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Use Cases and Requirements

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Abstract

This report provides a description of use cases and requirements and mainly uses input from WP2 tasks and other technical work packages. Some preliminary aspects of trustworthiness are also discussed here.

Keywords

Deliverable keywords go here.

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Contributing Partners

Abbreviation	Company name
BI	BARKHAUSEN INSTITUT
AUS	AUSTRALO
EUR	EURECOM
IFAG	INFINEON TECHNOLOGIES AG
IMEC	INTERUNIVERSITAIR MICRO-ELECTRONICA CENTRUM
RAD	RADIALL
TUD	TECHNISCHE UNIVERSITAET DRESDEN
TIM	TELECOM ITALIA
WINGS	WINGS ICT SOLUTIONS
IMS	INSTITUT POLYTECHNIQUE DE BORDEAUX
ETHZ	EIDGENOESSISCHE TECHNISCHE HOCHSCHULE ZUERICH
IHP	IHP MICROELECTRONICS
NNF	NOKIA NETWORKS FRANCE
IIV	NNF/IIIV LABS
IFAT	INFINEON TECHNOLOGIES
KAL	KALRAY

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Executive Summary

This document is the first deliverable of Work Package 2 (WP2) "Use Cases and Requirements". It presents a comprehensive overview of the COREnext scope, and a description of the case scenarios selected to show the goals of the project. The project is driven by the need for advanced network infrastructure to support emerging technologies and applications that demand high hardware performance to process the expected signal workload, the computations occurring on terminals, base stations and in the mobile edge cloud. Coming advanced network infrastructure must meet increasing performance goals in terms of throughput and latency. At the same time, this enormous compute capacity must be operated efficiently, requiring virtualization and disaggregation mechanisms to improve resource utilization.

The use cases outlined in this document showcase the potential of the proposed by trustworthy-by-design platform for signal processing and hardware acceleration addressing various industry verticals and societal challenges. The project focuses on leveraging a disaggregated computing architecture, where computing resources are distributed across different network locations, to enable efficient and flexible resource allocation, dynamic scaling, and improved network performance.

By providing a comprehensive overview of the use case scenarios, this document serves as starting point to identify the main requirements for evaluating the project's components which will be developed in the technical work packages. The outcome of the document will be relevant for the other WPs to realize a disaggregation landscape, which stretches multiple dimensions including analogue and digital signal processing, hyper-distributed applications (across multiple terminals, base stations, and edge clouds) requiring virtualization and inter-tenant isolation.

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Acronyms and Definitions

ADAS	Advanced Driving Assistance System
AI	Artificial Intelligence
DoA	Description of Action
ITS	Intelligent transportation systems
ML	Machine Learning
MR	Mixed Reality
HPC	High Performance Computing
V2I	Vehicular To Infrastructure
V2V	Vehicular To Vehicular
V2X	Vehicular To Everything
VR	Virtual Reality
XR	Extended Reality
WP	Work Package
ORAN	Open Radio Access Network

1 Introduction

The COREnext project is a forward-looking initiative aimed at developing a 6G platform based on an efficient and reliable disaggregated computing architecture at European level. Specifically, the project aims to address the two challenges associated with the design and deployment of disaggregated, virtualized networks, which are: 1) efficiency by way of virtualized disaggregated accelerators, and 2) end-to-end trustworthiness. Both gaps require innovation within the digital and the analogue domain.

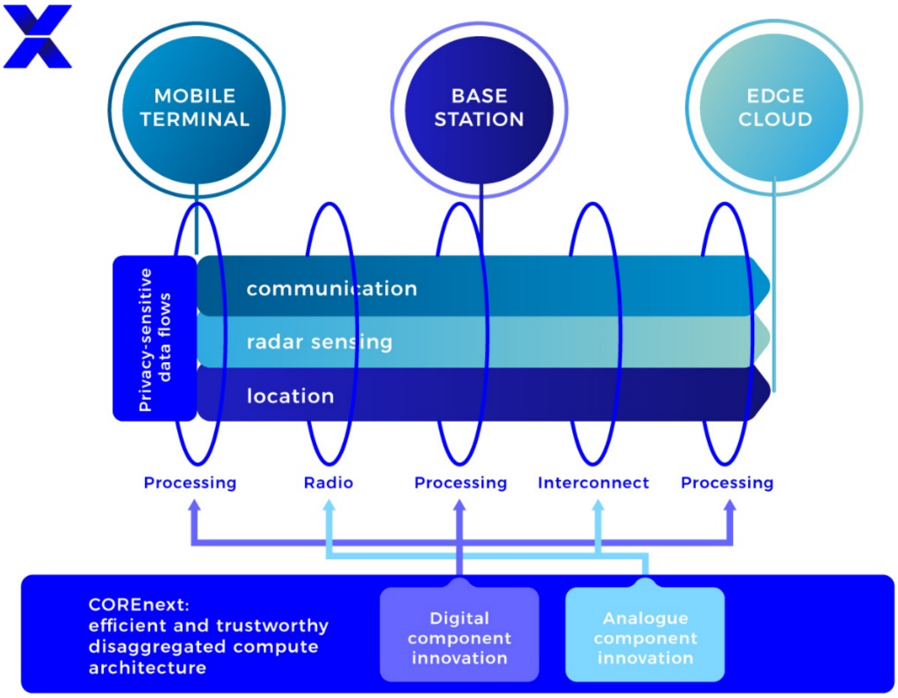

Figure 1-1: COREnext Components

At the heart of the COREnext project is the goal of providing a trustworthy-by-design infrastructure that is capable of supporting a wide range of emerging B5G and 6G use cases, including those that require high levels of reliability, security, and performance to meet expected throughput and latency. This capacity cannot be statically provisioned according to peak demand but must be allocated dynamically by scheduling workloads using virtualization capabilities. The higher flexibility of such an architecture allows data flows and associated processing workloads across terminal, base station, and edge cloud. A diverse range of processing tasks for communication (radio-frequency control, base band processing, etc.), sensing (location, radar, spectroscopy, etc.), and management (interfaces for network operation), as well as third-party applications, will be executed on this infrastructure, performed by a diverse set of efficient compute accelerators.

To this end, the project brings together a diverse group of stakeholders, including researchers, engineers, and industry experts, to collaborate on the development of innovative solutions that can drive the evolution of communication networks in the years to come.

This use case document serves as a comprehensive guide to the different use cases that can benefit from the advancements being made within the COREnext project. The document provides descriptions of each use case, outlining the specific requirements and challenges that need to be addressed to enable successful deployment. Additionally, the document highlights the requirement needed for a large adoption of the provided solution.

All the requirements defined by this document (COREnext D2.1) will be the input Information for COREnext D3.1 where an initial study will identify the necessary platform building blocks considering the disaggregated and virtualized resources, the trustworthiness of the processing and privacy sensitivity of the data.

This document's output jointly with information contained in COREnext D3.1 will be relevant also for the COREnext D4.1 and D5.1 where the necessary innovations for respectively digital and analog processing capabilities at the component level will be provided.

The use cases presented in this document span a wide range of industries and applications, from smart manufacturing and transportation to healthcare and entertainment. Each use case could showcase the unique capabilities of the COREnext approach, but the preference is to increase the detail of the analysis on a limited group of use cases well representative for the requirements and the possible scenario of utilization. The document also starts to emphasize the importance of security and trustworthiness in these use cases, and how the COREnext approach has been designed to ensure that these critical aspects are integrated at every level of the network architecture.

The document is structured to present in chapter 2 a generic description of the objectives and approaches that will be used in the project. The chapter 3 contains the use cases description, at the beginning the chapter contains a background of use cases already defined in other project, this allows to detail some challenging use-cases that can be used as references for the COREnext activity. The chapter 4 is an introduction on the description and the relevance of the trustworthiness. Finally, a conclusion will be drawn in chapter 5.

2 COREnext Target Properties

This section starts with the overall goal of COREnext, from which we derive the properties of the COREnext solution. In the next step, we use these properties to compare our approach with other EU projects (see section 3.1). Finally, we select the use case areas of COREnext matching the desired properties (see section 3.2) and identify the necessary requirements (see section 3.3).

2.1 COREnext Approach

The overall goal of COREnext is to build a computing infrastructure for sustainable and trustworthy B5G and 6G networks. This infrastructure should support a multi-vendor and multi-tenant disaggregated RAN and addresses the throughput and energy-efficiency requirements of applications, while at the same time be trustworthy.

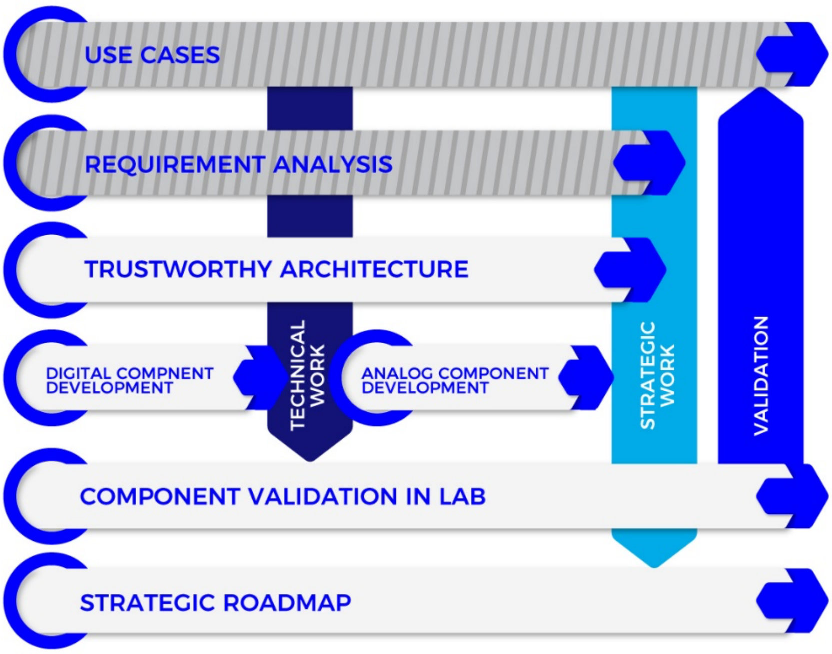

Figure 2-1: COREnext Project Approach

COREnext's approach to address these challenges is to extrapolate the mobile-network evolution for the projected 6G needs now in order to ensure European sovereignty leadership in mobile communication technology. This approach is based on the observation that mobile networks evolve in two steps: the first step introduces a new mobile-network generation for businesses (and verticals?), whereas the second step makes this generation available for personal usages. 1G started with voice services for businesses, followed by 2G with voice services for personal usages. The same happened for data services with 3G and 4G and is expected to repeat for control services with 5G and 6G. We therefore expect personal robotics use cases for 6G networks such as smart city and automotive. However, such use cases pose two major challenges. At first, 6G networks need to be energy efficient to support the expected large number of deployments and large amount of traffic.

Second, 6G networks need to protect the privacy of the users due to the personal nature of these use cases. The last is particularly challenging as vendors from other economies do not necessarily respect European values. For that reason, we consider research in this area to be critically needed and important for Europe and its citizens.

2.2 COREnext Scope

Due to the size of this research area we now want to define the scope of the COREnext project within this area. The scope of COREnext can be split in two dimensions: architecture tiers and technology stack.

COREnext considers three different architecture tiers:

1. Terminal devices: these devices are connected by air interface to base stations and come in different flavours. On the end-user side, these can be mobile phones or AR goggles. But terminal devices can also be machines like robots, factory equipment or cars.
2. Base stations: these devices terminate the wireless connection for terminal devices and are in turn connected via RAN to an edge cloud.
3. Edge clouds: these devices are responsible to run use-case specific application workloads.

An important factor in the interoperability of these heterogeneous devices is standardization performed for example by 3GPP or the O-RAN alliance.

Besides the different architecture tiers, COREnext considers the following technology platforms. On the lowest layer, COREnext performs research on the analogue/RF Hardware for ultra-high speed data links at short distances using transceiver front-end circuits and plastic waveguides. The radio access analogue components are the first circuits after the airwaves hit the antenna and therefore are the most exposed interface which make them vulnerable by construction. On the layer above, the signal processing continues in the digital domain and is more compute heavy. The next layer deals with computation required for the network itself, but also with computation on behalf of applications. The second last layer is the first software layer, which runs the operating system. The operating system is responsible to manage the resources of the underlying hardware platform and thereby a key element for non-functional properties such as security and latency. The final layer is devoted to applications, which can be deployed container in the infrastructure (O-RAN) or applications on end-user devices.

COREnext has the goal to innovate at the analog and digital hardware layers in all three architecture tiers. The operating-system and application layers need to be considered during the research but are not a contribution of COREnext.

2.3 Target Properties

Before we start with the considered use cases, we want to introduce the properties we consider fundamental for the computing infrastructure to fulfill the requirements of the use cases. Section 3 will reference these properties and map them to the individual use cases as required.

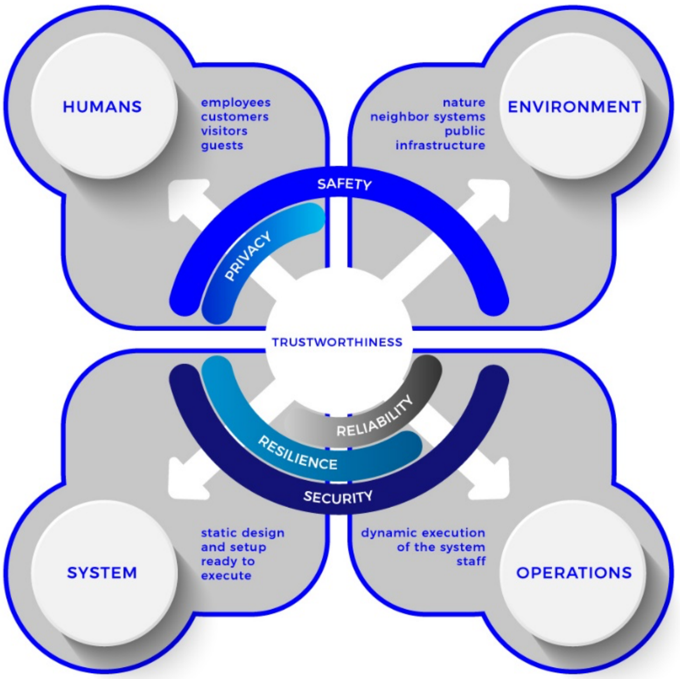

Figure 2-2: COREnext Target overarching requirements

COREnext aims to achieve overarching safety, privacy, reliability, resilience, and security through the means of throughput and latency, efficiency and disaggregation, multi-stakeholder security, multi-tenancy and openness and perspective on trustworthiness. As described in section 3, COREnext will specifically investigate aspects of privacy, reliability, integrity, trustworthy analogue access and distributed code execution, energy-efficient connectivity and energy constrained devices, ultra-low latency, and high-capacity connectivity through the selected case studies.

2.3.1 Throughput & Latency

Throughput refers to the amount of data that can be transferred per time unit from one device to the other. Latency refers to the time between a data transfer being initiated at a source to its completion by arrival of the last byte on the target device. Depending on the use case, throughput or latency is favored. Meanwhile, both throughput and latency are cross-cutting concerns as the entire hardware/software stacks on the devices and the interconnect between the devices can influence throughput and latency. For example, video streaming requires high throughput, but not necessarily a low latency. In contrast, extended-reality applications can require both ultra-low latency and high-throughput communication to deliver a convincing experience.

COREnext therefore considers high-capacity and ultra-low latency connectivity as necessary for its solution.

2.3.2 Efficiency & Disaggregation

Large-scale deployments require energy-efficient signal processing and infrastructure operation to be feasible. At the same time, disaggregation offers more flexibility by combining distinct and physically separate resources to aggregates that act as a whole. In the data center context, disaggregation keeps CPUs, accelerators, and storage in distinct nodes with interconnects between the nodes. The disaggregation increases the modularity of the datacenter and can also reduce the amount of deployed physical resources by flexibly combining and re-assigning these resources. Similarly, base stations can be disaggregated by keeping the antennas separate and distributed. Besides the advantages of disaggregation, physical separation of resources requires more energy for data transfers compared to a tight and therefore less flexible integration.

COREnext therefore considers energy-efficient interconnects and efficient analogue and digital components for energy-constrained devices as necessary for its solution.

2.3.3 Multi-Stakeholder Security

The envisaged COREnext infrastructure has multiple stakeholders with different security interests. End users might be most interested in the privacy and integrity of their personal data. In contrast, the primary interest of the vendor of handset devices might be the device's integrity to, for example, run payment and digital media services on the device as an additional revenue stream or the data collection for telemetry. Vendors of IoT devices or connected cars on the other hand might be primarily interested in the safety properties of their device and the connectivity, integrity, and availability of the services offered by the network. An additional stakeholder is the network operator, which cares primarily about the integrity and reliability of the network and its protection against attacks.

COREnext therefore considers privacy, integrity, and safety as necessary for its solution.

2.3.4 Multi-Tenancy and Openness

O-RAN enables multiple vendors to provide applications that run within the 6G network and provide services to customers. Software from these different providers can be running on the same shared digital platform in a multi-tenancy fashion. It can also interact with other software across all tiers of the architecture. These vendors therefore need to be able to trust the O-RAN infrastructure [7] that their service is highly available, and the integrity of their business secrets are upheld. Additionally, the openness of the infrastructure and their communication interfaces is important to on enable in one hand the vendors to put trust into it and on the other hand to allow different vendors to interoperate.

COREnext therefore considers trustworthy digital compute, trustworthy distributed code execution and openness as necessary for its solution.

2.3.5 Perspective on Trustworthiness

Finally, we would like to define what COREnext understands by trustworthiness and how this term is used within in the remainder of this deliverable. COREnext defines trustworthiness as the belief that a system upholds certain security properties. This belief may be substantiated by technical means such as cryptography or the openness of the used hardware or software to enable its inspection.

3 Use Cases

3.1 Use Cases Background

The development of 6G technology is going forward on 3GPP standards, and COREnext research will contribute to the details of its architecture and capabilities. Hexa-X (H2020) is a flagship towards the 6G network platform and system, to inspire digital transformation, for the world to act together in meeting needs in society and ecosystems with novel 6G services, and hence it is a reference project for COREnext for defining the use cases.

Hexa-X [1][2] has three core values: trustworthiness, sustainability, and digital inclusion. However, in the definition of B5G and 6G, Hexa-X use cases are focused on 6G networks performance, enabling a range of applications and services that are, however, not always currently possible with existing technologies. Taking this into account, COREnext will analyse Hexa-X use cases (i.e., virtual and augmented reality applications, advanced autonomous systems, connected cities, smart transportation systems, and advanced healthcare and wellness applications to investigate the impact of trustworthiness in the operational deployment of all the system components: the nodes, devices, and edge platform.

In Hexa-X, the use-cases are grouped into families, depending on the role of 6G technology. Hexa-X family headings are sustainability, immersive telepresence, massive twinning, robot tasks, hyperconnected resilient network infrastructures, and trusted and embedded Network**.**

Sustainability

Hexa-X demonstrates how 6G can enable sustainability through the development of smart cities. By utilizing the potential of 6G networks, smart cities can optimize their resources and energy usage, reducing the overall carbon footprint. For example, 6G networks can enable intelligent traffic management systems, which can reduce congestion and emissions by providing real-time traffic information and optimizing traffic flow. Additionally, 6G networks can facilitate smart grids that can better manage energy usage, allowing for more efficient energy distribution and reducing energy waste (this topic is analysed also in project 5G-Solution (H2020)[8]. Here, sustainability is considered at a general level, encompassing environmental sustainability, but also societal sustainability. For example, some of the use cases contained in this family are focused on more efficient usage of resources. Other use cases target protection of the environment ("Earth monitor") or inclusion with access to crucial services everywhere, even in remote areas (e.g., health services with "E-health for all", or education with "institutional coverage").

Hexa-X also examines how data analysis helps in identifying trends, correlations, and anomalies in large datasets, providing valuable information for sustainable decision-making. For example, it can help to identify energy consumption patterns in a manufacturing facility, to optimize supply chain logistics to reduce carbon emissions, or to analyse customer behaviours to design more sustainable products and services. By analysing data, decision-makers can gain a deeper understanding of the current state, forecast future trends, and evaluate the impact of potential actions on sustainability goals.

COREnext will take this further by analysing the computational requirement that is needed to take sustainable decisions across various domains. The computational complexity arises from the need to process vast amounts of data, perform complex calculations, and train models on diverse datasets. Embracing this complexity is essential for leveraging data-driven insights and driving sustainable outcomes.

Immersive Telepresence

Hexa-X presents immersive telepresence as a new way for humans to Interact with each other and with other digital or physical things.

This is a potentially powerful technology that needs a wireless network capable of delivering zero latency and massive data transfer capacities, still delivered in a sustainable way. The telepresence can also contribute to sustainability and meeting UN SDGs by reducing the need for travel. Telepresence involves transmitting sensitive audio, video, and data streams over networks, involving confidential information or private discussions.

In the scope COREnext is the realization of a trustworthy-by-design platform that is capable to ensure the security and privacy of these communications.

Massive Twinning

As it is mentioned at Hexa-X, the interaction between the physical and digital world will be possible exploiting the digital twins of the world, where rich sensor information can be used for deep data mining and analysis.

The massive scale of usage of digital twin will lead to increase the need for communication. Due to the information contained in digital twins' representation and the trustworthiness in massive twin deployments, organizations are able to mitigate risks, maintain the integrity of the digital replicas, and enable effective and safe use of these powerful tools. These aspects are investigated in the COREnext project in depth.

Robot Tasks

Hexa-X establishes that robots in the next years will be programmed to perform a wide range of tasks, from simple repetitive tasks to more complex operations that require dexterity and precision.

With 5G [3] and 6G technologies, a new industrial revolution – identified with the name of Industry 4.0 – can start. This revolution requires autonomous robotic/machines that sense the surrounding environment and communicate among themselves and with humans. This will lead to empower robots to become "cobots" where human-machine and machine-machine interaction will be described by collaborating and building symbiotic relations, complex tasks that will be fulfilled in a sustainable fashion. The use of cobots in industry is expected to increase in the coming years, as companies look for ways to improve productivity, quality, and safety in their manufacturing processes. The development of 6G networks may further enhance the capabilities of cobots by providing faster, more reliable communication and data transfer between the robots and their human counterparts, in this way enabling new use cases that were not previously possible.

In the context of cobots there are also several computation problems that need to be addressed to ensure their efficient and effective operation like: real-time control, path planning and collision avoidance, object recognition and manipulation, multiple sensors information fusion. COREnext proposes the development of a multi-tenancy platform for accelerators, enabling the dynamic resource allocation of the accelerators according to the changing workloads and computation demands.

Hyperconnected Resilient Network Infrastructures

Hexa-X explains how 6G networks are expected to integrate and interconnect various types of network infrastructures to enable hyperconnectivity and seamless connectivity in different scenarios. The roadside units, sensors, or the operator's base stations, collect and elaborate all the information provided by a multitude of vehicles as well as other relevant actors (e.g., pedestrians) or devices (some examples of use cases are described also in project C-Roads [5]. The presence of a "network of networks" approach can lead to a network federation for connecting responders, and other stakeholders that need information. In this scenario, advanced radio and management solutions can offer the necessary capacity, even in the event of faults increasing the resilience of the connectivity.

The trustworthy-by-design platform proposed by COREnext can increase the resilience of the network preventing threats, detecting and mitigating attacks, protecting data, establishing resilient communication channels, ensuring redundancy, and enabling rapid recovery. Security enhances the overall robustness and dependability of network infrastructure, leading to improved resilience in the face of challenges and disruptions.

Trusted and Embedded Network

The relevance of trustworthiness in Hexa-X is one of the three core values with sustainability and digital inclusion. This family include all use cases requiring communication capabilities for very sensitive information that are tightly integrated in wide-area networks. The concept of embedded networks is based on providing local zones of higher trust and higher performance based on dedicated networking nodes that can be used. For example, for trains moving in cellular wide-area networks, vehicles with their on-board networks, or for body area networks and medical applications. The trustworthiness is a central requirement for COREnext project that needs to be part of all the selected analysed use-cases.

COREnext focus areas for 6G research and development include improving network capacity and throughput, reducing latency, enhancing energy efficiency, increasing reliability and security, and enabling new applications and services. To achieve these goals, COREnext proposes that 6G networks are likely to incorporate a range of advanced technologies, such as terahertz and optical communications, intelligent and adaptive radio access networks, advanced signal processing and antenna technologies and new network architectures, such as mesh and fog computing. In the following chapters we will identify a grouping of use cases suitable for the purpose of the COREnext approach. The proposed use cases will be capable to summarize all the area that can impact in the definition of a novel trustworthy-by-design platforms and computing architectures.

3.2 Selected Use Cases and Requirements

Section 2 describes the scope of COREnext, including the development of a trustworthy-by-design platform. Section 3.1 shows the most interesting use-cases defined in Hexa-X and other H2020 projects, addressing network capacity, energy efficiency and sustainability of the technology. In this section (3.2), we will firstly focus on defining a reduced set of use-case-families that are a good representation of the extensive list of use cases that have been identified in recent years for 5G deployment and then for 6G standardization. While at the same time we want to identify families that are representative of different system architectures considering the type of client used, the involved devices and the type of users and information shared.

After careful consideration of the above and the present context, this is the defined short list of use-case-families and specific use cases for COREnext:

- **Enhanced Human Communication and Entertainment** represents the family of use-cases involving human devices enabling users to interact with digital content in a more immersive and natural way. Human interaction involves specific requirements deriving from the involvement of human senses (part of the success of the interaction depends on the capability of reality reproduction). The use case to be investigated within this family is **the Extended reality (XR) use case.**
- **Enhanced Machine Communication** represents the family of use-case involving non-human communication or interaction. This interaction can benefit of information compression, non-human communication is often required for safety when the ability to react of non-human actuator is higher than a human reaction. The use case to be investigated within this family is the **Automotive infrastructure use case.**
- **Intelligent Management** represents a family of use-case involving decision based on the collection of Information provided by multiple network elements (RAN nodes, edge nodes, sensor nodes). The main requirement for this family is the capability to collect high amount of data and a high level of data processing performance for algorithm training (ensuring the data security and trustworthiness). The use case to be investigated within this family is the **Smart city use case.**

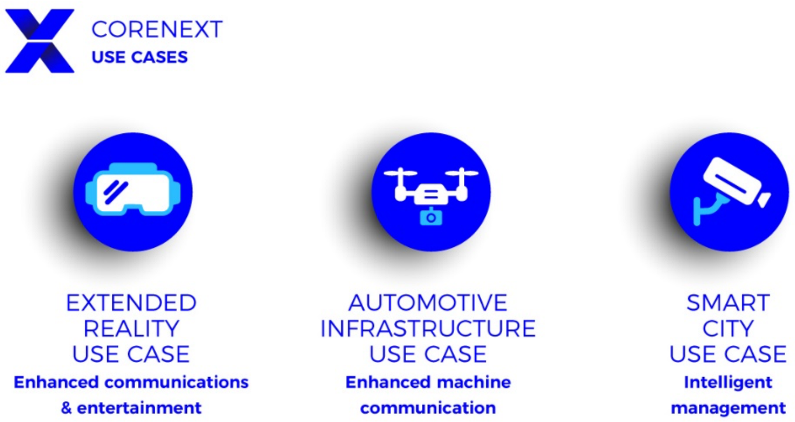

Figure 3-1: COREnext Use Case Families

3.2.1 Enhanced Human Communication and Entertainment: Extended Reality (XR) Use Case

Enhanced human communication and Entertainment represents a large family of use-cases for 6G networks that aims to enable more immersive and realistic interactions between people over a wireless network for both communication and entertainment purpose. The goal of this use case is to provide a level of communication that feels like face-to-face interaction, but over a network, using advanced multimedia technologies such as holographic projections, augmented reality (AR), virtual reality (VR) and Mixed Reality (MR). These three technologies can be summarized with the concept of Extended Reality (XR)

With the increasing demand for remote work, telemedicine, and distance learning, the need for high-quality and natural human communication is becoming more critical. 6G networks can address this need by providing an ultra-fast and reliable network that supports high-bandwidth to transmit in real time large amounts of multimedia content, (such as 3D graphics and audio) and low-latency communication for immersive multimedia applications.

One example of an application for enhanced human communication is remote collaboration. With the use of 6G networks and AR/VR technologies, people can work together remotely as if they were in the same physical space, enabling more efficient and productive collaboration across different locations.

Inside this use case family COREnext will be focused on the Extended Reality.

The Extended Reality (XR) Use Case

In COREnext the XR (extended reality) use case is highly relevant because of its requirement on trustworthiness. XR technologies aim to provide a highly immersive and interactive experience to users. As such, users place a high degree of trust in the XR systems (including the device itself) and applications they use. To ensure that users' trust is not misplaced, XR systems need to be designed to be secure, reliable, and privacy-preserving. Extended Reality systems need to be secure to protect users' data and privacy, prevent unauthorized access, and ensure the integrity and confidentiality of XR applications. This requires robust security protocols, secure data storage, and secure communication channels. COREnext platform requirements can be challenged by this use case that is select as one of the most interesting inside the Enhance Human Communication and Entertainment family of use case.

Another aspect is reliability. XR systems need to be highly reliable to ensure that users can rely on them for their intended purposes. This means they must be highly available, with minimal downtime, and should not generate performance issues that affect users' experience. To achieve the required performance the XR use case needs of an ultra-low latency connection capable to reach high throughput and high-capacity connection.

Trustworthiness is also related to privacy and Extended Reality use cases need to respect users' privacy and ensure that their data is not being misused or accessed without their consent. This means implementing privacy-preserving techniques such as data minimization, encryption, and user consent management. This requirement must be extended to all the devices used in the experience of Extended Reality that, involving several human senses, can require specific devices and infrastructure.

Overall, ensuring the trustworthiness of an Extended Reality systems is essential to ensure their success and user adoption. This will become increasingly important as XR technology continues to evolve and become more relevant in our lives.

3.2.2 Enhanced Machine Communication: Automotive Infrastructure Use Case

Enhanced Machine Communication represents a family of use cases wherein robots, vehicles, drones, or a generic not-human being interact with another not-human being or with a dedicated/public infrastructure. The aim of this category of use cases is to enable a complex interaction over network between such machine parties having specific requirements over trust, security, latency, energy consumption and positioning.

Precise positioning is necessary in use cases involving vehicles, drones, robots to enable the correct interaction with the external world and with other machines in the surrounding space. Low-latency transmission is required to initiate communication as fast as possible, enabling real-time responses and actions. Energy consumption and efficiency are fundamental requirements for sensors, or all battery-powered machines. Throughput capacity, instead, is generally not a strict requirement since the amount of information that is exchanged is not relevant.

Use cases belonging to the enhanced machine communication could be, for example, Vehicle-to-Everything (V2X), autonomous driving, inter-IoT device communication, e-health, and robot communication.

Several Automotive use cases are analysed by the 5GAA in the technical report: "C-V2X Use Case and Service Level Requirement" [4]. One of the categories described in the report are the Use Cases that provide value and convenience to the driver. Examples for this group can include infotainment, assisted and cooperative navigation, and autonomous smart parking that can be grouped in the Vehicle to Infrastructure category. These use cases can provide significant value to the driver or passengers in the vehicles. Additionally, they can more rapidly be deployed and integrated on the roads, compared to other more challenging solutions like, for example, autonomous driving. Based on the above, COREnext decided to look at **Automotive infrastructure** in this family, and this includes **Vehicle-to-Everything (V2X), Vehicle to Vehicle (V2V)**, and **Vehicle to Infrastructure (V2I).**

The Automotive Infrastructure Use Case

Automotive infrastructure use cases refer to the applications and scenarios where communication and connectivity technologies are deployed to enhance the safety, efficiency, and overall experience of vehicles and transportation systems. These use cases involve the integration of various technologies and infrastructure elements to enable seamless communication between vehicles, infrastructure, and other entities in the transportation ecosystem.

Vehicle-to-Everything (V2X) is based on the use of technology to enable communication between vehicles, infrastructure, and other road users. A vehicle that is equipped with V2X technology is capable to communicate with other vehicles and infrastructure in real-time, receiving information about road conditions, traffic, and potential hazards from other vehicles or infrastructure using the same V2X technology.

Vehicle-to-Vehicle (V2V) communication's ability to wirelessly exchange information about the speed and position of surrounding vehicles shows great promise in helping to avoid crashes, ease traffic congestion, and improve the environment.

The **Vehicle-to-Infrastructure (V2I)** enabled vehicle, approaching for instance an intersection, receives information from the infrastructure about the traffic signal timings, congestion, and other road hazards. This information is transmitted through V2I communication and allows the driver to make informed decisions about its driving behaviour.

Even low latency communication is the main performance requirement for most automotive use cases, trustworthiness is also crucial in the context of Vehicle-to-Infrastructure (V2I) communication. The integrity, confidentiality, and availability of the data exchanged between the infrastructure and vehicle is of utmost importance. Avoiding any possible malicious behaviour is a fundamental problem to ensure the security and success of the platform.

One aspect of trustworthiness is security: it is not guaranteed if the information received from the infrastructure or another vehicle is unreliable or malicious, leading to possible confusion or dangerous situation. Thus, trustworthiness is essential to ensure safety of drivers and passengers.

V2X, V2V and V2I systems can optimize traffic flow, reduce commute times, and improve fuel efficiency. However, if the received data is incorrect or incomplete, it might lead to traffic jams and increased fuel consumption, thereby defeating the purpose of the systems. Additionally, security and trust are key elements to ensure these systems to function efficiently.

Privacy in V2X, V2V and V2I communication systems must be granted. This is because sensitive information about vehicles is exchanged. If this information falls into untrusted party, it could be used for malicious purposes. It is essential to ensure that these systems are trustworthy to protect the privacy and security of users.

Ensuring the trustworthiness of V2X, V2V and V2I systems is critical to enable their success and adoption, and this will become increasingly important as more automotive infrastructure technology continues to evolve and becomes available for end users.

3.2.3 Intelligent Management: Smart City Use Case

With the name of Intelligent management, the project refers to applications that use advanced technologies such as **artificial intelligence (AI), machine learning (ML), and data analytics to automate and optimize business processes.** These applications aim to improve the efficiency, safety, and sustainability of a specific industries, verticals, or places (ex: cities, countries) by analyzing large amounts of data, identifying patterns, and providing insights to users. Intelligent management applications can be used in a variety of industries and domains, including finance, healthcare, manufacturing, logistics, and more. They are designed to help organizations to manage their operations more effectively and efficiently by providing real-time data, forecasting, and analysis.

One example of intelligent management applications is **predictive maintenance systems**, where machine learning algorithms are applied to analyze sensor data from machines and equipment to predict when maintenance is required. This can help organizations to reduce downtime and save money by preventing equipment failures.

Another example is the **energy management systems**, where data analytics and machine learning algorithms are used to monitor and optimize energy consumption in buildings, factories, and other facilities. They help organizations to reduce energy costs, improve sustainability, and comply with regulations.

Inside this family of use cases, COREnext will focus on **Smart city**

The Smart City Use Case

Smart city applications are a type of intelligent management application that leverages IoT (Internet of Things) devices, data analytics, and AI to optimize urban operations and improve the quality of life for citizens. Smart city applications can be used to manage a wide range of urban services, such as transportation, energy, water, waste management, public safety, and more. Examples of Smart city applications are:

- **Public safety systems -** Smart cities can use data analytics and AI to detect and respond to public safety incidents in real-time. For example, they can use video analytics to detect suspicious behavior or incidents of violence, and alert law enforcement or emergency services automatically.
- **Intelligent transportation systems (ITS) -** These systems use real-time data from sensors, cameras, and GPS devices to optimize traffic flow, reduce congestion, and improve safety on roads. They can also provide real-time information to drivers and passengers about traffic conditions, public transit schedules, and parking availability. Some examples of the use of information are presented in the C-ROADS project [5].
- **Waste management systems -** These systems use IoT devices and data analytics to monitor waste collection and recycling processes, optimize collection routes, and reduce landfill waste. They can also use sensors to detect waste levels in bins and alert collection crews when they need to be emptied. This is an example where energy efficient connectivity is an important consideration as this application can rely on wireless communication technologies integrated in energy-constrained sensors.
- **Energy management systems -** Smart cities can use IoT devices and data analytics to monitor energy consumption in buildings, streetlights, and other infrastructure, to optimize energy use for maximum efficiency and sustainability. They can also integrate renewable energy sources such as solar and wind power, to reduce dependence on fossil fuels.
- **Water management systems -** Smart cities can use IoT devices and data analytics to monitor and manage water resources, detect leaks, and optimize water usage. They can also use real-time data to inform citizens about water quality and availability.

Privacy, safety, and integrity are critical considerations for Smart city applications. As these systems collect and analyze large amounts of data, there is a risk that sensitive information could be compromised, leading to privacy breaches or safety concerns. Trustworthiness is an important aspect to be considered as a high number of transceivers can be involved including remote sensors. It is not guaranteed that the information received from some of them is reliable or not malicious.

On the contrary, the ultra-low latency and high-capacity connectivity are not deemed so important taking into account that Smart city applications are not demanding in terms of real time or high bandwidth.

3.3 Use Cases Requirements

The three use cases identified: XR, Automotive Infrastructure and Smart cities will be used as reference use cases in the COREnext project. This section will describe the different requirements needed for the use cases described above, considering the level of performance required and how relevant is the contribution of COREnext in the use-case for each specific area.

	XR	Automotive Infrastructure	Smart City
Requirements			
Privacy, reliability, integrity	High	High	High
Trustworthy analogue access	High	High	High
Trustworthy distributed code execution	Medium	High	Medium
Energy-efficient connectivity	High	High	High
Energy-constrained devices	Low	Low	High
Ultra-low latency	High	Medium	Low
High-Capacity Connectivity	High	Low	Low

Table 3.3-1. Use Case Requirements and Relevance

The requirement of **reliability, integrity and privacy** are relevant for all the reference use cases because the data needs to be always correctly transmitted without error. The information must be protected and not accessible. COREnext wants to guarantee the level of security introducing, for all the use cases, a relevant level of trustworthiness – even at the analogue access. Currently, applications are built as a collection of small, independent, and loosely coupled services. Each service focuses on performing a specific business function and communicates with other services through well-defined APIs. These services can be developed, deployed, and scaled independently, allowing for greater flexibility, agility, and scalability in software development. The code of the services is executed across multiple computing resources, such as servers, nodes, or edge devices, to perform a specific task. It involves breaking down the execution logic into smaller units that can be distributed and processed concurrently. This is relevant especially in an Automotive infrastructure where the driver's safety depends on applications running inside the car, the other vehicles and road infrastructure devices. **Trustworthiness** is crucial in a distributed code execution architecture. This includes ensuring that code is executed securely, reliably, and with integrity across a distributed system. For example, controlling access to distributed components, controlling the integrity of code executed across, monitoring and auditing distributed code execution, and keeping the distributed system up to date with security patches, bug fixes, and software updates.

In the context of technology and networks, including 6G networks, **energy efficiency** plays a crucial role, it is relevant in all the reference use cases to maintain a sustainable system: reducing environmental impact, saving costs for system owners, and promoting a positive public image. In the Smart city use case especially, the usage of many sensors for monitoring and collecting information introduces a relevant requirement of energy-constraint devices. These devices often operate in remote or inaccessible locations, making it challenging to replace or recharge their power sources frequently. Therefore, optimizing energy consumption becomes crucial to ensure their reliable and sustained operation.

Performance requirements for data transmission can be summarized by a **latency** requirement and a **capacity** requirement. A delay requirement refers to the maximum tolerable latency in the reception of transmitted data that can be acceptable for the user experience. Delays in XR applications can lead to a noticeable discrepancy between the user's physical movements or actions and the corresponding virtual response, resulting in a degraded experience and potentially causing motion sickness or discomfort. Therefore, ensuring low-latency and minimal delays is crucial for delivering a compelling and immersive XR experience. In an Automotive infrastructure the delay tolerance can be relaxed depending on the criticality of the service (for example: in case of a service of driving assistance ADAS the supported delay can be higher respect a service of full autonomous driving [4]). In the case of Smart city use case the requirement of low latency is less mandatory compared to the other use cases.

The requirement of **High Connection capacity** refers to the maximum number of simultaneous connections that a network or system can support with a high amount of data transmitted. It represents the ability of the network to accommodate a high volume of data from various devices or users. In the context of XR use case, connection capacity becomes crucial as XR applications often require real-time interactions and high data volume exchanged between multiple users or devices. To ensure a seamless and immersive XR experience for human, a large amount of information needs to be transmitted - compared to use case that does not involve a human device. In Autonomous Infrastructure and XR use cases, even if the number of connections could be relevant, the data exchange inside a single connection could be limited to a compressed set of information (for example: positioning, speed, context information). In the Smart city use case, it is essential an efficient data transmission technique that generates small packets of data sent with a large periodicity to minimize the power consumption of the sensors.

The COREnext project will enable novel **trustworthy-by-design** platforms and computing architectures, capable of efficiently and securely integration of third-party accelerators, supporting even the most demanding 5G/6G processes in cloud servers, base stations, and client-side devices. In that respect the **Table 3.3-2** summarizes the contribution to each of the reference use cases.

	XR	Automotive Infrastructure	Smart City
COREnext Contributions			
COREnext trusted base station platform	✓	✓	✓
COREnext trusted terminal platform			✓
COREnext trusted modem in untrusted 3rd party terminal device	✓		
COREnext efficient interconnects		✓	✓
COREnext efficient signal processing and acceleration	✓	✓	✓

Table 3.3-2. COREnext contributions

The definition of a **trusted base station platform** comprising of an **efficient signal processing** and **hardware acceleration** will be beneficial for all the use cases, as base stations are the fundamental element to create the wireless connectivity. Regarding a trusted terminal platform, COREnext will consider the Smart city use case where the sensible information is collected by multiple sensors provided by several vendors. In the XR use case, it can be difficult to verify the origin of the modem owned by the end user. In any case, the trustworthiness of the system must be guaranteed.

Efficiency of the **interconnection** is relevant in all the use cases, where the modem could be powered by a battery like in Smart city and Automotive infrastructure use cases. The COREnext platform and architecture will contribute to efficient signal processing and acceleration in all the analyzed use cases.

4 Trustworthiness Aspect

Trustworthiness is one of the main 6G research challenges. Security considerations must encompass all aspects of cybersecurity: resiliency against attacks, preservation of privacy, and ethical, safe application of automation to network operations and applications.

Most of the new use-cases considered for 6G are calling for higher network capabilities and performance improvements by one or several orders of magnitude compared to 5G. For example, throughput capacity is expected to grow from 100Gb/s to 1Tb/s. At the same time, critical additional requirements around privacy, security and resilience are needed to implement a trustable 6G network environments in an open environment and with potentially untrusted parts.

As illustrated in the Figure below, 6G networks consist of different devices build and used by different stakeholders. Therefore, trustworthiness has different aspects for different devices and stakeholders. In all cases, we strive to use technical means to substantiate the belief in the trustworthiness of that platform.

4.1 Terminal and Edge Devices

Since many years, extensive research efforts are conducted to use transmitted data radio waves like Wi-Fi frequency bands [6] to sense the environment and detect objects. With the advent of 6G and the opening of Sub-THz frequency bands an unprecedented sensing resolution will be made available for situational awareness, including target sensing and detection, proximity detection, imaging, localization and positioning, and 2D/3D mapping. Moreover, Joint Communication and Sensing (JCAS) is now emerging naturally as a key 6G enabling technology with a key objective to reuse the spectrum and hardware between the communication and sensing functions and leverage mutual benefits with a coordinated operation. Wireless sensing and positioning techniques with down to sub-cm range resolution will open a plethora of new applications such as road traffic monitoring, gesture recognition for human-machine interface and many more that still need to be invented.

As end-user devices such as smartphones are typically made by non-European manufacturers, whose technologies may pose privacy risks for the end user. For example, privacy-sensitive information like precise location information via GPS or radar via joint communication and sensing may be used to precisely track the movements and environment of end users. The research question is therefore how to selectively allow trusted applications access to these technologies even though the application processor and operating system is under the control of non-European vendors.

We derive the need for COREnext to provide a trusted terminal platform, and a trusted modem in third party terminal devices.

4.2 Base Stations

Base stations form the communication endpoint for wirelessly connected terminal devices and are therefore a critical part of 6G networks. However, with the ability for terminal devices to execute code on base stations, new challenges arise. For example, in the automotive infrastructure use case, the base station has a better overview of the traffic situation as a whole and is therefore better suited to calculate optimal routes through complicated intersections than individual cars. Being able to execute code within the base station would therefore allow cars to take advantage of the base station's information. However, the car needs to be able to trust the base station that the integrity and privacy of the code and data is preserved.

We derive the need for COREnext to provide a trusted base station platform that enables secure code execution for terminal devices.

5 Conclusions

In conclusion, this document has presented a comprehensive analysis of use cases and requirements for a computational platform. The document aimed to explore the diverse applications and scenarios where such a platform can bring significant value and address the evolving needs of various industries.

The selection of how grouping use cases is based on the identification of the data consumer entities because this could impact in the trustworthiness differently. These entities have been identified in the document as Human, Not Human and Management Function for resource optimization. A reference use case is identified for each group and end each use case highlights specific requirements and challenges that can be effectively addressed by a computational platform, such as high-performance computing, real-time data processing, and intelligent decision-making capabilities.

Throughout the document, it has become evident that the computational platform for hardware accelerators plays a pivotal role in enabling advanced technologies for dynamic resource allocation and demand-based workload scaling. These capabilities will support the high compute capacity required for B5G and 6G use cases. Novel high-speed interconnects with low energy consumption per transferred bit will enable efficient connectivity of heterogeneous devices to enable disaggregated resources to collaborate dynamically. The platform's ability to handle large volumes of data, leverage distributed computing architectures, and provide seamless integration with existing systems is crucial for unlocking the full potential of 6G technologies. The project activity could be relevant on O-RAN Alliance standardization activity for the implementation of an open infrastructure for hardware acceleration.

Security and privacy considerations have also been highlighted as fundamental requirements for the computational platform. As sensitive data is processed and transmitted, robust security measures must be in place to protect against cyber threats and ensure compliance with regulations. Trustworthiness, reliability, and data integrity are paramount to build confidence and foster adoption.

In conclusion, the COREnext platform has immense potential to drive innovation, enhance operational efficiency and enable new services and applications across various industries. By meeting the identified requirements and addressing the challenges, the platform can serve as a foundation for advanced computing capabilities, supporting data-intensive, real-time, and intelligent solutions.

6 References

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