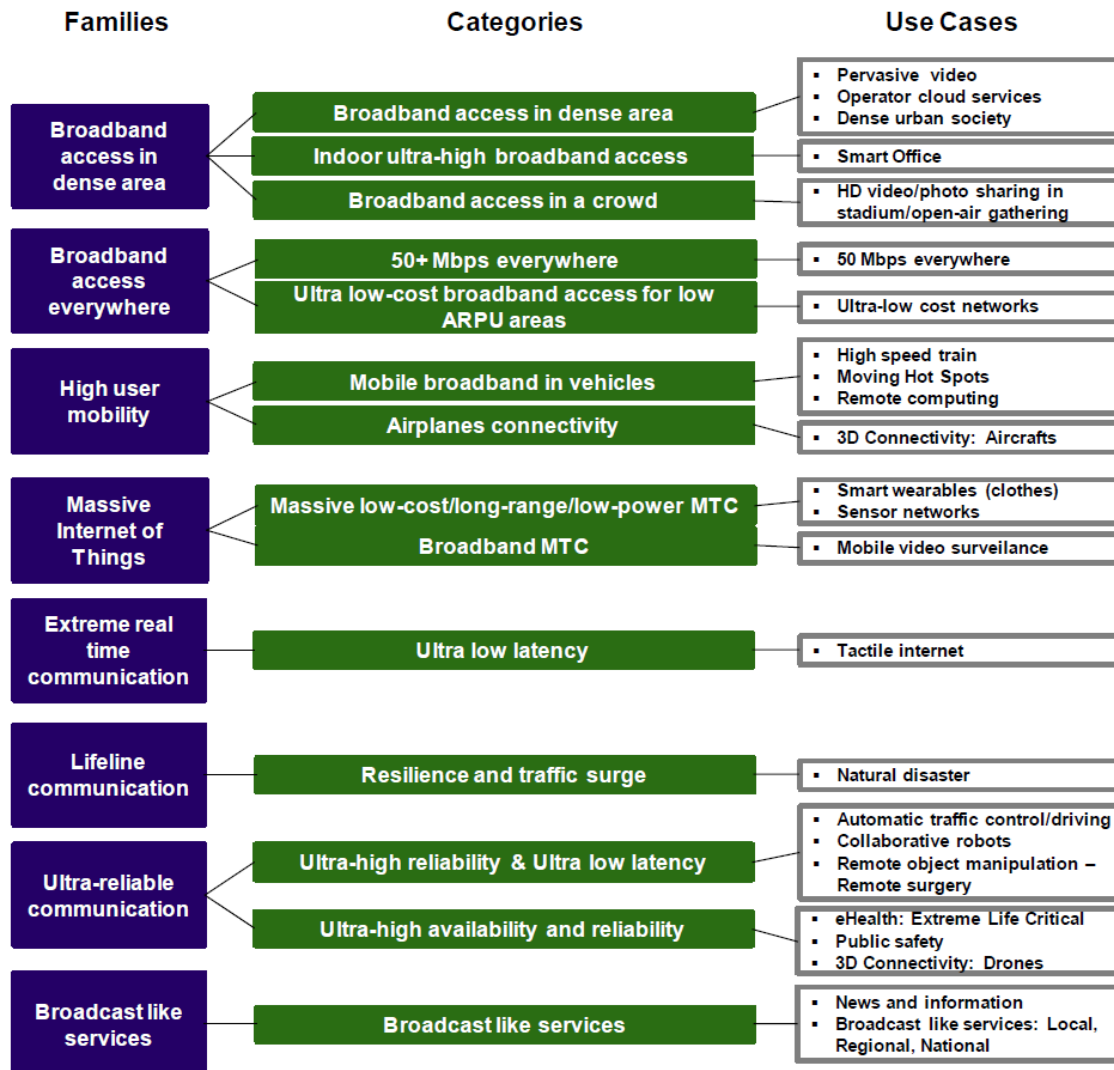


Figure 2-10 NGMN Use Cases

2.2.1.6 4G Americas'

4G America's divides the identified requirements in user and network driven requirements:

User-driven	Network-driven
1. Battery Life	1. Scalability
2. Per-User Data Rate and Latency	2. Network Capacity
3. Robustness and Resiliency	3. Cost Efficiency
4. Mobility	4. Automated System Management and Configuration
5. Seamless User Experience	
6. Context-Aware Network	



2.2.2 General Requirements from the 5G-PPP Community

The 5G-PPP community is considering a set of Key Performance Indicators (KPIs), classified as Performance, Societal and Business KPIs. As part of the 5G-PPP community, SUPERFLUIDITY will also contribute to the achievements of a subset of these KPIs. In the following tables, the 5G-PPP KPIs are listed and the relevance of the KPIs with respect to the scope of SUPERFLUIDITY is analysed.

Performance KPI

KPI		Relevance (High/Medium/ Low / N.A.)	Details on planned project contribution towards achieving the KPI
P1	Providing 1000 times higher wireless area capacity and more varied service capabilities compared to 2010.	High	Solutions to lower deployment and maintenance costs (e.g. BBU aggregation on the edge) through the use of standard high volume servers. Increased service diversity thanks to our “slicing concept”
P2	Reducing the average service creation time cycle from 90 hours to 90 minutes.	High	Automatic verification of service deployments before instantiation via static analysis to reduce the need for manual checks. Symbolic execution is a key enabler for this. Adoption of light weight virtualisation approaches such as unikernels or container-based approaches to significantly reduce service instantiation times Simplicity in network function deployment thanks to platform agnostic configuration/programming interfaces
P3	Facilitating very dense deployments of wireless communication links to connect over 7 trillion wireless devices serving over 7 billion people.	Medium	Cloud RAN concept particularly effective for dense environments Synchronization and collaboration between cells: Cloud-RAN, HW selection and acceleration, tackle this issue with a centralized BBU.



			Work on mobility at layer 4, based on Multipath TCP, to allow seamless handovers across a range of communication technologies. Connect to multiple technologies at once, favouring slow handover while connected via many links to fast handover of a single link, as done today
P4	Creating a secure, reliable and dependable Internet with a “zero perceived” downtime for services provision.	Medium	Almost instantaneous service instantiation. Use of symbolic execution to ensure robustness of the network, to check configurations and services before they are applied, and to ensure security by design, without sandboxing.

Societal KPIs:

KPI		Relevance (High / Medium / Low / N.A.)	Details on planned project contribution towards achieving the KPI
S1	Enabling advanced User controlled privacy;	N.A.	
S2	Reduction of energy consumption per service up to 90% (as compared to 2010);	Medium	Reducing the Energy consumption in NFV data centers by improving infrastructure utilisation through more intelligent placement of workloads and continuous optimisation of placement decisions. Fast Service migration and shift or processing from one hardware to the other enables energy efficient scheduling (and having most of the platform in low energy consumption mode). More in general, cloud networking helps to adapt resources allocation, increasing efficiency by matching the workload characterisation to optimised allocation of



			resources through resource aware intelligent orchestration.
S3	European availability of a competitive industrial offer for 5G systems and technologies;	High	<p>Consortium partners aiming at strategically placing themselves as a driving force in the area of converged 5G service and network architectures by becoming early adopters of SUPERFLUIDITY's system</p> <p>Interface definition and contribution to standards</p> <p>Contributions to industry initiatives such as OPNFV to accelerate the adoption and deployment of open platform solutions to drive the adoption of NFV.</p> <p>Creation of high fidelity prototypes to demonstrate feasibility of the approach developed by Superfluidity</p>
S4	Stimulation of new economically-viable services of high societal value like U-HDTV and M2M applications;	Medium	<p>Edge cloud concept facilitates delay-sensitive services and crowd-targeted video services (e.g. multi-camera video streaming apps of events)</p> <p>Easing the development of M2M markets via virtualized infrastructure</p>
S5	Establishment and availability of 5G skills development curricula (in partnership with the EIT).	N.A.	

Business-related KPIs:

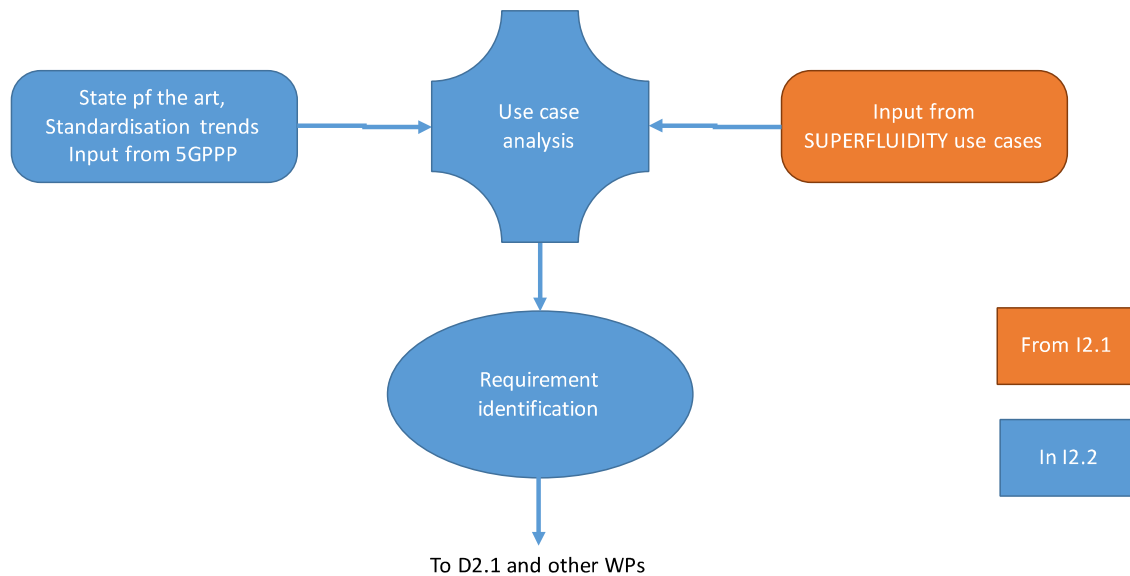
KPI	Relevance (High / Medium / Low / N.A.)	Details on planned project contribution towards achieving the KPI
B1	Medium	Exploitation of Superfluidity results and prototypes by industrial partners into internal



	funding in terms of private investment in R&D for 5G systems in the order of 5 to 10 times;		R&D programs Contribution to the open source community.
B2	Target SME participation under this initiative commensurate with an allocation of 20% of the total public funding;	Medium	Budget allocated to SMEs=€ 1.206.375, corresponding to 15,28% of the total public funding
B3	Reach a global market share for 5G equipment & services delivered by European headquartered ICT companies at, or above, the reported 2011 level of 43% global market share in communication infrastructure.	High	Use of Superfluidity collateral with customers to demonstrate feasibility of 5G use cases and solution paths to major 5G technical challenges. Investments by industrial partners.

2.2.3 Proposed Methodology

The Figure 2-11 shows the process adopted to extract the requirements from use cases. We start from the general requirements extracted from SDOs (see sections above) and from the use cases. After a first iteration, where we derived requirements on a per use case basis, we group requirements around main topics based on the interest expressed by the different partners. The requirement identification process also serves as a base to group the per-partner use cases into the use cases that will drive our work as a project.



3 Use-case Analysis

As a result of the use-case collection phase, I2.1 includes a set of elementary use cases that show specific aspects of the use cases that will showcase SUEPRFLUIDITY concepts. We have used them to gather both business and technical requirements with the same granularity. In this section, the individual requirements are analysed and clustered in order to give a sense of significance of the different concepts at a project level.

3.1 Business requirements derived from I2.1 use cases

We clustered the responses to the requirement questionnaire regarding business requirements. The topic that clusters most requirements is service agility.

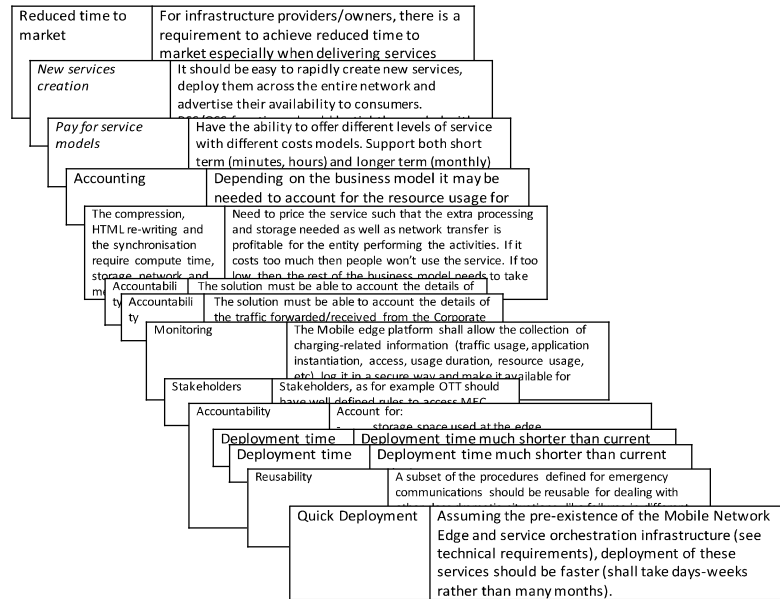


Figure 3-1: Business requirements cluster 1: Service agility

A significant number of requirements deal with cost savings:



Figure 3-2: Business requirements cluster 2: Cost savings

There are two clusters that reflect how the user is gaining significance, namely increased user experience and security concerns. After these three main clusters, another smaller cluster formed around the need for analytics embedded in the network as a means to extract intelligence from the network, to be fed back into the business processes.

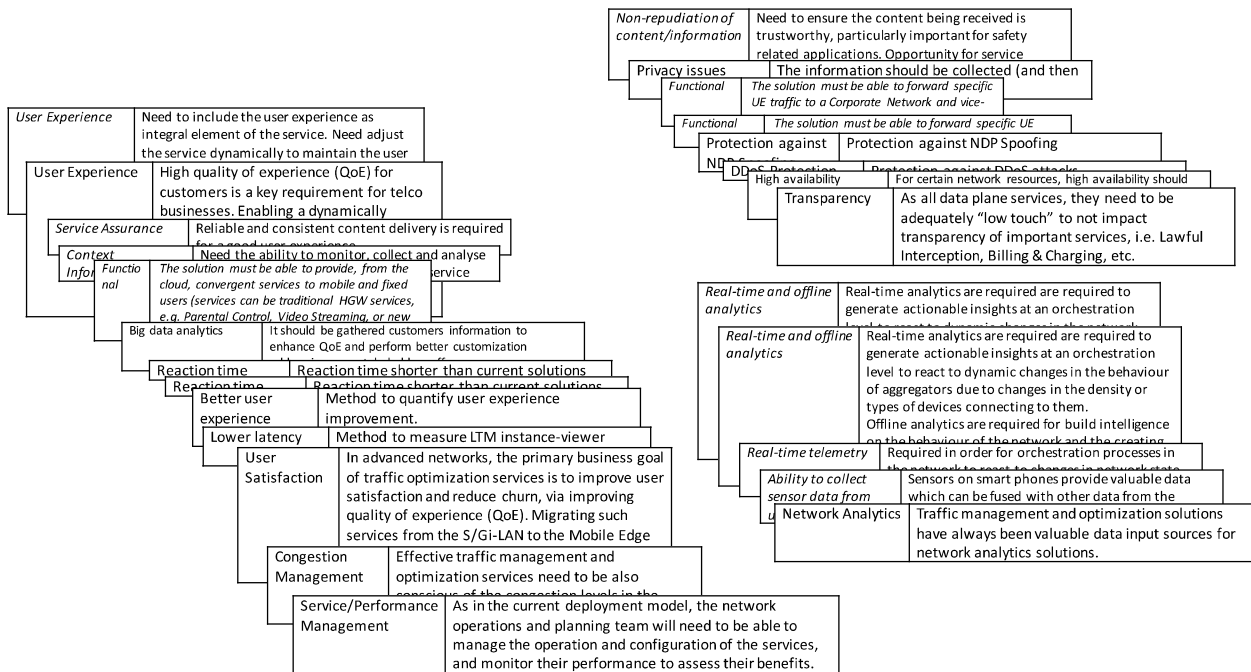
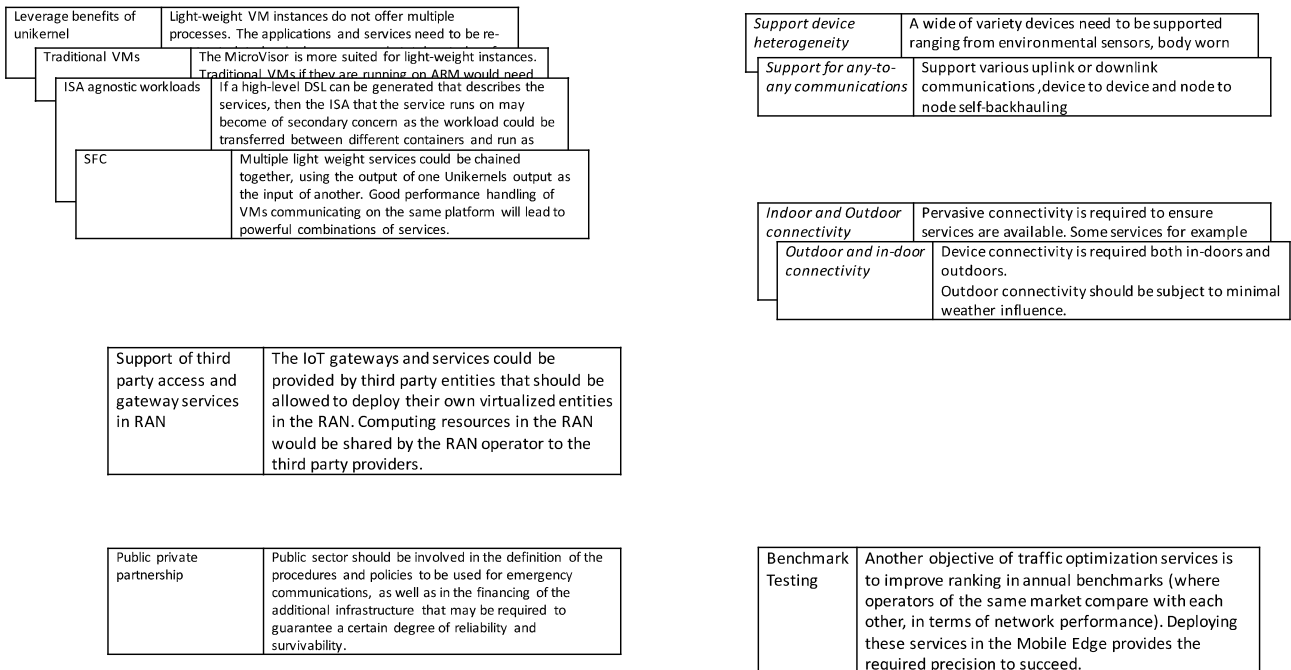


Figure 3-3: Business requirements clusters 3, 4 & 5: User Experience, Security & Analytics

Finally, there are other topics that form smaller clusters or cannot be included naturally in other





The five main clusters reflect the increase in importance of these topics in 5G networks and how SUPERFLUIDITY as a project ranks them. Figure 3-5 shows the interactions between the clusters in the SUPERFLUIDITY use cases.

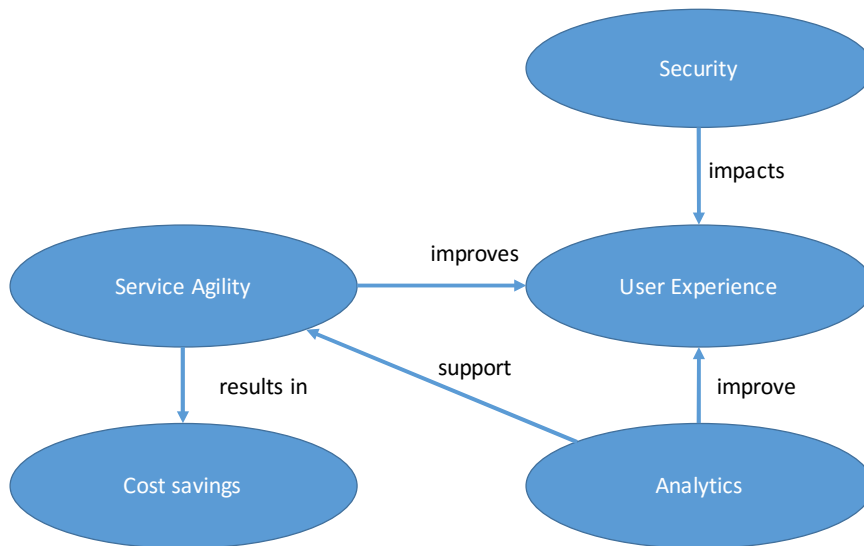


Figure 3-5: Interactions between the 5 main clusters

3.2 Technical requirements derived from I2.1 use cases

SUPERFLUIDITY set out to develop an architecture that allows network processing to run distributed from the wire-line and wireless edge to the core. In order to cope with the technical requirements consolidated by the different SDOs, as shown in Section 2.2.1, the project architecture will need to run high throughput network functions in an infrastructure that allows fast instantiation and rapid migration on servers that support up to thousands of service instances (“high consolidation”). This will enable building a network which provides users with an ultra-low latency and a high bandwidth (in the order of 100x more than today) experience, with higher density connections (in the order of millions of connections/km²), which result in an increased traffic volume density (in the order of tens of Tbps/km²).

The Figure 3-6 shows the overall clustering of the technical requirements collected from the use cases. Clusters appear around general concepts, such as converged architecture or generic platform requirements and around scalability, security, quality of experience (QoE), building blocks or orchestration, as specific requirements to the platform.



4 Conclusion and Further work

This deliverable presents the first requirement analysis on a project-wide scale. The use cases presented in I2.1 were analysed on a per-partner basis and then aggregated into common themes, which were shared across all the use cases identified. The business requirement aggregation confirms the potential commercial benefits of the project, which could be accrued in the realisation of network evolution towards 5G, while the technical requirement analysis shows that the use cases cover all relevant aspects in this evolution.



5 Appendix

In this appendix, the partners' answers to the requirement solicitation questionnaire are included. These questionnaires were the tools used to build requirements from user cases.

5.2 Use Case – On-the-fly monitoring

Use case	BT Use Case – On-the-fly monitoring	
Description in a nutshell	Implementation of Deep Packet Inspection (DPI) with virtual network functions (VNFs) for two scenarios (a) dynamic deployment of DPI to monitor selected network segments e.g. specific geographical regions, and (b) implementing multiple DPI deployments for disparate virtual customers sharing the same physical infrastructure	
Technical requirements	Dynamic placement	There is a requirement for an intelligent system that is able to automatically decide which network segments should be monitored. This could be based on time of day, geographically location, forecasted traffic levels
	Orchestration	This is a requirement for an orchestrator which has network-wide view and is able to dynamically instantiate all functions that compose a monitoring framework
	Service chaining	Most monitoring systems do not work in isolation so there is a requirement to support dynamic service chaining such as DPI → Analytics System → Traffic Shaper
Business Requirements	Cost savings	Continuous increase in bandwidth demands means network-wide deployment of DPI will become increasingly expensive and in most cases unsustainable. There is a requirement to enable relatively cheaper monitoring infrastructure
	Reduced time to market	For infrastructure providers/owners, there is a requirement to achieve reduced time to market especially when delivering services such as supporting multiple virtual customers sharing the same infrastructure with isolated DPI deployments
	User Experience	High quality of experience (QoE) for customers is a key requirement for Telco businesses. Enabling a dynamically configurable monitoring platform for observing customer usage of services with a view towards collecting inputs for capacity planning, cache placement, and infrastructure evolution/upgrades.



5.3 Mobile Based Augmented Reality for User Experience Enhancement

Use case	Intel Use Case 1 - Mobile Based Augmented Reality for User Experience Enhancement	
Description in a nutshell	<i>The ability to provide rich and dynamic information at very low latencies to support applications such as augmented reality dashboards for drivers, augmented reality glasses tendered to a 5G mobile handset to provide ambient intelligence to users such as tourists visiting a new city or providing multisensory stimulation to an on-line gamer interacting with their peers.</i>	
Technical requirements	Latency	<20msec for multimedia content or safety related data.
	Availability	>5 nines availability for safety related applications
	Scalability	Scalable or elastic infrastructure to support transient demand peaks.
	Caching	Local caching of content to improve. Linux platform that can support high-speed content delivery.
	Security	Ensure content is only available to authorised users. Content can only be added or modified by authorised users
	Platform	Highly distributed edge node platform to provide complete geographic coverage in an urban. For safety related applications such as intelligent cars urban and rural coverage is required.
	Acceleration	Hardware acceleration for content generation or rendering
	Orchestration	Need orchestration system which have a system wide view of resources and service needs and can reactive in dynamic fashion rather than in a predefined manner.
	QoS	Need to guarantees over the quality of the service a user receives
Business Requirements	User Experience	Need to include the user experience as integral element of the service. Need adjust the service dynamically to maintain the user experience. Service offerings with different costs models which are tied to the quality of the user experience.
	Dynamic Allocation of Resources	Need the ability to automatically re-provision resources in response to a geographic encapsulated demand spike.
	Non-repudiation of content/information	Need to ensure the content being received is trustworthy, particularly important for safety related applications. Opportunity for service providers to differentiate their



		offerings.
	Service Assurance	Reliable and consistent content delivery is required for a good user experience.
	Indoor and Outdoor connectivity	Pervasive connectivity is required to ensure services are available. Some services for example will take specific indoor use cases such as museum and gallery visits, personalised adverts in a shopping centre.
	New services creation	It should be easy to rapidly create new services, deploy them across the entire network and advertise their availability to consumers. BSS/OSS functions should be tightly coupled with service orchestration

5.4 Performance Optimisation for Distributed Multimedia Content Delivery.

Use case	Intel Use Case 2 – Performance Optimisation for Distributed Multimedia Content Delivery.	
Description in a nutshell	<i>The ability to adapt the delivery of content or to upload and process content based on context information through the use of edge clouds. Orchestration of the applications such as vCDN and video transcoding services is platform aware which ensures workloads can be scaled on compute platforms that have appropriate platform features and capabilities to deliver the required level of user experience.</i>	
Technical Requirements	Metrics	Capture of mobile device, application, infrastructure platform and network metrics and fusing them into an efficient and meaningful manner which can be used to drive system Orchestration
	Orchestration	Intelligent Orchestration to ensure that services are deployed and scaled on the most appropriate platform and consider the heterogeneity of resources in the decision making process.
	Storage	High-speed storage at the network edge to store and deliver multimedia content. Storage provisioning needs to be location aware i.e. close to the point of generation or consumption.
	Scalability	Scalable or elastic infrastructure to support transient demand peaks
	Transcoding	Efficient and scalable video transcoding which is resource aware in order to leverage platform features to improve



		performance e.g. hardware acceleration AVX, GPU etc.
	QoS	Need to guarantees over the quality of the service a user receives. Need the ability to implement different levels of QoS depending on type of user or state of the network.
	Control	Users who are generating content need to have the ability to control how the content lifecycle and how it is exposed.
Business Requirements	Real-time and offline analytics	Real-time analytics are required are required to generate actionable insights at an orchestration level to react to dynamic changes in the network behaviour which could adversely affect service behaviours or performance resulting in poor user experience. Offline analytics are required for build intelligence on the behaviour of the network and the creating insights in the patterns of service consumption such as video content generation.
	Real-time telemetry	Required in order for orchestration processes in the network to react to changes in network state or events.
	Mobile device metrics collection	Is important to have metric from mobile devices to determine the quality of the user experience both from a content generation and consumption perspective. It is important to understanding the effect different device version or OS versions have on service performance.
	Pay for service models	Have the ability to offer different levels of service with different costs models. Support both short term (minutes, hours) and longer-term (monthly) contracts.

5.5 Context Aware Smart Living.

Use case	Intel Use Case 3 – Context Aware Smart Living.	
Description in a nutshell	<i>A key focus for the proliferation of IOT devices is realisation of a connected world where devices and sensors are connected in a seamless manner to support humans in the daily activities of living. The combination of sensor, actuators, mobile devices, ubiquitous high-speed wireless connectivity and cloud infrastructures will the support the realisation of a smart society where intelligence is embedded into all aspects of daily life such as smart transport, smart home, smart health and wellness and so forth.</i>	
Technical	Aggregation	Base stations for IOT devices will need to be deployed at sufficient density to ensure that one more aggregation



Requirements		connections are available to an IOT device.
	Orchestration	<p>Intelligent Orchestration will be required to manage the IOT aggregation nodes at large scales to enforce consistent device policies.</p> <p>An orchestrator will be capable of isolating one or more base stations from the network when an anomalous event occurs such as a security breach due to a malicious attack.</p>
	Connectivity	<p>Aggregators will need to support a variety of front side radios such as Bluetooth, Bluetooth Smart, Ant, Zigbee, Wi-Fi etc. for sensor or device communications.</p> <p>Software define radios maybe a requirement to eliminate the need to implementation multiple independent basebands.</p>
	Flexibility	A base station will have the ability to support multiple use cases simultaneously or can be rapidly reconfigured via a remote firmware push to support either a new service to extent its existing service offerings
	Scalability	Scalable or elastic infrastructure to support transient demand peaks
	Security	<p>Aggregators need to provide secure connection to sensors and actuators</p> <p>Aggregators need to provide secure transfer of data over the network to point of final aggregation e.g. Cloud DC.</p>
	Reliability	Reliable communication should be available at times independent of location.
Business Requirements	Real-time and offline analytics	<p>Real-time analytics are required are required to generate actionable insights at an orchestration level to react to dynamic changes in the behaviour of aggregators due to changes in the density or types of devices connecting to them.</p> <p>Offline analytics are required for build intelligence on the behaviour of the network and the creating insights in the patterns of data generation or information consumption.</p>
	Context Information	Need the ability to monitor, collect and analyse context information in order to tailor service
	Outdoor and in-door connectivity	<p>Device connectivity is required both in-doors and outdoors.</p> <p>Outdoor connectivity should be subject to minimal weather influence.</p>



	Support device heterogeneity	A wide of variety devices need to be supported ranging from environmental sensors, body worn device, health devices, home sensors etc.
	Support for any-to-any communications	Support various uplink or downlink communications ,device to device and node to node self-backhauling
	Ability to collect sensor data from user smartphones	Sensors on smart phones provide valuable data which can be fused with other data from the phone such as location to provide context.

5.6 Internet of Things (IoT) & SUPERFLUIDITY Platform Scenario

Use case	Internet of Things (IoT) & SUPERFLUIDITY Platform Scenario	
Description in a nutshell	<p><i>Superfluidity and interoperability in the IoT: the ability to instantiate IoT services on-the-fly (pub/sub brokers, gateway between different IoT networks), run them anywhere in the network edge (micro server) and shift them transparently to different locations, integrating vertical and/or proprietary platforms and devices.</i></p> <p><i>The ability to create on the fly a network (ad-hoc or/and infrastructure) composed by smart objects.</i></p> <p><i>The ability to use local communication (LTE Direct, BLE) instead of remote when needed: E.g. not all nodes can reach the internet, e.g. some nodes have to save energy.</i></p>	
Technical requirements	Integration of IoT gateways in RAN	IoT devices connects to the internet: i) Using a specialized protocol, e.g. ZigBee, BLE, BACnet ii) Integrating the device into the IP-world, e.g. 6LoWPAN, CoAP, MQTT. In both cases the IoT devices connects to the internet using a kind of "gateway" that provides the entry to the network (i) or that translate between protocols (ii, e.g. 6LoWPAN to IPv6, CoAP to HTTP). The functions, performed by these gateways, could be virtualised using the SUPERFLUIDITY platform (e.g. on a microserver).
	Integration with local communication (LTE Direct, BLE)	<ul style="list-style-type: none"> - Self-configuration and reconfiguration - Support different network topologies: nodes can be deployed in deterministic or random topologies; in both cases, the network must adapt to the different topologies and adapt to changes - Support of mixed scenarios combining ad-hoc networks and provisioning of network infrastructure - Seamless combination of heterogeneous wireless accesses
Business	Support of third party access and gateway	The IoT gateways and services could be provided by third party entities that should be allowed to deploy their own



Requirements	services in RAN	virtualized entities in the RAN. Computing resources in the RAN would be shared by the RAN operator to the third party providers.
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5.7 Context-adapted data delivery

Use case	Context-adapted data delivery	
Description in a nutshell	<i>Ability to adapt the delivery of content based on context information, including location but not restricting to it and including also an estimate of the user behaviour (e.g. user on the move, potential user interests, etc.)</i>	
Technical requirements	Capability to monitor, collect and analyse context information	Ability to provide basic (and hopefully standardized or at least systematically addressed) “ambience” primitives which are offered by the RAN operator to the application providers (e.g. a “venue operator”) so as to rapidly deploy, provision, and customize the desired service
	Context processing in the edge	- ability to process sensed data on the edge and classify “context” - edge storage and processing of content for low latency delivery
	Context-aware scheduling and resource allocation strategies	The system should make sure that the right type of content type is pushed to the user: a walking/driving user is arguably not expected to be interested in full quality video opposed to a sitting/standing user
Business Requirements	Privacy issues	The information should be collected (and then exposed) with the user’s consent
	Accounting	Depending on the business model it may be needed to account for the resource usage for context processing

5.8 Transparent web service acceleration

Use case	SF-ONAPP-1 – Transparent web service acceleration to support lower latency and improve QoE for end-users	
Description in a nutshell	<i>Re-writing of static content is performed to take advantage of CDN paths that is then synchronised with the Edge nodes.</i>	
Technical requirements	Processing Latency	The latency is dependent on the size of the VM to be accelerated and the resources allocated to the accelerator
	Latency	Latency after the first re-direct should be that of the closest Edge-Node



	Availability of processing platform	The service should be stateless and be run as a VM on the host site. If it fails, this should be detected and the VM restarted and the admin notified.
	Availability	Edge nodes on the Federation will have their own availability values that will be captured in an SLA
	Scalability of processing platform	Currently only a single accelerator is allowed per network. Ideally this service will be scalable depending on the number of VMs that need to be accelerated
	Scalability	Many edge nodes / PoPs can be used. The load balancer with the re-direct should also be scalable
	Caching	As the content is all at the same site as the accelerator no caching is required
	Caching at the edge	Content caches should be large enough to fit all the content for which subscribers are paying for
	Security of processing system	The platform has access to all the VM resources that will be accelerated. Great care should be taken to ensure that content from users are isolated and cannot have an effect on other users of the platform
	Security of edge nodes	Given that the static content is replicated from the source, the integrity should be the first priority. A compromised edge node may try to perform a DoS attack but this can be mitigated.
	Platform	Requires a-priori knowledge of CDN edge sites that are compatible with the accelerator and a pre-established agreement with edge nodes for publishing content
	Acceleration	The level of performance required is expected to be low. If lower latency is required then acceleration may be required.
	Orchestration	The platform needs access to the VM content resources for accelerating. The platform also needs to be able to synchronise with edge-nodes in a consistent manner.
	Orchestration of CDN platform	Edge nodes need to be notified of content changes on the source. If a PoP goes down all routes through that PoP must be recalculated and performed on other Edge nodes.
	QoE	The latency should generally be that of the closest edge node. For dynamic content, delays are expected to retrieve content from the master.
Business	New additional service	This would normally be done by someone performing some



Requirements		manual operations to change the web-page content to use a CDN platform, or configure the web-development platform to use the CDN. This is a new value added service that helps those unfamiliar with CDN to take advantage of the platform
	The compression, HTML re-writing and the synchronisation require compute time, storage, network and memory	This takes resources away from other VMs on the platform and so should be taken into consideration. The resources though are taken from the same cloud operator as it is run on the operators' infrastructure.
	Possible extension – utilising an alternate CDN network	If another CDN network is used as the end-point rather than in-house CDN network then this CDN'ification of a web-site would need a different business model.
	User experience	The main business model is to keep the system very simple with few technical modifications and interventions required.
	Security	Confidentiality of web-site content must be assured as well as Integrity. For purposes of logging the changes and being able to assure users that only authenticated changes were made there should be non-repudiation

5.9 Rapid and massively-scalable instantiation of (virtual) application instances

Use case	SF-ONAPP-2 - Rapid and massively-scalable instantiation of high performance (virtual) application instances for high-performance storage solutions	
Description in a nutshell	<i>Current VMs are quite large and heavy, requiring a full Linux O/S to be provisioned. We challenge this model to use much more light-weight instances that can be then used for a multitude of applications that are otherwise inaccessible. In particular we use our experience of storage systems to migrate content close to the end-user to improve the QoS</i>	
Technical requirements	Modification of the HV platform to support light-weight instances	Xen / KVM and other HV solutions currently use bloated VMs and so are efficient for loading them in the time-scales relevant to that type of VM. The scalability has been shown to be quite limited without modification. See NEC / ClickOS framework papers. Need to reduce the overhead in the VM handling in these platforms. Xen-Store was modified in previous work by NEC
	Integration with hardware features	Take advantage of low-level hardware features for acceleration and attempt to couple the system as tightly possible for performance improvements.



	Scalability	Instead of the 100s of VMs that are currently possible on existing HV platforms the idea is to scale to many times this to take advantage of many-core platforms that are emerging from processor manufacturers
	Availability	The availability of any one instance should be quite high but given that the instances are stateless if an instance doesn't reply quickly enough, a new instance can be spawned. For high-performance storage systems the availability should approach 5 nines.
	Throughput	The throughput is the most important metric for the high-performance storage use-case. Each individual VM instance should take a fair share of the raw I/O performance. The overhead of the virtualised system w.r.t throughput performance should approach as close to 0 (e.g. raw performance) as possible.
	Security	Each storage instance should enforce isolation and there should be no confidentiality or integrity vulnerabilities
	Acceleration	The platform should take advantage of all NIC / RAID / CPU acceleration features to optimise the storage processing performance.
Business Requirements	Leverage benefits of unikernel	Light-weight VM instances do not offer multiple processes. The applications and services need to be re-constructed to be single process and stateless to be of maximum benefit.
	SFC	Multiple light weight services could be chained together, using the output of one Unikernels output as the input of another. Good performance handling of VMs communicating on the same platform will lead to powerful combinations of services.
	Traditional VMs	The MicroVisor is more suited for light-weight instances. Traditional VMs if they are running on ARM would need to be compiled to make use of the ARM ISA.
	ISA agnostic workloads	If a high-level DSL can be generated that describes the services, then the ISA that the service runs on may become of secondary concern as the workload could be transferred between different containers and run as required. Spare workload capacity could be auctioned off or sold, using a SUPERFLUIDITY business model – to be worked on.



5.10 Local Breakout (LBO)

Use case	Local Breakout (LBO) (PTIN-1)	
Description in a nutshell	<i>Local Breakout intends to avoid user traffic to be sent to the mobile network core, when communication parties are on the same edge network (e.g. eNB). On 3GPP networks, by default, all traffic is terminated on the mobile core (PDP/PDN). However, in many cases, knowing that users are attached on the same edge, communications can be circumvented, making the connectivity more efficient. A similar concept may also be applied to fixed networks.</i>	
Business Requirements	Functional	The solution must be able to forward specific UE traffic to a Corporate Network and vice-versa
	Accountability	The solution must be able to account the details of the traffic forwarded/received from the Corporate Network
	Scalability	The solution must be able to scale according to the required load
Technical requirements	User-Data Plane Access	The Edge System must be able to get access to user-data traffic (Uplink/Downlink)
	Traffic Inspection	The Edge System must be able to inspect user-data traffic (Uplink/Downlink) considering a set of traffic rules
	Traffic Breakout	The Edge System must be able to break out user-data traffic coming from UEs, according to a set of traffic rules, and forward it to a Corporate Network
		The Edge System must be able to break out user-data traffic coming from a Corporate Network, according to a set of traffic rules, and forward it to some UEs
	Filtering Rules	Traffic rules must support up to layer 7 parameters
	APIs	All Edge System functions are accessed by using specific APIs provided by the Edge System

5.11 virtual Convergent Services (vCS)

Use case	virtual Convergent Services (vCS) (PTIN-2)
Description in a nutshell	<p><i>The vHGW use case intends to move traditional functions (e.g. firewall, parental control, NAT, etc.) residing on the customers' home to a virtual HGW (vHGW) in the cloud. In a convergent scenario, these services apply both to fixed and mobile environments, providing a converged desired behaviour, either when the user is at home or using a mobile device.</i></p> <p><i>The vSTB component complements the use case, extending the usage of a virtual STB to a multi-screen scenario, simplifying the convergent environment, reducing operator</i></p>



	<i>investment and making easier the upgrade and deployment of new services, being accessible to the user from any terminal.</i>	
Business Requirements	Functional	The solution must be able to provide, from the cloud, convergent services to mobile and fixed users (services can be traditional HGW services, e.g. Parental Control, Video Streaming, or new services)
	Accountability	The solution must be able to account the details about the provided convergent services
	Scalability	The solution must be able to scale according to the required load
Technical requirements	User-Data Plane Access	The Edge System must be able to get access to user-data traffic (Uplink/Downlink)
	Traffic inspect and processing	The Edge System must be able to access user-data traffic to/from UEs, according to a set of traffic rules, redirecting it to the Services
	Latency	Latency should be unperceivable to users (in comparison with a real STB using remote control) and jitter should not preclude existent quality
	Service management	The system shall be able of perform the management of the service core control functional blocks (Firewall, Parental Control, NAT, etc.)
	Lifecycle management	The system shall be able to manage (Create/Activate/...) the lifecycle logical convergent services
	Services chaining	Multiple Converged Services can be chained in order to delivered combined services to the UE
	APIs	The Edge System functions are accessed through APIs
	Dynamic Services	The platform shall be able to dynamically change services to be made available to users
	Performance management	The platform shall collect and analyse data parameters (received packets, sent packets, lost packets, CPU usage and memory usage) to perform planning, provisioning, maintenance and quality measurements.
	Security	The system shall be able to guarantee service resources protection and isolation



5.12 Video Orchestration and Optimisation

Use case	Video Orchestration and Optimization (PTIN-3)	
Description in a nutshell	<p><i>Video Orchestration intends to orchestrate the video contents sent to users, in advanced scenarios like multi-camera events (e.g. football match), where the user may choose the camera he wants to see. This may include advertisement videos.</i></p> <p><i>Video Optimization intends to increase the quality experienced by the user, considering the current access conditions. The quality of the video is adapted to the receivers.</i></p>	
Technical requirements	Connectivity	The Mobile edge platform shall provide a secure environment for providing and consuming services when necessary.
		The Mobile edge platform shall be able to select one or more applications to which the same traffic will be routed and assign priorities to them. The selection, prioritisation and routing during traffic redirection shall be based on re-direction rules defined per application
		The MEC platform needs to provide mechanisms to connect the local production devices (e.g. video cameras and sensors) to the video orchestration Mobile edge application as well as the UEs of the consumers that use the video orchestration service.
		The Mobile edge system shall be able to maintain connectivity between a UE and an application instance when the UE performs a handover to another small cell to another cell associated or not with the same Mobile edge server
		The Mobile edge platform may use available radio network information to adapt contents, guaranteeing service delivery.
		A video adaptation feature may be associated to the service, being provided by the edge platform
	Security	The Mobile edge platform shall provide a service to allow authorised applications to communicate with services provided by the platform
		The Mobile edge platform shall provide a secure environment for providing and consuming services when necessary.
	Location	The platform shall provide a service presenting the list of UEs per particular locations, with context information
	Monitoring	There shall be a service providing appropriate up-to-date radio network information including measurement and statistics information related to the user and radio network.
There should be an application that will dynamically adapt user		



		traffic requirements to radio network conditions improving QoE
	Routing	The Mobile edge platform shall provide a service to allow authorized applications to send/receive user plane traffic to/from UEs
		The Mobile edge platform shall provide a service to allow authorized applications to inspect and modify selected uplink and/or downlink user plane traffic
		The MEC management functionality shall allow the management of the traffic redirection rules
		The Mobile edge platform shall be able to select one or more applications to which the same traffic will be routed and assign priorities to them. The selection, prioritization and routing during traffic redirection shall be based on re-direction rules defined per application. (The prioritization is used to determine the routing order between the applications)
		The Mobile edge platform should provide data distribution taking advantage of multicast technology (e.g. unicast/multicast adaptation)
Business Requirements	Monitoring	The Mobile edge platform shall allow the collection of charging-related information (traffic usage, application instantiation, access, usage duration, resource usage, etc.), log it in a secure way and make it available for business processing
	Stakeholders	Stakeholders, as for example OTT should have well defined rules to access MEC ecosystem
		The Mobile edge platform shall be able to present available services and the related APIs to applications for 3 rd party players (OTTs, advertisement)
	Big data analytics	It should be gathered customers information to enhance QoE and perform better customization addressing new stakeholders offers
		Location based services can be used to embrace new business partners in value chain

5.13 Virtual CDN for TV contents distribution

Use case	PTIN Use Case 4 - Virtual CDN for TV contents distribution
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Description in a nutshell	<p><i>This scenario addresses content caches deployment, close to network edge, running own rules, based in behaviour analysis and consumptions' forecasts. This may be associated to virtualised CDN, allowing several players to deploy their own CDN, according to their rules and needs.</i></p> <p><i>Current Internet contents distribution CDNs are based in traditional content caching algorithms, based in observed contents popularity and the distribution rules are similar for all contents and producers. However, other types of services require different rules to cache contents closer to users' location, like TV. Contents are stored in the edge repository but only become available after their scheduled transmission time. After that, they stay available in the edge for a defined period of time; after that, they become available only from a central data centre, freeing storage space for other contents.</i></p> <p><i>This may be associated to mobility, with contents following potential consumers, while they change attachment points to the network, creating a more demanding use case, closer to Superfluidity objectives.</i></p>	
Technical requirements	Storage	Need to deploy storage capacity at the edge to store multimedia contents
	Analytics	Traffic and service monitoring to extract statistics on the viewed contents
	Connectivity	For fast content transfer between edges, following users
	Users tracking	Be aware of users' profiles served by a certain edge
	Content mobility	Be able to efficiently transfer content between edges
	Multicast/unicast	While contents are distributed and transferred using multicast between edges, efficiency in the radio interface can be improved with the adoption of multicast; a unicast/multicast adaptation function may exist
	Monitoring	Produce cache usage indicators
	Content adaptation	In order to better adapt to radio conditions, video adaptation at the edge can be provided.
Business Requirements	Accountability	<p>Account for:</p> <ul style="list-style-type: none"> - storage space used at the edge - transferred data volumes - transcoding operations - uni/multicast adaptations - served volume of data - served number of users - number of visualizations



5.14 Business Communications

Use case	Business Communications (PTIN-5)	
Description in a nutshell	<p><i>Enterprises and operators with installed small cells may take advantage of traffic breakout at the edge, allowing an efficient communication at their premises without requiring the traffic to go to the core of the network. This is valid for data exchange but also for other type of communication services, like voice and Unified Communications.</i></p> <p><i>In particular, the applications to support the unified communications can be deployed at the edge, become even mobile, following the user when outside the enterprise, reducing the backhaul resources consumption and increasing the network responsiveness (low delay).</i></p> <p><i>Context:</i></p> <ul style="list-style-type: none"> • <i>Smartphones, tablets, etc. (mobile terminals), replace traditional fixed terminals at the enterprises</i> • <i>The ‘office’ moves to the terminal, using services provided by the operator, in both cases possibly hosted in a Cloud</i> • <i>Mobile networks replace private traditional enterprise networks</i> • <i>Small cells being installed at companies to increase capacity</i> • <i>The operator network is used as additional, distributed, enterprise resources</i> 	
		<p>The Mobile edge system shall be able to maintain connectivity between a UE and an application instance when the UE performs a handover to another small cell to another cell associated or not with the same Mobile edge server</p> <p>On demanding network should be made available to enterprise employees depending on the used business applications (HD videoconference, enterprise video messaging...)</p> <p>The Mobile edge platform shall be able to select one or more applications to which the same traffic will be routed and assign priorities to them. The selection, prioritisation and routing during traffic redirection shall be based on redirection rules defined per application</p> <p>Small cells interconnection should be ensured by automatic setup</p> <p>Storage</p> <p>There should be made available elastic and persistent content storage space</p> <p>Security</p> <p>The Mobile edge platform shall provide a service to allow authorized applications to communicate with services</p>



		provided by the platform
		User communications should be based on a single user identity providing easy access management service controlled by a MEC application
	Breakout	The Mobile edge platform shall provide a local breakout feature
		The LBO should filter and route the intended enterprise business traffic
		The Mobile edge platform shall provide a service to allow authorized applications to inspect selected uplink and/or downlink user plane traffic
		Redirection of traffic between UE and to/from Internet applications to Mobile edge platform according to configurable parameters.
	Monitoring	A MEC application should be designed to gather statistics concerning usage of available services (in order, for instance, of pre downloading and caching information that could be of interest to other employees)
		To implement a MEC application able to ensure user traffic dynamic adaptation (e.g. via contents recoding) to the current small cell capacity (bandwidth, latency,...)
Business Requirements	Monitoring	The Mobile edge platform shall allow the collection of charging-related information (traffic usage, application instantiation, access, usage duration, resource usage, etc.), log it in a secure way and make it available for business processing
	Configuration	MEC applications configuration shall be easy in terms of offering new service Bundles with dynamic pricing offers
	Stakeholders	Stakeholders shall have well defined rules to access MEC ecosystem
	Big data analytics	Customers behaviour information shall be gathered to enhance QoE and perform better customisation addressing new stakeholders offers
	Management	Applications to converge enterprise and operator services should be scalable allowing the adding, modifying or deleting of users and services.
	Location	It shall be possible to deploy the Mobile Edge Server at



		various locations (at operator or at enterprise) according to chosen business model.
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5.15 NDP Spoofing

Use case	Telcaria Use Case 1 - NDP Spoofing	
Description in a nutshell	<i>Implementation of a defence against NDP-Spoofing, for example the SEND protocol, by means of VNFs.</i>	
Technical requirements	SEND protocol	Implementation of the SEND protocol
	Detection time	Seconds or minutes
	Identification time	Seconds or minutes
	Reaction time	Seconds or minutes
	Effectiveness	At least similar to current implementations Measured as: <ul style="list-style-type: none"> • Percentage of attacks detected • Percentage of attacks blocked • Percentage of false positives
	Building Blocks	Implementation of the following building blocks: <ul style="list-style-type: none"> • Idle: discards packets • Switch: sends packet stream to settable output • Hub: duplicates packets like a hub • Queue: stores packets in a FIFO queue • EtherSwitch: learning forwarding Ethernet switch • CheckIPHeader: checks IP header • IPFilter: filters IP packets by contents • SEND: SEND protocol implementation
Business Requirements	Protection against NDP Spoofing	Protection against NDP Spoofing
	Cost savings	Development and deployment costs less than current solutions
	Deployment time	Deployment time much shorter than current solutions
	Reaction time	Reaction time shorter than current solutions
	Effectiveness	Effectiveness at least equal to current solutions

5.16 DDoS Attack Protection

Use case	Telcaria Use Case 2 – DDoS Attack Protection
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Description in a nutshell	<i>Implementation of a defense against DDoS attacks, by means of VNFs.</i>	
Technical requirements	Detection time	Seconds or minutes
	Identification time	Seconds or minutes
	Reaction time	Seconds or minutes
	Restoration time	Seconds or minutes
	Tracking time	Seconds or minutes
	Effectiveness	At least similar to current implementations Measured as: <ul style="list-style-type: none"> • Percentage of attacks detected • Percentage of attacks blocked • Percentage of false positives
	Building Blocks	Implementation of the following building blocks: <ul style="list-style-type: none"> • Idle: discards packets • Switch: sends packet stream to settable output • Counter: measures packet count and rate • Queue: stores packets in a FIFO queue • IPRouteTable: Ip Routing Table superclass • RadixIPLookup: IP lookup using a radix trie • CheckIPHeader: checks IP header • IPFilter: filters IP packets by contents • IPRateMonitor: measures incoming and outgoing IP traffic rates
Business Requirements	DDoS Protection	Protection against DDoS attacks
	Cost savings	Development and deployment costs less than current solutions
	Deployment time	Deployment time much shorter than current solutions
	Reaction time	Reaction time shorter than current solutions
	Effectiveness	Effectiveness at least equal to current solutions

5.17 Emergency communications

Use case	Emergency communications (TID)
Description in a nutshell	<i>Capability of the network to repurpose itself after a disaster for providing specific services based on the remaining infrastructure available, including user devices and other networks. Support of specific services for specific groups (police, firefighters, rescue teams,...), including the capability to locate specific devices, broadcast messages and form device supported extensions to the network.</i>



Technical requirements	Emergency detection	The network should be able to detect when an emergency situation has happened and, consequently, the emergency communications operational mode should be activated. This activation should happen with enough security guarantees to avoid false alarms that may disrupt the normal operation of the network.
	Self-evaluation	After an emergency situation has been detected, the network should be able to assess the resources that are available for the support of the services. For these purposes, the network should be able to carry out connectivity tests as well as being able to report the processing resources available at different locations. These self-evaluation procedures should encompass the infrastructure from different operators and tenants
	Self-configuration	Based on the results of the self-evaluation process, the network should be able to configure itself in order to provide emergency services. In this sense it should be able to assign roles and allocate functionalities to the resources available.
	Resources grabbing	The network should be able to take resources from other applications in order to support emergency communications. They may include, e.g., spectrum resources allocated to other services like broadcast services, or computing and storage resources in data centres
	Service prioritisation	The network should be able to prioritize the different service requests according to the policy that has been defined for emergency situations. This may include blocking end user services in order to avoid congestion situations.
	Broadcasting support	The network should support the broadcasting of specific messages, like alerts or instructions for the population. The network should be able
	Energy saving	The network should be able to control the configuration of devices and network elements in order to save energy, especially if access to the power grid is not feasible or is not reliable
	Special services support	The network should be able to support special services, like group communications between specific groups (police, firefighters, rescue teams,...), location assistance services (e.g., for people under collapsed buildings), etc.



	Network expansion through D2D	The networks should be able to use UEs in order to extend the coverage area. The network should be able to discover the topology of the connections established among the devices.
	Name based addressing	The network may be able to support the access to specific contents based on their name, regardless of their collection.
	Network securing	The network should be able to provide basic security services even in the case that the security infrastructure is not available or reachable.
		The network should be able to prevent or minimize the effect of Denial of Service (DoS) attacks.
Business Requirements	High availability	For certain network resources, high availability should be provided in order to increase the network survivability in case of disaster.
	Reusability	A subset of the procedures defined for emergency communications should be reusable for dealing with other, less dramatic situations, like failures in different parts of the network, loss of connectivity, sabotages, etc.
	Public private partnership	Public sector should be involved in the definition of the procedures and policies to be used for emergency communications, as well as in the financing of the additional infrastructure that may be required to guarantee a certain degree of reliability and survivability.

5.18 Late Transmuxing (LTM)

Use case	Late transmuxing (LTM)	
Description in a nutshell	<i>Instead of using the CDN network only as cache, the CDN (edge) nodes could be used to create requested formats when needed, saving bandwidth and storage within the network, increasing edge resource usage and improving user experience.</i>	
Technical requirements	libfmp4	The USTR muxing software used in the web-server for LTM.
	Webserver	Linux platform that can support a web-server e.g. Apache or Nginx, the LTM instance.
	Storage	Upstream providing mezzanine audio/video samples, accessible over HTTP (accepting range requests, e.g. S3).
	CMS	Service for LTM instances to fetch configuration (server manifest) from, configuration can change dynamically.



	Keyserver	In case the output needs to be encrypted or DRMed a keyserver is needed (which can be behind the CMS, where the CMS adds keys to the server manifest).
	Latency	Latency between storage and LTM instance should be low enough but cache priming (setting up local caches with content to be ready for expected load) or 'prefetch' (fetching next chunk before time) may be employed as well.
	Autoscaling	The setup should be able to add and remove LTM instances based on load or other metric, automated.
	Loadbalancer	For failover and orchestration purposes.
	Monitoring	Monitor stream characteristics on LTM instance (bandwidth, sessions, streams).
Business Requirements	Cost saving	Method to quantify cost saving from lower internal network traffic and storage use.
	Lower latency	Method to measure LTM instance-viewer latency in comparison to traditional setup.
	Sizing	Method to size resources needed for specific scale / output.
	Better resource utilisation	Method to quantify resource usage in comparison to traditional setup.
	Better user experience	Method to quantify user experience improvement.

5.19 S/Gi-LAN Services on the (Mobile) Edge

Use case	S/Gi-LAN Services on the (Mobile) Edge (CITRIX-1)
Description in a nutshell	<p><i>In today's mobile networks, services involving traffic management/DPI and transport/content optimisation have traditionally been deployed on the Internet side of the GGSN/P-GW, i.e. in the S/Gi-LAN.</i></p> <p><i>Even though the industry recognizes the utility of these services, always in the context of the Mobile Data Tsunami and the desire of operators to differentiate from their competitors on the basis of QoE, deploying such solutions in a scalable fashion is becoming increasingly challenging/costly.</i></p> <p><i>Moreover, the lack of accurate visibility on RAN conditions makes it very difficult to</i></p>



	<p><i>deliver traffic management and transport/content optimization in a way that achieves balance between network efficiency and QoE.</i></p> <p><i>The flattening and “IP-fication” of the network, in the evolution from UMTS to LTE and, eventually, to 5G, provides opportunities of pushing these services into the RAN and towards the Edge of the network.</i></p>	
Technical requirements	User-Plane Access	The traffic inspection, management and optimization services will require access to user-plane traffic, i.e. the data flows enclosed in packet data protocol sessions.
	Content/Application Awareness	Traffic must be inspected (on the basis of data flows) to identify the type of content being transferred and the type of application that is consuming the content. Focus would be on identifying traffic that can be optimised (e.g. ABR video, even if it is encrypted).
	Mobile Network Awareness	The traffic management/optimization functions should be aware of the radio-access type, radio resource allocation, cell congestion level, cell location/topology and other such information necessary for adapting the delivery of services.
	Subscriber/Device Awareness	The services must have access to subscriber identifiers (MSISDN, or equivalent) and, optionally, device identifiers (IMEI, or equivalent) to apply traffic policies with the corresponding granularity (i.e. on a per user or UE basis).
	Mobile Edge APIs	Accessing the above information from the control-plane should not require implementing the relevant protocols, but must be exposed by APIs provided by the Mobile Edge infrastructure.
	Policy Engine	Combining the data-plane and control-plane inputs with the configuration/preferences of the operator to make decisions and apply actions requires a Policy Engine.
	End-to-End Transparency	Traffic manipulation actions must not break end-to-end transparency. Session state will still have to be tracked.
	Transport Optimization	Transport-layer (L4) optimization, initially focusing on TCP. Objective is to achieve high network speeds, efficient use of network resources, congestion control and low latency.
	Traffic Regulation	Regulation/pacing of traffic flows is a traffic management action that helps to conserve network resources. Useful for ABR video (nowadays and in the foreseeable future).
	High Speeds	Services must support per-user speeds aligned with the maximum bounds offered by the 5G mobile network.



	Low Latency	Injection/activation of these services must not increase end-to-end latency by more than a few milliseconds.
	Mobility Aware	Services must be robust to mobility effects, even in the presence of state that is maintained on a per flow basis.
	Dynamic Placement	Instantiation/tear-down and placement of the services must be dynamic, taking into account time-of-day, traffic levels, cell congestion levels, user experience metrics, etc.
	Throughput	Service instances must support total throughput aligned with the throughput of Mobile Edge Data Centres (DCs). Resource efficiency can be optimised internally, if the implementation uses lightweight instances, and traffic processing takes place in the user-plane (not kernel).
	Auto Scaling	Resources allocated to the service instances must be automatically/elastically scaled, on a per Mobile Edge DC basis, depending on load and to support transient peaks.
	Availability	Traffic processing services must offer 5 nines availability.
	Load Balancer	If traffic needs to be balanced between multiple service instances, load balancer must support stickiness on a per subscriber/UE (or underlying data flow) basis.
	Orchestration	Intelligent orchestration infrastructure that ensures that services are deployed on the most appropriate platform, taking into account the heterogeneity of resources and scaling them according to the business requirements.
	Service Chaining	Since these services will be probably deployed together with other traffic inspection or traffic processing services, the Mobile Edge infrastructure needs to provide a traffic steering and/or service chaining function.
	Service Monitoring	Estimates the QoE delivered by these service instances.
	Resource Monitoring	Monitors HW resources to drive orchestration decisions.
	Security	Injection of these services must preserve overall security
Business Requirements	User Satisfaction	In advanced networks, the primary business goal of traffic optimization services is to improve user satisfaction and reduce churn, via improving quality of experience (QoE). Migrating such services from the S/Gi-LAN to the Mobile Edge maximizes chances of achieving the above objective.
	Benchmark Testing	Another objective of traffic optimization services is to improve ranking in annual benchmarks (where operators of the same



		market compare with each other, in terms of network performance). Deploying these services in the Mobile Edge provides the required precision to succeed.
	Network Efficiency	Mobile operators would want to maximize the use/yield of their RAN network investment. Transport optimisation helps with accomplishing this. Migrating these services to the Mobile Edge will allow them to leverage information that is not available in their current placement (S/Gi LAN), which will further assist accomplish the specific goal.
	Congestion Management	Effective traffic management and optimization services need to be also conscious of the congestion levels in the radio network. For example, being too aggressive in transport optimization may actually make the situation worse in a congested network. One downside of moving these services to the Mobile Edge is that they will no longer be able to manage congestion in the mobile core.
	Cost Savings	Instantiating traffic optimization services only in areas that require them will make the costs of deploying them more sustainable, in both emerging and advanced Telcos.
	Quick Deployment	Assuming the pre-existence of the Mobile Network Edge and service orchestration infrastructure (see technical requirements), deployment of these services should be faster (shall take days-weeks rather than many months).
	Service/Performance Management	As in the current deployment model, the network operations and planning team will need to be able to manage the operation and configuration of the services, and monitor their performance to assess their benefits.
	Network Analytics	Traffic management and optimisation solutions have always been valuable data input sources for network analytics solutions. We envision that detailed KPI metrics generated by these services shall be integrated into the big data analytics infrastructure, supplementing or superseding the metrics generated by (virtual) probes. Based on the historical metrics, and using trending, forecasting and machine learning techniques, insights extracted can be fed back to the traffic handling services, in terms of policies, towards optimizing them further.
	Transparency	As all data plane services, they need to be adequately “low touch” to not impact transparency of important services, i.e.



		Lawful Interception, Billing & Charging, etc.
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5.20 On the fly Ad Removal Offloading

Use case	On-the-fly Ad Removal Offloading (NEC)	
Description in a nutshell	<p><i>Given the proliferation of online advertisements and the fact that a large number of players based their revenue model on them, it is perhaps unsurprising that ad blockers have become commonplace. While certain useful, they do consume CPU cycles as they scan incoming traffic which results in reduced battery life when talking about mobile devices. In this use case we propose to provide an on-the-fly, virtualised ad blocker service that can be run in edge networks, essentially offloading this functionality from mobile devices in order to increase their battery life.</i></p>	
Business Requirements	Functional	The solution must be able to remove online advertisements from incoming traffic
	Accountability	The solution must be able to log its usage for accounting purposes
	Scalability	The solution must be able to scale according to the required load
Technical requirements	User-Data Plane Access	The system must be able to get access to user-data traffic
	Traffic Inspection	The system must be able to inspect user-data traffic considering a set of traffic rules
	Ad removal	The system must be able remove online advertisements from incoming traffic.

6 References

- [1] Ramjee Prasad and Alben Mihovska, "Challenges to 5G standardisation", <https://itunews.itu.int/En/4619-Challenges-to-5G-standardization.note.aspx>
- [2] Recommendation ITU-R M.2083-0 (09/2015) IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond. http://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2083-0-201509-1!!PDF-E.pdf
- [3] Wonil Roh, "5G Mobile Communications for 2020 and Beyond - Vision and Key Enabling Technologies", Samsung Electronics Corp., EUCNC 2014, Bologna, June 2014.



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- [4] Juniper Research, 5G Market Strategies, <http://www.juniperresearch.com/researchstore/enabling-technologies/5g-market-strategies/4g-lte-evolution-spectrum-analysis>
 - [5] Cisco Visual Networking Index: Forecast and Methodology, 2014-2019 White Paper, http://www.cisco.com/c/en/us/solutions/collateral/service-provider/ip-ngn-ip-next-generation-network/white_paper_c11-481360.html
 - [6] “5G Vision - The 5G Infrastructure Public Private Partnership: the next generation of communication networks and services”, February 2015, Available: <https://5g-ppp.eu/wp-content/uploads/2015/02/5G-Vision-Brochure-v1.pdf>
 - [7] NGMN 5G Whitepaper, https://www.ngmn.org/uploads/media/NGMN_5G_White_Paper_V1_0.pdf
 - [8] Mobile-Edge Computing – Introductory Technical White Paper, https://portal.etsi.org/Portals/0/TBpages/MEC/Docs/Mobile-edge_Computing_-_Introductory_Technical_White_Paper_V1%2018-09-14.pdf
 - [9] Mobile Edge Computing - A key technology towards 5G, http://www.etsi.org/images/files/ETSIWhitePapers/etsi_wp11_mec_a_key_technology_towards_5g.pdf