



Next Generation
Telecommunications
for the Digital Society

Scope and Research Areas



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CELTIC-NEXT

SCOPE AND RESEARCH AREAS

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CELTIC-NEXT: BACKGROUND AND RATIONALE

In 2018, the EUREKA High-Level Representatives decided to give the Eureka label for the CELTIC-NEXT EUREKA Cluster to operate for 8 years. At that time, 5G and Artificial Intelligence had not yet such a powerful impact on the society. Part of the data traffic has now been moving from large datacentres with high latency to nearby datacentres at the network edge to respond to the need of real-time applications. This creates new technological and societal challenges, primarily related to the security and privacy of data transmission and storage. People and machines entered a smart connected world and experience the internet with all its new facets. We are living in interesting times where new concepts and projects are needed to progress and to push new ways of communications and secure critical infrastructures and the CELTIC community is proud to contribute to make these important innovations happen. Bringing the major European telecommunications vendors and operators together into an ambitious European intergovernmental R&D programme that tackles the main means related to an end-to-end approach in communications was the best option to address a “system view” of communications to complement the other existing Clusters.



CELTIC has been key for initiating ambitious and innovative projects dedicated to end-to-end communications solutions.

Until today, CELTIC has labelled, funded and performed 150 projects in all their research areas with a total volume of more than one Billion Euro. By facilitating these collaborative R&D projects, the CELTIC cluster has made a great contribution to help Europe to stay at the competitive edge of the telecommunications industry.

The participation of SMEs in CELTIC has continuously increased throughout the years, to reach more than 40%. Today, the total budget of SMEs in CELTIC projects overcomes the total budget of large Industry¹

CELTIC & CELTIC-PLUS
15 years of success

900+ products commercialised

150+ R&D projects

1 B€ invested in R&D

40% SME participation

900+ PhD and Master Thesis

The CELTIC Cluster has contributed significantly to the growth of the annual turnover of firms involved in Cluster projects (+13% compared to nonparticipating firms) and to the development of employment (+7% employment growth compared to non-participating firms)².

This document provides insights into the scope and main research areas, which CELTIC-NEXT projects should focus on. The research areas in this document, however, are not binding. CELTIC-NEXT follows a bottom-up, industry-driven approach, which allows proposers of CELTIC-NEXT projects to define the content of their project proposals according to their own research interests and priorities.

¹ "Industry" in the sense of Celtic-Next excludes telecommunication operators.

² "Impact Assessment of EUREKA Network Projects and Cluster Projects – Main findings and recommendations". Berlin/Brussels/Graz, May 24, 2017

CELTIC-NEXT: IN THE EUROPEAN RESEARCH AND INNOVATION LANDSCAPE

CELTIC-NEXT projects are oriented along the societal trends and needs, commercial opportunities, and technological challenges in our global society.

CELTIC-NEXT with its end-to-end approach is key for allowing the development of dedicated applications using the network with all the required features for a given economic sector.

CELTIC-NEXT will be based on the core values that have been supporting the Celtic community for 15 years, i.e. a bottom-up industry-driven approach, along with large “flagship” projects aimed at solving issues of strategic importance through a combined effort and coordinated approach of public authorities and industry. CELTIC-NEXT will regularly look at improving the processes and tools in a similar manner as in Celtic-Plus so that they timely match the evolving demands of the overall landscape. It will also refine periodically its scope and orientations, to further strengthen the initiative. Increasing the flexibility of the programme to cope with the quicker pace of technological and market developments, as well as allowing projects that are closer to the market, up to high technology readiness levels, will increase the impact of the projects and of the programme on economy and society. Providing the opportunity for students and researchers to contribute with innovative ideas shall remain a key asset of the CELTIC-NEXT community.

Main Technological Trends

There are critical technological and societal issues that need to be addressed in the coming years, that are not addressed by other EUREKA instruments, and only partially by other instruments in Europe. From a technological standpoint, Networking and Cloud Enablers addressing and using technology from such research areas as **cyber security, artificial intelligence, 5G and beyond, FinTech, big data, business analytics, and IoT** are considered as important orientations to develop. A special focus of CELTIC-NEXT will be on **applications and services serving vertical sectors such as content (video, gaming), e-health, smart cities, agriculture, mobility, energy, automotive, e-commerce, and industry/ manufacturing**. Those verticals are equally important to advance, along with optimising and improving efficiency and reliability with the best end-to-end connectivity and security. The evolution of ICT services over the next period will be achieved via a partnership model where the vertical sectors collaborate in determining their ICT solutions. This will be a key focus of the CELTIC-NEXT end-to-end perspective.

Another key issue for CELTIC-NEXT will be to develop communications infrastructures and services that can adapt to the requirements of various business sectors. The need of communications between vehicles are indeed quite different than the needs for piloting electrical power in buildings and houses. The same applies to the virtual and immersive reality techniques, that will become a critical element in the health and media/digital industry in the coming years. There will be many unique challenges behind innovative manufacturing processes that must be supported by one ubiquitous infrastructure. We expect that many of the CELTIC-NEXT projects will define and develop self-adaptable solutions, able to fit the needs of many different sectors and societal challenges.

CELTIC-NEXT with its end-to-end approach is key for allowing the development of dedicated applications using the network with all the required features for a given economic sector.

Representatives from vertical sectors will be progressively invited to participate in the CELTIC-NEXT Industry Core Group to ensure the continuous cross-fertilisation of ideas. In parallel, the telecommunications industry shall exploit the full power of cross sectors technologies such as Artificial Intelligence and Big Data, to define and provide customised and smart solutions for the different economic sectors and the whole society.

Scope of CELTIC-NEXT



Today, everyone listens to music and watches online videos on their mobile devices anywhere and anytime, and both businesses and individuals have their data stored in large data centres located all around the world. This creates new technological and societal challenges, primarily related to the security and privacy of data transmission and storage.

The vision of the future communications is the ongoing digitalization and automation of many aspects of our lives — the automation of everything. This shift is driven by the current enabling technology trends like cloud-based services with dynamic and adaptive scaling, extensive virtualization, novel software-defined automated solutions and wireless connectivity with the 5G mobile networks. We will move from an era defined by the connection of people and simple things by Mbps of capacity and ~100 ms latency to one defined by Gbps of capacity and ~1 ms of latency. This is characterized by 360-degree video, virtual and augmented reality, as well as autonomous system control with associated cognitive systems that augment human intelligence. All this will demand a fundamentally different, distributed network architecture comprised of cloud processing

resources, interconnected by optimized IP and optical edge networks, and this with a converged ultrahigh capacity broadband access layer. The edge cloud network will need to support data rates of 10 Gbps, latency as low as 1 ms, and a trillion connected devices with 10+ years of battery life. Network slicing is a key capability underlying the new business model opportunities by which dedicated virtual networks to various customer groups will be provided much more economically than in the traditional model where these customers would build their own dedicated private networks. All these new capabilities will enable the communications networks to become a tool for the digitalization of various industry areas.

Cybersecurity is a fundamental element for the Digital Transformation of the Digital Single Market aiming at both protecting the European citizens, enterprises, infrastructures or institutions against cyber-risks as well as developing the cybersecurity sector competitiveness. It applies in very diverse environment such as Cyber Physical Systems, 5G & Beyond (thus cloud), social networks, web-based applications.

Mastering the creation of value from Big Data will be a cornerstone in the future economic development and societal well-being. To achieve that goal CELTIC-NEXT will work on Big Data challenges and pave the way to strengthen all parts of the “data value chain” so that a Big Data value ecosystem and data-powered innovative business models can evolve. That includes people and organizations involved in data whatever their role, be it producing, analysing, using or creating value from data.

Concerning **Artificial Intelligence** (AI), key research targets include learning with fewer examples, the application of learning methods to dynamic systems, the capability to explain AI decisions, the combination of AI with model based optimization, the development of machine learning methods coping with distributed data sources and computing processors.

The development of AI and **Big Data** is one more incentive for users and consumers to **take better control of one's digital life** in the forthcoming years. Concretely it means that users will need to be accompanied in their usage and in their need of transparency and control of the digital tools. The future digital platforms and tools will need to strike the right balance between empowering and assisting the users versus giving them the control and the choice. Privacy issues will need to be taken care of, not only but especially in the eHealth domain.

CELTIC-NEXT will work on the research challenges in the **eHealth** sector, such as high reliability and guaranteed Quality of Service; high security, privacy and authentication; Scalability to high number of users, as well as ease of use for non-ICT specialists.

Besides eHealth another vertical is related to **smart cities**. Considering the continuous fast growth of wireless Internet usage and the emerging new smart city applications such as smart traffic control, smart lighting (including the LED technology), self-driving cars and air quality monitoring, the smart city infrastructure will take into account the disruptions from digitalization towards the higher level of automatization and from the related new business models. A digital ecosystem of a future smart city will improve safety, energy efficiency, air quality, effectiveness of transportation, and quality of living. “Breaking up the silos” is essential to leverage smart city opportunities. CELTIC-NEXT will help defining an open and interoperable urban platform reference architecture, forming a system of system approach. To achieve that goal and open interfaces are a prerequisite, allowing new ways of interaction between different industries.

The digital infrastructure of transportation in a city should merge all physical transport assets in a single and easily accessible platform through the use of all smart city technological enablers such as big data, IoT and 5G to provide novel services to the integrated transport system such as new business models, new transportation models and social innovations. Such **smart transport** platforms can form a basis of multimodal travel planners, transportation networks, mobility services, transport on demand services, tracking and tracing activities.

The services provided by the digitization and integration of transportation platforms can benefit from crowd-sourcing based real-time user and vehicle information to enable a faster, comfortable and controllable experience to users leading to a fully personalized services and offers.

It is important that the different actors of the value chain cooperate in order to invest the best **connected and autonomous vehicles**: car manufacturers, OEM, electronic equipment manufacturers, IT and telecom companies and mobile operators.

Linked to the CELTIC-NEXT vision of Smart Cities our vision of the **Smart Home** foresees users being offered a seamless and consistent experience when interacting with products and services bridging home, on the move and integration with smart city infrastructure. The future smart home should benefit from an open ecosystem allowing third party services to be integrated with the different Smart Home elements with AI-driven service improvements and cross-service possibilities.

Smart agriculture as well as the whole agro-food sector will benefit in the coming years of the deployment of massive connected objects. Traceability will be enabled by IoT platforms, empowering agro-food sector and allowing traceability of food information for consumers. The Digital platforms for e-Agriculture and smart manufacturing should finally use common enablers for optimization purposes. In response to ecological and budgetary issues, new consumption patterns are emerging. **Personalisation and Quality of experience** will be key trends, not only in ICT but also in all industry sectors. New ways for production will meet those new consumption ways. **Smart manufacturing** often referred as 4th industrial revolution will transform the traditional business of manufacturing of goods towards service-based business in global value chains.

Digital enterprises complement the smart manufacturing processes: Digitalization will develop at each stage of the lifecycles of the products and services from development to deployment, from purchasing to services, from manufacturing to logistics covering all the vertical processes that an enterprise has, generating value all across the stakeholders (customers, suppliers, shareholders, value chain partners, third parties etc.)

In the next years we expect a convergence of learning and work in the Enterprises. Personalized digital learning environments will help reducing skills gaps and will therefore have a very important positive impact on economy and social innovation for society. **Digital Education** will benefit of emerging technologies like artificial intelligence, big data analysis and machine learning, virtual reality, augmented reality, speech recognition, conversational interfaces, drones, robotics, and 3D printing.

In the **media, entertainment and gaming areas**, media will become immersive and highly interactive to provide ambient media consumption at home but also on the move. There will be a big focus in coming years on mixed reality. Interactive technologies such as Augmented (AR) and Virtual Reality (VR) are set to transform the ways in which people communicate, interact and share information on the internet and beyond. Besides new 5G capabilities will enable Ultra High Fidelity media and live

event coverage. Content production will diversify: there will be both user and machine generated content, as well as cooperative content production.

Gaming will expand into a full immersive multi-sensorial environment. Collaborative gaming will expand while game development may also become more cooperative with users directly interacting with the developers in real time. New gaming technologies will take gamification to all business lines and industry sectors.

Sustainability and energy efficiency will get a similar range, spanning from telecom networks and services to the whole industry, transports, smart buildings, smart cities and smart agriculture. Sensors will be used to measure and take counter actions when needed. New technologies should be used to prevent, measure and communicate pollution information. New applications should exploit data for climate, and anonymized health data to warn and avoid damages at a bigger scale. Artificial intelligence with machine and deep learning may also help reduce the energy consumption.

Last but not least new markets may open to ICT players, such as **future financial and Fintech services** which have great potentials for a growing shift in the revenue pools of the operators and ICT players especially concerning the digitalization of lending payments and investment, online P2P (person to person) money transfer, e-wallet usages, changing customer relations with online/mobile transactions and customized financial solutions and digitalization in insurance. ICT players as new comers in the financial business should bring impressive solutions and services, achieving the desired, efficient, optimized and secure fintech platforms established on the needs of the citizens, governments and the actors of the technology and market value chains.

CELTIC-NEXT: MAIN RESEARCH TOPICS AND CHALLENGES

This chapter outlines topical and important research subjects and challenges in the ICT and Telecommunication area.

The lists of items in the following sub-sections are not comprehensive. Following the “bottom-up” approach of CELTIC-NEXT, proposers are free to propose projects on any subjects, as long as they are related to ICT and Telecommunication.

Communicate and Share

The fundamental driver to transform the communications network architecture and functionality for the vision of the future is the ongoing digitisation and automation of many aspects of our lives — from communication and content to compelling human shared experiences and the control of any physical system and infrastructure — what we will call the automation of everything. This shift is driven by current enabling technology trends like cloud-based services with dynamic, adaptive scaling, extensive virtualisation, novel software-defined automated solutions and ever-increasing wireless connectivity with a great promise of 5G, and will require a redefinition of networking concepts and a new digital infrastructure involving radical shifts in technologies, architectures and business models to meet future digital needs.

We will move from a regime defined by Mbps of capacity and ~100 ms latency – an era defined by the connection of people and simple things, to one defined by Gbps of capacity and ~1 ms of latency, characterised by 360 degree video, virtual and augmented reality, autonomous system control, with associated cognitive systems that augment human intelligence.

The era of automation of everything will demand a fundamentally different, distributed network architecture comprised of cloud processing resources, interconnected by optimised IP and optical edge networks, with a converged ultra-high capacity broadband access layer. These elements will be coherently formed and reformed into a converged, cognitive and cloud-optimised network. The edge cloud network will need to support data rates of 10 Gbps, latency as low as 1 ms, and a trillion connected devices with 10+ years of battery life.

This will lead to a new era of industrial value creation across a broad range of sectors including healthcare, manufacturing, energy, agriculture, transportation, mining, etc. leading to a potential economic impact in the range of \$4 trillion to \$11 trillion per year by 2025.

Overall trends and requirements

Almost infinite capacity: Network capacity is one of the key drivers for the network architecture evolution with respect to continuously growing data and video traffic. However, this massive demand increase comes at a time when network technologies are reaching physical limits, which are hard or even impossible to overcome with conventional architectures and technologies.

Spectrum resources in lower frequency bands (< 6 GHz) are almost exhausted and spectral efficiency is approaching the Shannon limit as digital signal processing technologies have improved significantly over the past decades. As a result, spatial density is the only dimension with sufficient potential for further significant capacity growth. In essence, this means that network dimensions have to get smaller, allowing significantly higher spectrum reuse per spatial area. Both fixed and wireless access

networks will have to reduce their reach to ~100 m to scale density by at least 10x and provide per-user data rates of 10 Gbps. In the wireless domain, these shorter distances open up new frequency bands above 6 GHz, which have much shorter propagation reach. In the low band, beamforming enabled by massive antenna arrays can also be used to increase spectral efficiency, providing additional capacity gain over conventional systems.

Means for spectrum sharing and co-existence like spectrum pooling and automatic spectrum allocation based on agreed policies will improve spectrum exploitation, which ensure access, availability and reliability as well as QoS requirements of different spectrum owners and services.

The capacity problem in the access domain can mainly be solved by moving the physical layer termination close to the end user to open up new frequency bands, and by wireless beam-forming to increase spectral efficiency.

Imperceptible latency: Human communication and entertainment services using audio, video, email, or text messaging, or information retrieval from web services and applications, are currently the dominant applications running over the network. Human perception is on the order of 100 ms for such services. Augmented, Virtual and Mixed Reality services will enable physical interaction of humans with virtual and remote real-world objects.

In addition, mass deployment of video cameras, connected sensors and actuators enables the development of mission-critical cyber-physical systems for the automation of manufacturing processes, large-scale traffic coordination of autonomous vehicles and logistics, and adaptive precision control systems such as remote surgery. Optimal operation of these machine-machine systems requires cloud-based supervision (for more complex decision making) combined with semi-autonomous local control (for simple/well-defined decisions), which in turn requires reliable connectivity latencies as low as 1 ms. This requires the distance to the service to be less than 100 km. Current wireless technologies, together with centralised cloud architectures support latencies on the order of 30-100 ms, sufficient for a satisfactory Quality of Experience (QoE) for human communication and information retrieval. New services require a 10-100 x improvement in latency. Notably, achieving this latency requires optimisation of every link in the network, including optimisation of the radio interface, and streamlining RAN and core processing.

Terascale things: We anticipate that a trillion IoT devices and sensors will be attached to the physical world and stream data that will allow our world to be continuously understood, adapted and remotely controlled to meet emerging needs and significantly improve productivity.

The total cost of deploying, connecting and operating this terascale of IoT devices needs to be disruptively low to be economically sustainable. For long-lived, simple sensory devices for remote applications, battery life is a major determinant of operational cost. Thus there is the need for 10 year battery life to match the typical device service life and allow 'deploy (or drop) and forget' deployment and operation. This requires highly optimised wireless communication for short data bursts with minimal signalling and control overhead.

With the growing IoT space the variability in the needs of devices is increasing as well as the number of applications demanding orders of magnitude higher daily data consumption and processing capacity of this big data.

Cognitive operation: The dynamic, distributed networks and associated systems and platforms, and the data generated by the terascale things will result in an unprecedented level of complexity that is beyond the ability for humans to process. The degree of network and service control will manifestly increase, with the advent of so-called network slicing to provide the flexibility for an operator to support the rapid deployment of new services with well-defined and often critical requirements (latency, bandwidth, availability, reliability, security). In addition, personalisation of services by

contextualisation of each solution to match user expectations will also increase transactional complexity. These evolutions require an increase in network-based intelligence, to both monitor and optimise service experience.

The continuation of Moore's Law with new transistor designs, 3D stacking with silicon photonics and optical interconnects, GPU (Graphical Processor Unit) architectures supporting advanced matrix/parallel computation, the continued revolution in neural networking methods and advanced machine learning, and possibly neuromorphic chips and quantum computing paradigms, will support to handle the complexity.

Perpetual protection: Scalable, contextualised and automated security, privacy will go well beyond current solutions, which is driven by:

- The increasing number of data breaches triggered by the increasing value of digital data.
- The low risk and high potential gain from 'ransomware' attacks.
- The expanding threat surface due to a move from billions of smart devices to trillions of simple things that will be connected to the internet.
- The future potential for disrupting industrial and infrastructure systems via network-based automation and cognitive operation systems.

The resulting security and data integrity and privacy impact will be enormous as attacks will affect human-interface devices and also relatively simple IoT devices that can be activated or deactivated en masse, by compromising their control systems, or be converted to billions of bots propagating attacks. Mission-critical networks will increasingly be targets for attacks.

Future network architecture

Addressing the digital needs will require significant changes in network architecture and technology. Nine architectural dimensions are identified to ripe for disruption, forming the pillars of an end-to-end convergent network architecture.

Massive-scale access: Future network capacity and traffic density needs can only be met by a massive spectrum expansion combined with a significantly higher access node density, and a major increase in spectral efficiency for each link and carrier deployed. Spectrum expansion will occur by selectively tapping into centimetre and millimetre wave frequency bands and leveraging additional, often shared, spectrum in the sub-6 GHz range. Carrier aggregation techniques ensure that end-users can seamlessly exploit all available spectrum resources. Access node density will rise through cell splitting in macro deployments as well as a substantial increase in small cells for public and industrial usage, ensuring coverage for high data rate services.

Massive antenna arrays (mMIMO) will be essential enablers of ultra-capacity networks by improving spectral efficiency through spatial multiplexing gains, thus providing higher data rates for more users and with extended data rate coverage.

Sub-millisecond latency is feasible based on an appropriate radio interface numerology and frame structure including variable scheduling intervals with a resolution down to fractions of a millisecond. Persistent priority scheduling will ensure predictable queueing and extremely short delays for critical low-latency flows. End-end latency starts to be limited by the speed of light in transport and backhaul networks, which implies that low-latency applications must be hosted in distributed edge clouds closer to the end user devices.

Other dimensions of the future systems are extending operation into long range operation for broad coverage of narrowband IoT applications and the reduction of energy consumption especially for IoT applications. Sleep modes are an efficient means especially when networks operate at low average load.

With fiber reaching to or close to all end users, non-fiber, ‘last-100 m’ extensions will enable high capacity access over existing copper, coax and mmWave wireless systems. As all of these technologies approach capacities of 10 Gbps and beyond, they will use similar signalling processing capabilities to minimise impairments, maximise signal-noise ratios, and bring fiber-like speed to next generation non-fiber DSL (Digital Subscriber Line – XG-Fast), cable (XG-Cable) and wireless (mmWave) access.

Converged edge cloud: Telecommunication networks and cloud infrastructures are currently based on centralised architectures where traffic is transported to small numbers of core nodes and datacentres hosting services and applications. While this model is suitable for mobile internet services and reduced operator’s TCO (Total Cost of Ownership), it has limitations in terms of low latency applications requiring round trip times below 10 ms. It is also subject to bottlenecks in transporting large traffic volumes to those core locations.

The emerging architecture features are distributed to small-scale datacentres at the network edge, located at the convergence point between access/aggregation and metro core networks, or in some cases dedicated clouds are pushed all the way to the industrial location (e.g. advanced AR/VR, ultra-high resolution content delivery, critical IoT, automation, robotics and control systems). To support applications and services that require the lowest possible latency, key edge/core functions of the network must be distributed differently. Network functions will be decomposed by separating control from data plane functions to enable independent scaling and flexible placement in a distributed architecture. Data plane functions will be more distributed, while control plane functions can typically remain centralised.

Smart network fabric: The ‘smart’ network fabric will dynamically interconnect new converged network edge clouds and core clouds, large cloud providers, global CDNs (Content Delivery Network) and the internet. It will also connect high-density enterprise locations and wireless cell sites, alongside the software-defined PON (Passive Optical Network), cable and DSL access systems.

As the functions of the network are virtualised, and the functional nodes of the network become a mesh of edge clouds and core clouds, the primary role of IP/optical networks becomes cloud interconnection. To ensure both efficiency and reliability, the scaling and placement of all cloud network workloads must be dynamic. This creates a unified cloud infrastructure dynamically distributed over a mesh of locations — driving correspondingly dynamic traffic patterns.

Scalability and programmable flexibility will be critical for the optical layer providing the raw transport capacity spanning the network, because traffic patterns become more dynamic due to on-demand services and shifting cloud workloads.

Flexible optics with tunable wavelengths, variable modulation formats and levels, and variable spectral-width channels will enable optimisation of the information rate vs. distance vs. spectrum used. This enables to dynamically adapt to changing traffic patterns and network degradations. Taking advantage of all this to optimise the network requires a comprehensive network view of topology, resources, traffic and utilisation, as well as programmatic control over these flexible resources.

The optical layer also must continue to scale massively. This includes raw system capacity, and supported interface rates when interconnecting large routers. Current systems are fully exploiting

amplitude, phase and polarisation of light but are approaching the non-linear Shannon Limit of spectral efficiency. Thus, further large gains require leveraging the two remaining dimensions: frequency and space.

Given limits to digital signal process speeds for advanced higher-order modulations, scaling the transmission rate per wavelength to Tb/s and beyond will require efficiently aggregating multiple parallel carriers on the same fiber. Long-term scalability will require spatial super-channels utilising parallel light paths (fibers and/or modes on a fiber).

Universal adaptive core: Enabling new business models as well as the need for extreme operational agility and automation require a fundamentally different cloud-native core network which is based on the following architecture principles:

- Radical simplification by separating orthogonal functions — session management, access/mobility management and user plane are independent network functions. User and control plane have been split to enable distributed user plane deployments for latency-critical applications hosted in edge clouds.
- A service-based architecture allows for rapid creation of new services. Network functions will expose their capabilities as ‘services’ that can be consumed by any other network or application function, enabling flexible per-service software deployment.

Programmable network Operating System: Virtualisation and software-definition of network assets, whether for connectivity or network functions, are the key components of a programmable network. The critical control and management that intelligently orchestrates these assets and makes them available programmatically for both internal and external needs, is the programmable network OS, which forms fundamental enablers together with virtualised assets for:

- Capex efficiency, through flexible and dynamic assignment and reassignment of assets to current needs.
- Operational efficiency, through automated speed and agility of assembling and operating virtual building blocks.
- Growth, through on-demand virtual connectivity and NaaS services.

Network slicing: The concept of network slicing is enabled by the programmability and automation of the network OS. Network slicing is a key capability underlying new business model opportunities. Operators will be able to provide dedicated virtual networks to various customer groups much more economically than in the traditional model where these customers would build their own dedicated private networks. Network slicing gives operators the flexibility to dynamically instantiate and run multiple network instances (slices) on the same physical network infrastructure. A network slice is an independent, virtualised e2e network, which, from a customer or business partner perspective, is behaving in the same way as a dedicated private physical network, including business logic and network management.

Augmented cognition systems: Comprehensive and efficient network automation is especially important for operating highly disaggregated and virtualised production service environments with massive numbers of dynamic endpoints and connections. These needs for automated service instantiation, agile scaling and live function migration, threat detection and remediation, auto resiliency, and more apply not only to network operators, but also extend to the programmable NaaS consumers and their virtual networks, such as MVNOs, global enterprises, verticals undergoing their own industrial automation transformations, and the digital value platforms discussed.

While automated service instantiation is handled primarily by the network OS, reacting proactively in time when complex arrays of resources need to be adjusted to prevent demand, failure, and security events from impairing QoE requires application-awareness, deep insight into application flow demand and performance, and advanced predictive analytics capable of triggering network actions. The analytics and machine-learning at the core of the cognitive cloud work in concert to enable automation of the three operational dimensions of elastic capacity, cognitive security and autonomic reliability — coordinated through an overarching orchestrator utilising a common policy engine.

Digital value platforms: Digital value platforms will provide global virtualised enterprises with the ability to scale with worldwide demand and yet leverage local infrastructures and resources to deliver their digital goods and services with unmatched user experience. Likewise, it will provide industrial, agricultural, healthcare and other verticals more agile and efficient ways to produce and deliver their physical goods and services. The automation and programmability of everything will permeate and transform virtually all industries.

Dynamic data security: The future network architecture introduces a new paradigm for dynamic data security which is based on two pillars: the systematic automation of multi-layer security mechanisms orchestrated across the e2e network, and the creation of a digital trust framework architected to ensure data and system integrity, visibility, and regulatory compliance in a highly dynamic and multi-entity environment.

Network-wide automation of security is needed to cope with the scale and sophistication of future threats including advanced ransomware and APTs (Advanced Persistent Threat). Digital trust mechanisms need to offer for example the verification and audit of data, processes, decisions and rules that are driving the work flows and the dynamic behaviour of digital automation systems such as the control of autonomous cars and robots.

Pushing cognitive security agents to the edge of the network supports most effective scaling, and defends against threats and attacks as close as possible to the source.

Major research challenges

Major future research challenges are expected in the following areas:

- Exploration and exploitation of centimetre and millimetre wave frequency bands.
- Massive antenna arrays and use of carrier aggregation techniques across available frequency bands.
- Means for spectrum sharing and co-existence.
- Low latency requires: New network architecture with edge clouds close to the end user and centralised clouds with flexible function split and optimisation of radio interface, RAN and core processing.
- Use of network analytics, big data and artificial intelligence/machine-learning, neural networks and quantum computing to enable complex network control, management and automation, as well as intent-based networking
- New security mechanisms as part of the overall system design from the start.
- Broad deployment of software technology for efficient and secure implementation.
- Optimisation of network protocols beyond the today's Internet protocol to meet new requirements.

- Optical communication: Scalability and programmable flexibility of optical links, tuneable wavelength, variable modulation schemes, approaching limits in optical transmission by exploiting all dimensions amplitude, phase, polarisation of light, frequency and space.
- Feasibility study and deployment blueprints for emerging transport technologies, such as Radio-over-Ethernet, transport-sensitive networking and FlexE
- Energy efficient devices, systems and protocols.
- Chip architecture design and implementation for high processing power.
- 5G xHaul solutions (front-, mid- and backhaul) for various 5G RAN functional splits and support of slicing capabilities, for stand-alone 5G deployment and multiple non-stand-alone scenarios
- Implementation of open source pieces for software and hardware components
- New technologies to monitor the performance of next generation networks (5G and beyond, SDN-NFV, optical networks, etc.)
- New techniques to determine and improve the user experience to assure a satisfactory Quality of Experience (QoE)

Taxonomy

A1 - A15

B1 - B9

C1 – C7

D1 - D5

Build Trust and preserve it

Cybersecurity is a fundamental element for the Digital Transformation of the Digital Single Market aiming at both protecting the European citizens, enterprises, infrastructures or institutions against cyber-risks as well as developing the cybersecurity sector competitiveness. European cybersecurity should be considered as specific as it must respect European values. As a direct consequence digital autonomy deserves trustworthy cooperation between academics, industry and public agencies. Considering digitalization of the B2C/B2B/B2G, common major trends drive Cybersecurity through transformation to comply with the new ICT picture:

- Convergence of ICT and OT (Operational Technologies) is becoming a reality and requires engagement of Verticals (Public Safety, Health, energy, transport, banking, industry 4.0,...) potentially with Mission Critical constraints or even operator of essential interest.
- Emergence of the IoT leading to new issues in terms of vulnerabilities, authentication and scalability. Both for mass market or Industrial applications.
- Continuing Cloud evolution with Service-based architecture and “XaaS” (Everything as a Service) paradigm
- 5G and beyond 5G infrastructures and services coming with predominant software and virtualization usage
- Identity and Access Management challenges in highly complex Cyber Physical Systems
- Data life cycle with privacy and confidentiality enforcement in a competing world of Big Data and Artificial Intelligence
- Need of Evaluation, Certification and Exposure of Cybersecurity properties/attributes for complex systems and Services End-to-End aggregation.

- ...more and more numerous and sophisticated cyber-attacks

Digital Transformation must come together with cybersecurity transformation.

Developing Efficient Protection Solutions

Protection “by design”, “by default”, “by orchestration” remain a cornerstone of cybersecurity but has to evolve to comply with systems and services. It applies in very diverse environment such as Cyber Physical Systems, 5G & Beyond (thus cloud), social networks, web-based applications.

There is in particular some needs to develop further the following topics:

- Data Protection, all along its life cycle, including GDPR application. At rest, on the move but also as sharing is required, solutions allowing multi-party computation with privacy and confidentiality respect. This may include cryptographic technologies and/or anonymization technologies.
- Safe Code assurance and life cycle from source code analysis towards control of update/upgrade phases
- Cyber Physical architectures with Security enforcement
- Hardware and embedded secured platforms
- Software Defined Security for security function deployment
- Software Defined Security for innovative strategies (micro segmentation, deception,...)
- Software Defined Security using autonomic (self*) technologies: Detecting misconfigurations and vulnerabilities so that corrective actions can occur to assure policy compliance and risk reduction
- Continuous Security assessment of systems and Services including configuration of the termination points/devices attached to a network
- Security as a Service, including Identity and Access Management for users/devices.
- Security Policies consistency and conformity. From edition towards formal proof.
- Privacy preserving mechanisms
- Authentication in complex IoT and Cyber Physical Systems
- 5G slicing Security
- Liabilities and forensic in 5G systems and services
- Security properties/attributes exposure, Service composition and user awareness
- Evaluation, certification and trust
- Post quantum cryptography

Use of artificial intelligence and blockchain in cybersecurity

Artificial intelligence and blockchain are promising technologies expected to play a major role in the ICT domain.

Blockchain is defined as a digital, decentralized ledger that keeps a history of all transactions made over a peer-to-peer network.

Blockchain is revolutionizing many transaction-based industries. At the beginning, in focus were mainly financial services. However, applicability & further technology developments goes far beyond the financial area. Blockchain was, at the beginning, viewed mainly in connection with Bitcoin. Broadly speaking, Bitcoin is a scheme designed to facilitate the transfer of value between parties.

Unlike traditional payment systems, which transfer funds, denominated in sovereign currencies, Bitcoin has its own metric for value. Bitcoin is a complex scheme, and its implementation involves a combination of cryptography, distributed algorithms, and incentive driven behaviour. Due to the

creation of Ethereum project & smart contracts, the applicability areas of blockchain technology are growing fast.

Corporations and startups explore functionality of distributed ledger technologies, defining use cases with broad applicability, from public to industrial and private applications. The technology is believed to have the potential to transform almost all industries. Anywhere value is created, where trust and security are concerns, one can think of a potential application of the blockchain related technologies. Just as the World Wide Web created an “internet of information”, blockchain can be seen as the fundament of the “internet of value”. Thus, business potential together with applicability areas focusing on use cases, are relevant for many actors of the ICT value chain.

Developing efficient detection and remediation solutions

Attacks are also subject to innovations and cybersecurity must run this race with two main categories: known attacks and patterns and “zero days”.

- Artificial intelligence application for attack patterns learning
- Artificial intelligence application for attack patterns correlation over complex systems and third parties
- Software Defined Security: smart probes deployment
- Algorithms for self-adaptation and reconfiguration against attacks IoT weakness mitigation by Policy Enforcement distribution (Gateways, diodes,...) in the architecture
- Deception strategies
- Response to incident coordination (data models, protocols,...)

Taxonomy

A13 A14

B7 B15

C4

E8

Artifical Intelligence and Big Data

Big Data

In recent years, there is an explosion in the size of data being generated all over the world and there are numerous possibilities in several areas to further collect data. Data are only meaningful if they can be analyzed to produce new improved products and services in all domains including science. Big Data and Artificial Intelligence are key enablers in storage, retrieval and analysis of data. Currently there are big implementations by technology giants but smaller scale implementations are just starting to become mature. Therefore those important technologies will provide big opportunities.

New products and services using Artificial Intelligence and Big Data will change the way people will live and work. There will be a big market for development, sales and service of enablers for Big Data and Artificial Intelligence ranging from hardware, software, repair services to technical /management consultancy in these areas. The products themselves will be another big market. As companies and governments start to deploy related technologies, all organizations will need to follow to stay competitive.

New data and new algorithms using the data will provide many new or improved products or services to people. A good example already being developed is the self-driving car.

Analysis that could either not be done in the past due to lack of data or processing power will possibly be performed with new technologies. As a consequence Data and Artificial Intelligence will reveal unknown relations and pave the way to new advancements in science and technology. All these factors together will lead to a big market and big advancement in science and technology. with widespread use of these technologies we also expect new social and legal implications.

Big Data is a key economic asset to achieve competitiveness, growth and jobs due to its potential for impact and as an enabler for both horizontal and sector-specific gains. For instance Big Data and all information collected by the medical staff can help doctors make the right choices more quickly. A smart use of Big Data can help in managing traffic flows and in making our cities smarter. Big Data enables the timely and appropriate delivery of products for consumers and efficient processes for business.

Mastering the creation of value from Big Data will be a cornerstone in the future economic development and societal well-being.

Europe should better exploit Big Data potential in the coming years. To achieve that goal we need to strengthen all parts of the “data value chain” so that a Big Data value ecosystem and data-powered innovative business models can evolve. That includes people and organizations involved in data whatever their role, be it producing, analysing, using or creating value from data.

CELTIC-NEXT will work on Big Data challenge:

- Volume: Which data should be stored ? For how long ?
- Velocity: how to react to the flood of information in the time required by the applications
- Data discovery and relevance: how to find high-quality data from the vast amount of data available ?
- Variety: how to handle multiplicity of types, sources and formats?
- Data ownership: who owns the data ?
- Privacy: Can we extract enough information to help people without compromising their privacy?
- security, governance, and ethical issues.

Artificial Intelligence

Artificial Intelligence has a long history, starting in the 1950's with the Turing Test and gaining recent momentum since the early 2000's with technological breakthroughs (e.g. Deep Learning), large investments as well as broad mass market applications (e.g. Apple's Siri, Amazon's Alexa, etc.). Today a variety of technologies bring AI to life, such as computer vision, machine learning, natural language processing and some more. Already in 2016 50% of the internet traffic was generated by bots, as well as 23% of the twitter accounts.

Artificial Intelligence is defined as the imitation of human intelligence/intellectual processes by machines, especially computer systems. These processes include learning, reasoning, and self-

correction. Particular dimensions of AI include machine learning and expert systems. Machine Learning: Machine Learning mainly deals with pattern recognition and the automation of algorithms to enable computer systems to learn from huge amounts of data. Supervised Machine Learning is used for prediction and classification and unsupervised Machine Learning for clustering.

- Deep Learning
- Statistical machine learning
- Artificial neural networks
- Expert Systems: Programs which are designed to support specific tasks (in areas for monotonous and rule based tasks), by following complex algorithms.
- Automation (e.g. Manufacturing)
- Recommendation Engines (e.g. Financial Dec. Making)
- Diagnosis, Troubleshooting

“Intelligent Machines”

Cognitive capabilities enable machines to become “intelligent”:

- Reasoning: In information technology, a reasoning system is a software system that generates conclusions from available knowledge using logical techniques such as deduction and induction.
- Perception: The capability of a computer system to interpret data in a manner that is similar to the way humans use their senses to relate to the world around them. Hardware and software have allowed taking sensory input in a way similar to humans.
- Planning: Branch of AI that concerns the realization of strategies or prediction of action sequences, typically for execution by intelligent agents, autonomous robots and unmanned vehicles. Planning is also related to decision theory.
- Extended cognitive capabilities
- Communication: Focus on interactions between computers and human (natural) languages. Challenges like language understanding, gesture or emotion recognition exist in order to enable computers to derive meaning from human or language input.
- Knowledge Representation: Focus on information representation in a form that a computer system can utilize to solve complex tasks such as diagnosing a medical condition or having a dialog in a natural language.
- Generalized Intelligence: The intelligence of a machine that could successfully perform any intellectual task or the ability of a machine to perform general intelligent action that a human being can.

Future AI use cases for ICT and industry

Artificial Intelligence technologies hold tremendous potential to improve and automate many aspects across the Telco value chain, ranging from:

- Network planning and automation
- Infrastructure performance

- Infrastructure security
- Innovative services (B2B and B2C)
- Smart human computer interactions (natural language understanding and generation; visual voice and multimodal recognition; conversational agents)
- Sales (Sales agent support systems),
- Products (Recommendation systems, smart hubs),
- Customer service (automated CRM)
- Internal processes (Online marketing optimization, financial forecast automation, etc.)

The increasing use of AI and machine learning technologies turn the converged and cloud-optimized network architecture into a cognitive system. AI enables a higher degree of automation and adaptability of the infrastructure, allows to cope with the increasing complexity of networks and systems, and helps human operators by providing assistance and insights on complex matters.

Some specific use case examples are the following:

- Contextual service creation and management tailored to user needs Fault management, proactive maintenance
- Cybersecurity threats identification and remediation
- Prediction of resource requirements to guarantee the quality of experience and associated proactive network/computing/storage resource allocation and orchestration on virtualized, programmable infrastructures Optimization of physical layers performance (coding, interferences, handovers..)

Besides, AI will have uses cases in smart industry, digital enterprise, digital education, smart cities and smart transport, autonomous cars and fintech.

Rigorous research and open and transparent dialogue with the experts from industry and academia networks, will multiply the potential of Artificial Intelligence in the coming years and allow the commercialization of valuable solutions for industry and end-users.

In this context CELTIC-NEXT ecosystem will do research and development of best practices, Proof-of-concepts (PoC) and Minimum Viable Products (MVP) within relevant areas of the telecommunication value chain and beyond.

Next research challenges of Artificial Intelligence

- One important limitation is the necessity of huge labelled data sets to train AI systems. For some topics, these labelled data are easily accessible (pictures of cats, pictures of faces, audio signals and their textual transcription, etc). But for more specific domains such as networks, expert knowledge is expensive for training. Consequently learning with fewer examples is still a key research target for AI.
- A telecommunication network is more and more a highly dynamic system, application of learning methods to such non static system is a challenge.
- it is difficult to understand "what is learnt, why, and how". There is no explanatory power to these classification or interpolation techniques, i.e. they cannot explain the reasons of their response, the concepts or logical relations that they have

discovered. Therefore the capability to explain AI decision is a research topic for the coming years.

- It is very difficult to design hybrid methods that combine known models of phenomena (like physical models, equations, etc) with Neural network based learning methods. Combination of AI with model based optimisation should be investigated as it has the potential to bring further relevance, efficiency and performances in the digital infrastructure automation and optimisation
- Information and data is massively distributed within the cloud and in the Internet of Objects. In this context developing distributed machine learning methods coping with distributed data sources and computing processors is a key innovation topic. Exploiting massive parallelism, intelligent distribution of processing between edge clouds and core clouds, and efficient scheduling of the training phase of AI apps during off peak hours are some of the approaches that need exploration and solutions.

Taxonomy

A10 A11 A12 A13

B8 B10 B11 B12 B13 B14 B15 B16 B17 B18 B19 B20 B21 B22 B23

C1 C4 C5 C8

D1 D2 D3 D4

E1 to E14

Protect the Planet

The threats over our planet are more and more numerous. The environmental crisis is enlarging from nature to food and health. As a consequence of the continual increase of greenhouse gas, the climate change is getting faster and threatening our water resources, food safety, and ecosystems. Pollution of air, water, soils and noise pollution are increasing sanitary risks.

The world energy consumption is expected to increase of 48% between 2016 and 2040, whereas some critical resources (like rare earth metals...) may lack at some point.

As taxes against carbon dioxide will appear in more and more countries and increase in value new technologies should be used to prevent, measure and communicate pollution information. New applications should exploit data for climate, and anonymized health data to warn and avoid damages at a bigger scale.

The citizens, governments and firms are getting more and more aware of the need to protect against pollution, recycle resources and use renewable energies. National and international regulations will push companies and customers to more efficient use of resources in production modes and towards the generalization of recycling. In the next 8 years we will see the transition between a logic that is still close to intensive industry production to a logic of eco-conception while ways to bypass resistance to change should be invented.

New technologies and solutions should answer all those environmental challenges. Frugal innovation may also inspire the conception of new ways, equipment's, services and applications.

Energy efficiency will be a key word not only for telecom networks and services but also for the whole industry, transports, smart buildings, smart cities and smart agriculture. Sensors will be used to measure and take counter actions. Among the previsions the world market of

smart agriculture should reach 11 Billions USD in 2022 (with a Compound Annual Growth Rate (CAGR) between 2017 and 2022 of +13,2%)

These constraints will have impact on the production and recycling of telecom and IT devices and networks (use of substitution materials, intermediation, waste management, conception of devices that have more autonomy or event that are energy self-sufficient.

Telecom and IT networks will need to be more and more energy efficient, using new tools for predicting and managing their traffic loads. At service level the environmental footprint of digital usages will be more and more monitored in order to reduce it as much as possible while preserving the quality of experience.

As responsible equipment sourcing will be of utmost importance, this will foster eco conception:

- "from cradle to cradle" concept (already 85% of the waste from electronic devices should be collected and recycled from 2019 onward),
- innovative modular designs for hardware (e.g. for networks of antennas) and software,
- telecom and IT equipment using renewable energies.

New technologies will be developed to store energy (domestic batteries,...) and to get energy back, and smart and micro grids will develop even more. (The CAGR of smart grid between 2016 and 2021 is expected to be +27%).

Solutions for energy management in homes, offices and industries will be enhanced and interconnected with remote management control. Energy efficiency labels should develop.

Artificial intelligence with machine and deep learning may also help reduce the energy consumption.

At service and application level we should also imagine innovative tools for social regulation of consumption. Innovative services should ease and develop the circular economy, and eco-responsible consumption modes. Collaborative consumption (sharing instead of owning) help reduce the impact of human activity on the planet. It is expected to be multiplied by 10 in 10 years to reach a world market of 302 Billions Euros in 2025.

Taxonomy

A7

B10 B12 B13

E1 E9 E10

Foster Health and Wellness

The World Health Organization (WHO) defines eHealth as "the cost-effective and secure use of ICT in support of the health and health-related fields including healthcare, health surveillance and health education, knowledge and research."

The spread of eHealth applications will help reducing the cost and the societal burden of Healthcare in Europe, with needs that are likely to grow further over the next decades. Thanks to the growing

penetration of smartphones M-health is actually expected to potentially cut costs of healthcare by 15% and increase the effectiveness and efficiency of the delivery of care.

People will in the future have multiple sensors and actuators placed on their body and around it. Those things will synchronize with the phone and give an active person an overview of the workout statistics, elderly person an outlook of the body condition, or a diabetic the sugar levels. These things may also communicate with the city infrastructure providing statistics on the most popular running tracks or health conditions of people in different neighbourhoods, for instance. When somebody has a degraded health condition, or if there is a health emergency, doctors will be able to use body sensors and smartphone camera to remotely diagnose the patient and – if needed – send help much faster.

Key topics in the health domain at this point in time are the real time integration of a massive number of “things” (IoT), processing of large amount of data (Big Data), the integration of data on the fly from different sources and across different networks, and aggregation of services across different domains to support integrated care models.

This is a wide area from the ICT perspective, including, e.g. the interoperability of computer-based medical systems, management of electronic patient record, and the interconnection of hospitals and medical team remotely. 5G is seen as a key enabler for large-scale adoption of eHealth services.

CELTIC-NEXT will work on the research challenges in the eHealth sector, such as:

- High reliability and guaranteed Quality of Service
- High security, privacy and authentication
- Scalability to high number of users
- Ease of use for non-ICT specialists

Taxonomy

E7 E14

New ways for Consumption and Production

New consumption ways

In response to ecological and budgetary issues, new consumption patterns are emerging. Individuals are more and more looking towards sustainable, economical and ethical consumption. Those different aspects are considered before the buying decision. Thanks to information available on internet consumers compare and optimize their buying acts.

Do It Yourself , Local and collaborative consumption (e.g. car sharing) as well as circular economy are expected to develop further. New business models will adapt to new consumption modes, for instance “pay on use” is expected to develop in the coming years thanks in particular to available data from IoT platforms.

Digital tools facilitate the communication between the brands and the consumers in both ways.

Consumers are developing toward "*Consumactors*". Social networks will have a growing role in future consumption modes through ratings and recommendations.

In parallel manufacturers are getting more knowledge about the customer needs, usages and preferences and therefore will be able to offer more and more personalized products and services, in real time, according to the context and even the emotions of the client. Brands are developing new strategies to engage their clients via personalization or gamification.

Industry 4.0

This chapter will present trends and needs of the manufacturing sector that is undergoing a fundamental change often referred as 4th industrial revolution. The revolution of manufacturing industries transforms the traditional business of manufacturing of goods towards service-based business in global value chains. The disruption of manufacturing business poses a huge need for new ways of doing things: intelligent operations, tight collaboration with ecosystem partners, flexible production systems, increased customer intimacy and non-traditional employment models. All this is enabled by digital technologies, such as internet of things, big data analytics and artificial intelligence, mobile technologies, robotics/automation and digital platforms.

The manufacturing sector has a huge potential to benefit from the fast-developing digital technologies.

According to McKinsey, already IoT has a global market potential of \$1.2T - 3.7 T by 2025 in factory operations and equipment optimisation, which is by far more than in any other sector outlined in the survey. Manufacturing is also producing vast amounts of big data that is often not well exploited. Global manufacturing amasses over 2,000 petabytes of data annually, but currently, the Industrial Internet Consortium estimates that in a "typical factory, more than 99% of data is discarded" without any attempt to derive value. [1]

However, the sector is also a very challenging one to digitise, due to its complexity and strict demand for reliability, safety and interoperability with legacy systems.

Overall trends and requirements

There are several significant trends in modern manufacturing, every one of them dependent heavily on the advances in digitalization. Firstly, manufacturing occurs in company networks or ecosystems. A factory is typically linked upstream to many subcontractors or suppliers serving the factory with components, subsystems, raw materials, etc. Digitizing or automating a factory itself is a tremendous challenge but as manufacturing has been distributed to the supply chain it creates the need for connecting such smart actors seamlessly together and thus enabling a holistic connectivity across the value chain. Connecting a factory in downstream, i.e., to customers, integrators or retail, is becoming increasingly significant as servitization of manufactured goods or customer support are becoming important, as well as, many kinds of feedback to manufacturing or to R&D. Secondly, from product point of view, the so-called digital twin is increasingly important from early product idea through high value-added product design, assembly or manufacturing, and operative use. Such product lifecycle stages need to be seamlessly connected through respective digital twins.

The use of digital platforms is increasing heavily, both from company network or ecosystem point-of-view (operative technologies) and from product life-cycle point-of-view. One significant trend is that operative functionalities are being outsourced and offered remotely via cloud. This trend has started

in condition monitoring, etc., but in the course of increased high-speed communication, far more operative tasks can be potentially implemented or provided via internet or cloud, even most time-critical control-loops or alarm signals. Even though such all-in-the cloud concepts may become technically possible, it is foreseen that many kinds of cloud-edge architectures emerge. It may not become feasible or rationale to broadcast back and forth huge amount of data across continents, or subjected to communication breaks, security threats, etc. Autonomy within edge remains preferred, whereas, certain functions remain in clouds.

Increased complexity of products and production, more agile business cycles, many kinds of time, safety and quality criticalities, moving to lot-size-one or tailored products with mass-production efficiencies, human-system interaction or user experience multiply the requirements for software systems as such, as well as, communication speed, latency, and reliability.

The landscape and contexts of digital manufacturing are significantly governed by Industry 4.0 in Europe and Industrial Internet Consortium (IIC) in America. They both build on top of 3G or 4G technologies but also need very essential higher-level connectivity, interfaces, interoperability, standards, and tools.

Implementation Issues:

Connectivity by 5G for Internet of Things: The forthcoming 5G mobile network will provide many service capabilities and features essential for the digital manufacturing of the future. It provides Internet of Things (IoT) wireless connectivity to the sensors, control and operations & maintenance systems of the factory machines. The wireless connectivity will enable flexible re-placement of the machines and other systems within the factory for a dynamic manufacturing environment. The ultra-high reliability and ultra-low latency of the 5G connectivity will enable joint innovations of the wireless and the digital manufacturing for even the most critical applications.

Cloud: Cloud computing and high-speed connections enable centralized processing of data in distance from the manufacturing sites. However, the privacy and protection of the data, ultra-low latency response times of some factory applications, such as robots control, will require local edge cloud computing at the factory site. In addition, ultra-high reliability requirements will require edge cloud computing. There will be need for innovations for such distributed network architectures. The innovations on the digital manufacturing and digitalization of the value chain can build onto this cloud computing platform, complemented with the 5G wireless connectivity platform.

Big Data Analytics: Data yielded from sensors within and around the machinery and the products themselves will create feedback loops. In a manufacturing environment, big data can be used on large quantities of produced data to uncover trends, and useful insights, that can later then be relayed for use under human intervention. Furthermore, this data may be linked with artificial intelligence and machine learning, to be able to drive towards a more automated factory floor.

Automation and robotics: The use of robots in manufacturing will increase even more in the future. They will enable automation of production, and even in increasingly complex and precise processes. Wireless IoT connectivity by 5G will open the possibilities for innovation on the monitoring and control of robots. In particular, robots for extremely precise tasks will require innovations on the extremely low latency communications paths between the robots and the control functions.

Additive manufacturing: As consumers desire for increasingly customised products, designs become too, increasingly complex. However, assuming there is no increase in the amount of material used, there is no additional cost on a 3d-printable design because the manufacturing technique is additive rather than subtractive, i. e. there is no material base to cut or erode from. This enables the production of tailored products on a more cost-effective and scalable basis. Together with lower costs of 3D printers and increased functionality enabling manufacturing companies to leverage them on a more industrial scale than at present (where use cases are typically limited to prototyping / research and development), 3D printers will become a mainstay in the manufacturing environment.

Metrology technologies: Metrology technologies are evolving rapidly, with technologies based on quantum physics promising results unattainable by measurements taken in a classical framework. In a factory, solutions shifting from the off-line paradigm, where the product has to be taken from the production line in order to be inspected, towards an in-line model, where the product is inspected whilst still on the production line, will lead to a more automated digital factory, requiring even a lesser degree of disruption to the production line.

Taxonomy

A1-A3 A13

B6 - B8 B12

C4-C5

D3-D4

E3

Smart Cities and Smart Territories

Future Smart City landscape

Ongoing climate change, global and local demographic changes, waste and lack of natural resources in conjunction with the hunger for a comfortable life require action in various dimensions. Since the majority of humans do already or will live in cities, cities become the focus of action due to their rising importance and sheer size, e.g. in 2025 around 40% of Japan's population of around 105 million, will live in the area of the capital Tokyo.

The role of the cities as living environments will continue to increase for migration of the population to the large cities and thereby a critical mass for new service paradigms based on digitalization. To address increasing urbanization and provide a good quality of life, e.g. provide a functioning supply, requires innovation often coupled with technology, e.g. the Internet of things. This process of modern urbanization is currently seen as becoming a "Smart City" whatever it means depending on the role, interests and needs of the different actors in a city or region. The leaders of the cities are becoming increasingly aware of the need to design the fast transformation of infrastructures, processes and landscape in a holistic, multi-disciplinary and sustainable manner. A successful city needs to continuously develop its attractiveness and efficiency as a whole while navigating through the complexities of urban digitalization. This can be seen as the international race toward the "smartest city".

Ultimately, the public authorities of a city will have a full sensor-based visibility to all necessary parts

of the city operations as well as real-time control allowing optimization of them. Many cities have already applied integrated and holistic approaches on the design of the city infrastructures but one important component – telecommunications - has still been largely ignored. The radio base stations, the visible part of the telecommunications networks, often emerge as an incremental add-on without coordination between the competing mobile operators. Considering the continuous fast growth of wireless Internet usage and the emerging new smart city applications such as smart traffic control, smart lighting (including the LED technology), self-driving cars and air quality monitoring, the infrastructure for a smart city has to evolve with well planned steps, taking into account the disruptions from digitalization towards the higher level of automatization and from the related new business models.

To manage the uncertainties of the steps and fast innovation on the smart city applications, the cities need to secure the availability of the underlying infrastructure at the right spots, especially electricity and telecommunications for the future smart city digital ecosystems.

Our society and cities face great challenges to improve safety, energy efficiency, air quality, effectiveness of transportation, and quality of living. A digital ecosystem of a future smart city will enable:

- Development of a new smart city infrastructure and digital services
- Improvement in maintenance of the city infrastructures
- Improved data capacity for the applications and services for the citizens
- New services and business opportunities for the companies
- Opportunities for new types of micro-operators in the value chains

“Breaking up the silos” is essential to leverage smart city opportunities

One of the big challenge that smart cities are facing is the need for “breaking up the silos,” meaning a cross-silo interaction and exchange of information. This “horizontalization” requires action within the administration of cities, organization within industrial companies, new ways of interaction between different industries and technical interworking across silos, e.g. on an open urban platform. To achieve that goal interoperability and open interfaces are a prerequisite. Harmonization of actions and integration of technical solutions is especially required in the ICT domain, since the core benefit is service interworking and data analytics of converged domains. The integration of different vertical and existing legacy systems towards a central “horizontal” open urban platform is a major interest for the cities. It is addressed in various organization and standardization bodies. Focus lies on defining an open interoperable urban platform reference architecture, forming a system of system approach. It is important to offer cities a trustful approach not leading to a vendor lock. The integration of different verticals in an open standardized way requires development of a reference architecture. It needs to address integration of legacy with currently needed systems and still enable simple integration of upcoming technologies. This requires working on data formats and usage of interoperability standards to provide interoperability within a city domain.

Communications networks - the nervous system for a digital smart city

The capacity of the mobile networks has to grow significantly to enable the digital smart city services of the future for the increasing number of the users. The services will be connected with the users through a reliable high capacity wireless network on a very high frequency and deployed in very

small cells. The high frequencies above 6 GHz of the 5G mobile system will be required for the steeply growing data traffic in the smart cities due to the surveillance cameras, 3D-streaming and other high bandwidth services. The radio signals on a very high frequency travel only short distances and therefore a high number of small radio cells with a distance of 50 meters will be deployed. This can only be achieved in a city environment in an economic way by using the street light poles as the platform for the 5G small cell base stations and multiple sensors. This kind of infrastructure of the light poles, electricity and data transport form a platform for the 5G radio network and a variety of sensors. The platform is economically viable only as a solution with one 5G base station and one set of sensors per pole which is provided by the city as the public authority. It is then shared by the mobile network operators as the sensor data and transfer platform of the digital smart city eco-systems. The citizens will benefit from the new smart city services based on the open data shared in the eco-systems and utilized by the providers of services & applications.

The implementation of a smart city will require innovations on the new types of street light poles onto which the 5G radio equipment, wireless backhaul, video cameras, as well as the air quality, weather and location sensors can be attached to, and of course the intelligent LED street lights on the top. The 5G networks will provide the common, flexible and total cost optimized high capacity communications network for the smart cities. All the data transferred from the smart light pole platform is connected to the open 5G computing nodes at the edge of the network, potentially also partly placed inside the poles. The computing nodes make the data from the sensors available to the eco-system of service providers for their innovative applications serving the citizens of the city.

Research areas

- Novel business models on the ownership and sharing of the infrastructure will need to be applied.
- Since different domains use in many cases their own protocols and data formats, the need for further investigation on suitable meta-data formats is important.
- The new GDPR laws on data privacy require additional efforts, e.g. the deletion of all data tracks if individuals upon request.
- The 5G networks on the street level will require innovative solutions and versatile service platforms utilizing the 5G technology. This implies also the connection and investigation of interdependencies of an open urban platform and 5G slicing concepts.
- The impact and growing request for low-latency data and upcoming artificial intelligence show the need for further investigation.

Taxonomy

A2 A9 A13

B4 B7 B8 B10

C4-C6

E1 E4 E10 E14

Smart Transport

One of the most significant services in Smart City platforms is the integrated smart transportation and assistance services for citizens. In a poll organized at the Smart(er) Cities conference session in

Mobile World Congress 2018, nearly 70% of the attendees have noted that smart transportation is the most significant service expected from a smart city.

Smart and fast transportation is even more crucial for large and complex cities. The digital infrastructure of transportation in a city should merge all physical transport assets in a single and easily accessible platform through the use of all smart city technological enablers such as big data, IoT and 5G to provide novel services to the integrated transport system such as new business models, new transportation models and social innovations. Such digital platforms can form a basis of multimodal travel planners, transportation networks, mobility services, transport on demand services, tracking and tracing activities.

The services provided by the digitization and integration of transportation platforms can benefit from crowd-sourcing based real-time user and vehicle information to enable a faster, comfortable and controllable experience to users leading to a fully personalized services and offers. This model in transportation requires users to be involved in the system actively, requires a strong impact on users and ensuring all stakeholders to be able to benefit from the services provided by the platform to its full extent.

Features such as gamification and other innovative solutions based on crowd-sourcing could provide the required level of involvement in user activities. Therefore, the digital platform should specifically focus on the needs and attitudes of specific groups of users such as elderly, disabled, low-income citizens. The digital transportation services should also cover personal and community based behavioural variations in transportation, barriers in digital mobility and measures taken in case of interrupted transportation.

Connected and autonomous cars

Connected vehicles already exists and will develop further toward autonomous cars. Different connectivity types are needed: Vehicle to Infrastructure (V2I) and Vehicle to Vehicle (V2V). Inside the car a wireless LAN allow passengers to share the connectivity and enjoy infotainment services. Actually the connected car is expected to offer innovative services not only to the conductor and to the passengers, but also to many stakeholders: car owner, cities, territories, insurance companies, car manufacturer, garages...

The connected car may be coupled with Augmented Reality : Passengers would get information about their environment, projected on the windscreen.

There is a strong need for Cybersecurity to minimize the risk of cyberattacks both on cars and on infrastructure. Without cybersecurity autonomous cars will not be able to develop. IA will allow the connected cars to learn by themselves how to take the best decisions but also to adapt to their owner, conductor or passengers.

In order to cohabit with classical vehicles, autonomous cars will need a high level of embarked Intelligence from the very beginning, using for instance machine learning.

Therefore it is important that the different actors of the value chain cooperate in order to invest the best connected and autonomous vehicles: car manufacturers, OEM, electronic equipment manufacturers, IT and telecom companies, mobile operators...

Taxonomy

E1 E4 E6

Smart Energy

One of the main tracks in providing a smart city is providing digitalized facilities to have more control on energy consumption and to provide a more sustainable energy supply. The smart energy concept covers all aspects in energy context, from production to consumption. Smart energy aims at greener energy generation, lower energy consumption, an energy consumption pattern with flattened peaks, and a resilient distribution grid.

The main objective in energy sector is the reduction of consumption to conserve natural and financial resources. This requires urban sustainability through the promotion of structural and coordinated actions with service providers. Big data analytics, Internet of things and communication infrastructures such as 5G are the main technologies to enable a fully monitored and more efficient energy cycle in a smart city.

Among the solutions to provide a more sustainable energy policy in a city is the replacement of street and public building lighting systems with more automated low power ones and the use of photoelectric and motion sensors to automatically turn the lights on and off and adjust their intensity according to the environment needs. In addition, centrally managed or automated approaches can be used in energy management facilities to manage the energy flow to energy grids and infrastructure.

Furthermore, the energy grids needs to be smarter, so as to promote the rational use of electricity also on public roads, in homes, hospitals, public buildings, and industries. The consumption can be monitored using automated meter reading approaches based on Internet of things, that covers 3GPP technologies such as NB-IoT or LPWAN approaches such as LORA.

Lower energy consumption can be influenced in citizens through the use of gamification based on the data extracted from consumption profile of citizens individually or as a group. Also the more responsive devices should be adapted to daily life which can manage the energy consumption depending on the current total energy demand to reduce the peak levels in energy.

Microgrid and smart grid involvement and management in a smart city is crucial for sustainable energy policies. Anomaly detection is a must to avoid non-authorized energy consumption and resource accessibility. All of these components may be locally or remotely managed which heavily relies on Big data analytics, edge computing and Internet of Things.

Taxonomy

E1 E9

Smart Agriculture

Smart agriculture as well as the whole agro-food sector will benefit in the coming years of the deployment of massive connected objects. The Internet of things (sensors, cameras, connected scales, ...) applied to smart agriculture will allow fine monitoring and collection of biophysical data (water, solar radiation, temperature, weights,...) for healthy development of plants and animals as well as management of irrigation, fertilization and crops. The digital platforms for e-agriculture and smart manufacturing should finally use common enablers for optimization purposes:

IoT platforms with reliable connectivity, Cloud computing, Big Data processing linked with AI and machine learning, standards API, automation and robotics.

The ultimate digital platform and connectivity networks in the smart agriculture area should allow the traceability of food in the production process all over from farms and vineyards to consumers. On the other way round some feedback communication loop about customer satisfaction and preferences will allow quality improvement of future agriculture production.

Taxonomy

E1 E3 E4 E6

Smart Home and Smart Building

Today, a Smart Home consists of a series of fragmented vertical markets served by a complex integrated ecosystem of players and devices across multiple industries which is generating an exponential increase in the number of connected home devices:

- Comfort: thermostats, automations, lighting, remote control...
- Security: intrusion alarms, remote surveillance, presence simulation...
- Peace of mind: smoke or flood detectors, baby monitors...
- Energy efficiency: demand response, battery charge...
- Infotainment: TVs, STBs, OTT media applications...
- Health: remote monitoring, elderly care, quantified wellness...

With just a few exceptions, these vertical industries involve local or regional third parties, such as healthcare services, property insurance companies, private security, local commodities...

According to the level of ambition and the investment required to provision the service inside the home, there are two different types of Smart Home services:

- On the one hand, long term investments in home improvements by the home owner (either building companies, landlords, or private owners), usually requiring bigger expense with a long-term goal such as security, energy savings... They are similar to any investment in home infrastructure and may also be funded by public funds in order to achieve strategic goal, such as heating reductions. These investments (especially when funded in any way) are more of a conservative nature and rely on stable, perhaps certified / standardized products with an expected lifespan and the availability of spare and replacement parts over a period of decades. Usually longer maintenance cycles, but then may be regulated and only be operated by experts
- On the other hand, short term investments, which follow trends, technical leaps, entertainment and other influences. Usually they are done more spontaneously, and

are much cheaper, with lower quality of service commitments. Installation and operation is done by the consumer himself. There is basically no regulation (besides the usual consumer protection laws and regulations). The expected lifespan of the services is usually shorter, sometimes only a few years or even months (and so is the lifespan of many service providers)

Successful short term Smart Home services may evolve into long term services.

Each household has different requirements and needs, different spending behaviours, and varying quality expectations. On average the number of connected devices at the home of a family of four persons has increased from 10 in 2010, to 25 in 2017 and is expected to be above 50 by 2022. Some market studies suggest that the connected home device shipments will grow at a CAGR of 67% to reach € 1.350 Mn by 2018.

While traditional deployed dumb devices and appliances have a single purpose, today's connected and smart devices can be deployed in much broader scenarios. They can be adapted, re-programmed and re-used in many different scenarios, which span more than one use case silo. For example, a movement sensor that is used today in controlling light scenarios can also be part of an alarm system. Tomorrow, the same sensor without any change of the device itself can be used to control movements in elderly care scenarios.

WiFi has become the predominant connectivity of choice for home devices. Currently home connected devices data is mostly (90%) wireless, whereof 94% is WiFi and 6% mobile.

The increasingly growing number and diversity of devices, together with the complexity of the deployment and the setting up of the connection, not only overwhelms most consumers (and sometimes even experts in the field), but actually pose huge security risks to consumer data and the safety of operator's infrastructures.

Because of the inherent complex nature of these systems (uncontrolled, self-managed, varying qualities and quantities) it can be expected that only gradual steps towards a self-organizing smart home will happen in the near future. A service provider that takes responsibility for managing the quality, security and complexity of a smart home is costly but sometimes the only way to help consumers to live in a smart home.

Worldwide players race to achieve a position in the Smart Home market as the home centralized gateway: the key element that controls home life while juggling with all connected home devices and connectivity.

Different industries are positioned differently in this race:

- Telcos and pay-TV providers: already delivering home services with experience setting-up and managing CPE and home connectivity

- Vertical service providers (e. g. remote healthcare) are pushing their devices at home, but most are limited to one vertical silo
- Hardware manufacturers: able to deliver attractive consumer technology into homes
- Digital players: who leverage on their size and agility to provide a standardized home operating system under their control

But it can also be expected that in the future devices, appliances and services interoperate with each other. Today, most solutions are basically simple operations of "one device one service" offerings. There is basically no interaction between the different solutions and devices. This could change in a way that allowed devices to interoperate with each other, exchange capabilities, and as a consequence offer improved or new services to consumers.

The Smart Home ecosystem goes well beyond ICT industry, and the outcome of this race can deeply transform the related vertical services industries.

Taking the vision further, these solutions could be provided to the complete set of residential units within a building, or applied to non-residential buildings, such as offices, or commercial spaces, effectively creating a Smart Building which in turn creates new opportunities for additional evolution. In this sense, we can define a smart building as any structure using automated processes to control systems such as heating, ventilation, air conditioning, lighting, security, etc. A smart building involves sensors, actuators and communication capabilities (such as 5G, LPWAN or local self-managed networks) to collect data, analyse and manage it according to its functions and services. These capabilities enable owners, operators and facility managers to improve asset reliability and performance, reduce energy use, optimize the utilization while minimizing the environmental impact of the building.

Smart Homes and Buildings, form part of an extended vision of a Smart City. One possible such scenario is the integration at home of vertical features related to municipality services – in particular Smart City services – such as intelligent shared transportation systems or connection to public alarms.

Another more complex scenario is the orchestration of the Smart Home energy efficiency policies with the grid supply or municipal efficiency strategy, where the Smart Building becomes relevant from the city point of view.

CELTIC-NEXT vision of the Smart Home has four pillars:

- An open ecosystem allowing third party services to be integrated with the different Smart Home elements. In the coming years we expect AI-driven service improvements and cross-service possibilities.
- A smart central gateway, that ensures secure remote access to the Smart Home through user-friendly interfaces. Innovative chat-bots and voice assistants, acting as the main entry point will facilitate the control of the services, devices and connectivity.
- Smart management of connectivity, including solutions that provide optimised WiFi home coverage, increased network security, secure guest access...
- Management of vertical-specific devices that need to seamlessly connect to the home WiFi with easy set-up and operation

This vision links to the CELTIC-NEXT vision of Smart Cities, with users being offered a seamless and consistent experience when interacting with products and services bridging home, on the move and integration with smart city infrastructure.

Taxonomy

A1 A2 A3 A4 A10 A11 A13 A14

B8 B10 B11 B14

C1 C2 C4

D4

E1 E2 E7 E9

Digital Enterprise

Digitalization in the enterprises is a living roadmap for the organizations since it is a continuing process that evolves with the changes in digital technology. Digital enterprises position digital technology in the core of their organizations which is in interaction; with the products and services they produce, with their customers they interact, with their business operations they process, with their strategic perspectives that they envision, with their professionals working inside and with the relationships with the ecosystem that they are in. The enterprises are more competitive, flexible, dynamic and efficient in their market value chains increasing their market values and stakeholder values by utilizing digital technologies. According to the Global Industry 4.0 Survey [2]; big gains are anticipated by industrial product companies in all regions, expecting gains over 20% in the next five years by additional revenue, lower costs and efficiency gains.

Regarding to the digitalization of the enterprises, the essential part of this transformation is the engagement of the professionals into the digitalization, forging their mindsets as technology centric which means a change in the culture of the company, placing speed, agility, automation into the system and having learning organizations with a high adherence to the digital education. The digitally transformed professionals digitalize processes of the vertical operations within the enterprises, influence the horizontal layers by working together with customers and suppliers within the digital ecosystem, introducing innovative and digital functioning products and services that are augmented by other digital interfaces. As the European actors play an important role in binding the companies and countries across Europe and beyond Europe, the parties of the ecosystem become more associated within the worldwide data networks and supply chains. In this aspect digital enterprise and digital education envisage the future of organizations globally with the acceleration initiated by the industrial leaders both influencing developed economies and emerging economies.

Digitalization and Integration of Vertical and Horizontal Value Chains

Digitalization exists within each stage of the lifecycles of the products and services from development to deployment, from purchasing to services, from manufacturing to logistics covering all the vertical processes that an enterprise has, generating value all across the stakeholders (customers, suppliers, shareholders, value chain partners, third parties etc.) that are horizontally integrating to the enterprise. Digitalization of the enterprise embraces all the transformation and integration of these elements blending the data into real time, efficient, optimized, augmented and intelligent processes and operations.

Use of Data Analytics in Digital Transformation

Data analytics is the crucial capability in digital transformation of the enterprises both in digitizing the products and services and in creating new digitized products and services by interpreting the data flows coming from all of the resources. Advanced capabilities in data analytics generates outputs that lead for revenue boosts bringing competitive advantage. The usage of digital business models and analysis of the customer, transaction, access data creates value on existing portfolio and enriches the range. This leads to data driven services, offers, products, platforms and integrated solutions.

Ensuring Digital Trust with Data Integrity and Security

Digital Trust is the factor that digital enterprises cope with, in order to assure security and safety functioning over all the elements of the digital enterprise. The data communication, integration and storage should be complying with all the security requirements, harmonized to the regulations and to the intellectual property rights, building and protecting trust in the digitized era.

Digital Transformation of the Professionals

The vision of digitalization is determined and driven by the leaders of the organization, bringing in the digital culture and managing the transformation of the professionals. Changing the way of thinking and acting of the employees is crucial by supporting their motivation and improving their skills via learning, experimenting, implementing of the new technologies, collaborating with digital leaders in and outside of the organization. Precisely, digital education plays an important role for the professionals in gaining the required approach and capabilities in this new norm of future.

Taxonomy

E3

Digital Education

Coping with 21st Century Skills Gap Challenge in a Digital World

New technological trends like Industrial Internet of Things and Industry 4.0 powered by Artificial Intelligence (AI) are becoming important factors in transforming conventional business models and jobs. Machine Learning experts foresee that all jobs whose automation is possible will be replaced by software and robots in the not too distant future. In this new digital world, massive use of machine learning will impact the skills set of future human resources in a dramatic way. Today's workforce, to a large extent, lacks the set of capabilities required by this new world and must therefore be developed very quickly.

Self-regulated Learning and Personal Learning Environments

Traditional instructional education means (Conventional Learning institutions, Learning Management Systems or MOOCS, etc.) and master – apprentice model is not enough for the enterprises and their human workforce anymore. There is a major skills gap between graduating students' capabilities and industries' expectations. In the meantime, it is a major challenge for enterprises and people to find relevant learning knowledge in an unstructured, scattered, distributed, and overwhelmingly large amount of big data ocean and un-learn / learn endlessly in this dynamic environment. Personal Learning Environments supported by emerging technologies like artificial intelligence, big data analysis and machine learning seem an effective solution for the skills gap problem. Addressing

aforementioned skills gap issue will have a very important positive impact on economy and social innovation for society.

Convergence of Learning and Work in the Enterprises

Products and services provided by enterprises to their customers are in a constant change. Therefore all employees of the organizations should continuously cope with the learning challenge of new and modified features of existing products, modified or expired marketing campaigns, brand new services and products, etc. In such a challenging environment, the learning problem of the teams cannot be solved solely by traditional in-class courses or coaching support any more. Required knowledge including state of art in the world and best practices within the company should be fed to employees while they work in a personalized manner by using Artificial Intelligence methods and all the knowledge accumulated in the company.

How Learning and Education field can utilize Artificial Intelligence, Machine Learning and other emerging technologies?

Big data analysis, machine learning and artificial intelligence are two technologies which has a great potential for learning and education as described briefly in previous sections. Besides, virtual reality, augmented reality, drones, robotics, speech recognition, conversational interfaces and 3D printing etc. will have several applications in learning and education field.

Taxonomy

E5

Content, Entertainment and Gaming

Entertainment and gaming, including next generation of multimedia technologies, are undoubtedly considered as the uppermost important research technologies to be developed during the following years. Immersive experiences and gamification are a common place of the top trends for emerging technologies. Indeed, media and entertainment has been identified Most promising verticals for 5G [3]. In addition, the hyper-personalization of services around user and customer experience are embedded in the DNA of future generation of entertainment and gaming.

According to [4] Augmented reality (AR), virtual reality (VR) and mixed reality are changing the way that people perceive and interact with the digital world. Combined with conversational platforms, a fundamental shift in the user experience to an invisible and immersive experience will emerge. Over the next five years the focus will be on mixed reality, which is emerging as the immersive experience of choice, where the user interacts with digital and real-world objects while maintaining a presence in the physical world. Mixed reality exists along a spectrum and includes head-mounted displays (HMD) for AR or VR, as well as smartphone- and tablet-based AR.

Besides, immersive technologies are moving closer to the edge of artificial intelligence [5]. Over the next five years, enterprises will move closer to adopting immersive technologies such as augmented reality (AR), virtual reality (VR) and mixed reality (MR). These technologies will in turn force vendors to figure out how to get more artificial intelligence (AI) functionality out of the cloud and into the edge. When discussing immersive technologies, a fundamental point emerges: Both immersive technologies and AI are actually a collection of subset technologies. Tuong Nguyen, principal research analyst at Gartner, says businesses need to consider both immersive technologies and AI to be mutually beneficial. As AI improves, so do immersive technologies, and vice versa.

Regarding the potential between augmented reality (AR) and social media [6], when it comes to transparently immersive experiences, technology is introducing transparency between people,

businesses and things. As technology evolves to be more adaptive, contextual and fluid, it will become more human-centric.

Interactive technologies such as Augmented (AR) and Virtual Reality (VR) are set to transform the ways in which people communicate, interact and share information on the internet and beyond. This will directly impact a larger number of European industries ranging from the cultural and creative industries, manufacturing, robotic and healthcare to education, entertainment and media, enabling new business opportunities. The challenge is to forge a competitive and sustainable ecosystem of European technology providers in interactive technologies. Better exploiting opportunities offered by multi-user interactions, researching and developing technologies augmenting human interaction in groups within both professional and private contexts. Or developing future interactive systems offering higher quality experiences, for instance through systems which are mobile, support additional senses, have higher accuracy or incorporate bio or environmental sensors.

In addition, 5G-PPP has published the main 5G Use cases for Media & Entertainment [3], which are:

- Ultra High Fidelity Media
- Live Event Coverage
- User Generated Content & Machine Generated Content
- Immersive and Interactive Media
- Cooperative Production
- Collaborative Gaming

On one hand, regarding User Generated Content & Machine Generated Content, People and objects are and will capture more and more content in order to share it with others in the cloud. That means that the future 5G network should be able to support on demand high upload bandwidth and streaming from various devices / objects (camera, health and wellness measurements, building sensors...) in order to bring a good user experience in such a situation.

On the other hand, regarding Immersive and Integrated Media, Media will become immersive and highly interactive to provide ambient media consumption at home but also on the move, with content capable of following the users and adapt to his ambient for viewing (e.g. In the car, at home etc.) New 5G capabilities will enable immersive video experience, to retransmit holographic type video beyond telepresence (2D) closer to a virtual presence experience in 3D. In the business environment for instance people are more and more working in a collaborative way even in the same company in order to be more efficient and to accelerate the innovation to the market – immersive video conferencing will simulate the face to face experience that present videoconferencing systems do not allow.

Moreover, Gaming will expand into a full immersive multi-sensorial environment which will result in a more realistic experience, improved ability for users to collaborate within the game and no limitation on the number of simultaneous users. Similar to other media areas, gaming is likely to move from a primarily “home based” experience towards an “anywhere” experience with user collaboration being both simultaneously in the physical world and the augmented reality domain, based on the users actual location. Game development may also become more cooperative with users directly interacting with the developers in real time.

In this line, the introduction of gamification has been unstoppable in recent years. However, it has gone unnoticed by many people. No doubt, gamification is present in such varied fields as learning, banking, energy or health, but what is most important is that about 85% of activities in our lives will

include aspects inherent to games by 2020 [7]. In other words, we are gradually witnessing the gamification of our life, the definitive game.

Finally, Customer experience in Entertainment and gaming is one of the cornerstone that will make possible to make these new technologies possible. Digital experience management (DEM) is the impact of presenting the right digital experience to customers [8]. The experience could be mobile or web-based, and should be always available, continually improving and perform quickly and consistently. If any of these tenants are lacking, customer satisfaction is in peril. If customer satisfaction is in peril, especially in today's social media savvy world, corporate reputation could quickly be damaged.

All in all, major future research challenges are expected in the following areas:

- New multimedia content technologies, such as Augmented reality (AR), Virtual Reality (VR)
- New gaming technologies to take gamification to all business lines and industry sectors
- Artificial Intelligence and machine learning methods applied to multimedia and gaming
- New hyper-personalized and collaborative services and applications that gather entertainment with social media
- New technologies to monitor the performance of next generation networks (multimedia, entertainment, gaming, etc.)
- New techniques to determine and improve the user experience to assure a satisfactory Quality of Experience (QoE) AI/deep learning driven media content recommendation and personalization based on predictive behaviour prediction and advanced user profiles by continuous AI assisted user role modelling
- AI/deep learning driven adaptive personalized media user interfaces, especially for TV and video, providing visual representation of content choice and discovery based on context and actual user preferences
- AI supported service quality management for video quality

Taxonomy

B3 B4 B17 B18

C3 C7

E11 E12

Quality of Experience and Personalisation

The quality is a critical factor for the success of service providers because if the requested service is not delivered with the expected quality, it may penalize the service provider's reputation, diminish its revenues and affect the performance of its business model. However, being able to assess the capability of service providers to guarantee a certain level of performance (QoS provisioning) is not enough. The focus of QoS is typically on telecommunication services, taking the perspective of a service provider, and it deals with quality aspects of the physical system, while Quality of Experience (QoE) covers a much broader domain from the users' point of view

It is necessary to develop a framework with the aims of evaluating the user perceived quality (commonly referred to as QoE). In experimental evaluations it will be also necessary to consider

business perspectives (e.g., the service cost in order to achieve a specific quality level, the adaptation of costs to the QoE requirements), being the latter part of the requirements of the concept of Quality of Business (QoBiz). From this perspective, the management of emerging service platforms requires a multidimensional ecosystem, which should take into account QoE, QoS and QoBiz [9], and consider suitable incentives for the different stakeholders (e.g., telcos and OTT providers) to cooperate. The first approach to integrate the user's perception into the quality concept started from the QoS definition itself.

Later, these ideas were captured by a series of Dagstuhl Seminars and the Qualinet COST Action with the definition of Quality of Experience (QoE) as "the degree of delight or annoyance of the user of an application or service. It results from the fulfilment of his or her expectations with respect to the utility and/or enjoyment of the application or service in the light of the user's personality and current state".³ This definition has become widely accepted, as it intrinsically captures the fact that the experience of a service is a subjective opinion in line with user's expectations. This version of definition of QoE has been adopted by the ITU-T in Rec. ITU-T P.10. in 2016 after being supported by a large number of scientists in the field of QoE. It follows from this definition that any service provider that wants to deliver high QoE or control the QoE that is delivered to its user, needs to understand its user very well.

QoE is a multidimensional construct with a variety of underlying influencing factors coming from three categories i.e. Human, System and Context influence factors. For example, for media distribution QoE is influenced by all system elements involved in the end-to-end service delivery, namely network, equipment, codecs, techniques protocols, terminals, etc. [10]. The human influence factors could be e.g., socio-economic background or emotional state and the context influence factors are factors coming from the user's environment. Traditionally the system influence factors have been in focus.

Besides, according to [11], quality is the result of judgement of the perceived composition of an entity with respect to its desired composition (totality of recognizable and nameable characteristics of an entity related to individual expectations and/or relevant demands and/or social requirements).

Usually, the methods to gain insight into the delivered quality of a service and the users' experience of it have been done through controlled laboratory experiments, where the opinions of panels of users have been collected. These methods are very often referred to as subjective quality assessment, and although there are standardized methods for conducting them, such as speech quality (ITU-T Rec.P.800) and visual quality (ITU-T Recs. P.910, P.911 and P.913) among others, there are still many open questions for studying and understanding QoE, in particular on 5G networks.

All in all, QoE assurance requires extraction of QoS parameters from different points of the multimedia network ecosystem. From this perspective, the measurement of potential QoS parameters plays a crucial role in providing the required input data for the quality estimation model. Therefore, new models using statistical properties of the network traffic need to be designed for new technologies, such as 5G, multimedia, smart cities, transport, SDN/NFV, etc.

In order to assess the QoS and QoE in media and content environments, advanced monitoring solutions are needed to deal with the specific requirements of such technologies. Due to the distributed nature of contents distribution and media infrastructures, traditional monitoring solutions that are usually based on centralised architectures are no longer valid. Several issues appear in this kind of solutions, such as, lack of scalability, high network bandwidth and computational power needs, and being prone to single points of failure.

Major future research challenges are expected in the following areas:

³ www.qualinet.eu

- New algorithms and methods to correlate QoS and QoE from customer perspective, especially for new types of services
- New techniques for relating QoE to User Experience (UX) in interactive services, and determining their impact on acceptance
- Multidimensional approaches for an enhanced understanding about the cause of quality degradation
- QoBiz (Quality of Business) solutions
- New techniques to provide objective and subjective measurements of customer experience
- New methodologies to involve real users in customer experience
- New Customer Experience Management architectures and frameworks
- New monitoring solutions to provide user experience in real time
- New monitoring solutions to take into account user insights
- New platforms and services to hyper-personalized and collaborative contents and services
- Hyper-personalized mechanisms that correlate customer experience

Taxonomy

B23 B24

Fintech: New Ways for Financial Secure Services

There is a need in the finance industry to support the creation of innovative tools and services in order to help the finance industry adapt to the challenges it currently faces. Robust yet agile and tailored financial services are essential for our economies, citizens and enterprises.

Eit Digital [12] defines the needs for the three most important sectors for the finance industry: the retail banking sector, corporate banking services and the asset/wealth management sector.

The future of retail banking focuses on the way financial institutions will interact with their retail customers (i.e. our citizens) in the future, using modern digital devices and tools. A broad range of themes need to be supported, including cybersecurity, authentication, online payments, micropayments, cashless societies and personal financial management.

Modernised corporate banking is fundamentally important for the efficiency and productivity of European industries. Modern corporate banking services will help companies get more tailored access to the financial resources they need. The finance industry need tools that help to create better financial transparency, automate and simplify financial and accounting tasks for companies, ensure fluid and secure lending, and improve financial services available to corporates, SMEs and startups in Europe.

In the Digitalised Wealth/Asset Management domain, technologies like machine learning and artificial intelligence algorithms are needed to provide better advice, structure better financial products, improve reporting, and support investment professionals in selecting the best financial products to withstand systemic risks.

Future financial services have great potentials for a growing shift in the revenue pools of the operators and ICT players. According to the prediction reports, in the year 2026 6% of all the 5G enabled digitalization revenues will come from financial services with 24 billion EURO. Significant

new value generation opportunity for operators lie in digitalization of lending payments and investment, online P2P (person to person) money transfer, e-wallet usages, changing customer relations with online/mobile transactions and customized financial solutions and digitalization in insurance. [13]

The adoption of new ways for financial services is contingent upon inevitable secure solutions that are supplied tremendously within all the transactions. The numerous challenges may only be surpassed by the involvement of the states on a consensus, framing the main requirements of the fiscal measures and protecting the citizens that are needed to be compromised in European level and incompatible with world-wide spectrum.

Nevertheless blockchain technology is one of the crucial instruments that provides a solution to digital trust because it records important information in a public space and does not allow the data to be removed in any way. The transparent, time-stamped and decentralized features of blockchain enables the transactions to be recorded in a permanent scale without needing third-party authentication. [14]

We believe that fintech focused projects within the CELTIC-NEXT Community will support the European region and beyond, in regard to achieving the desired, efficient, optimized and secure fintech platforms established on the needs of the citizens, governments and the actors of the technology and market value chains bringing impressive solutions and services.

Taxonomy

E13

Help the users to keep control of their Digital Life

More people in the world have access to a smartphone than they do have running water.

The digital life of citizens is organized around the smartphone and its applications. Apps represent 75% of the smartphone usage and allow the users to control their health, finance, home, purchases, education, entertainment, as well as their social life.

At the same time, social media are becoming more and more used - to the detriment of traditional media. Within a few years, social networks have become an essential communication means. As a consequence, the control of one's digital image or e-reputation is gaining extreme importance. Not only individuals but also companies and organizations need to keep control of their e-reputation and digital communication, in particular if and when a crisis occurs.

People are getting aware of being more and more monitored through their digital footprint and sometimes even eavesdropped. In the meanwhile, cyberattacks have been threatening billions of consumers.

Some experts forecast that the average daily connection time, estimated today around 8 hours, could reach 16 hours in 2025.

In the forthcoming years users and consumers will need to be accompanied in their usage and in their need of transparency and control of the digital tools.

The future digital platforms and tools will need to strike the right balance between empowering and assisting the users versus giving them the control and the choice.

Developing new digital tools and services will have to avoid the following risks:

- Exposing users and their data to cyber-threats
- Extreme monitoring that jeopardizes privacy
- Exploitation of unnoticed or unauthorized use of users' personal data
- Opacity of algorithms or data calculation resulting in biased information presented to customers
- Artificial Intelligence algorithms fostering generalised measures without taking context and personalised factors into account
- Blurring frontiers between reality, augmented and virtual reality and even pathological reality perception

In the coming years we expect the development of secure and advanced multiservice digital platforms with messaging, e-commerce enablers (see WeChat messaging platform in China). The digital enablers will be enhanced, e.g. Chat-bots with advanced conversational systems including the automatic processing of natural language.

Digital coaches will be further developed to answer elaborated questions from the users and empower them in daily life and provide contextual services according to the personal usage.

These digital coaches will come along with new tools to manage the personal data. They will develop into advanced smart digital assistant, able to reduce information overload (including protection against too invasive contents like certain ads) and to organize individuals' time, meetings, delegation processes, automate tasks, and even propose and guarantee the right to disconnect.

Digital guardian angels are expected to be developed in the coming years to take care of each and everybody digital image as well as of the e-reputation of organizations.

At the border of ICT, cognitive sciences and psychology, affective computing should develop further. Innovative systems will be able to recognize, model and express human emotions to integrate them in a feedback loop for the provision of ad-hoc customized services.

New technical solutions will integrate "privacy by design". Digital tools and ICT networks will have to reflect the new European regulation on data privacy (General Data Protection Regulation GDPR). New tools will be developed to evaluate websites and services with regard to the respect of personal data. Further to the European regulation, sophisticated mechanisms to allow data traceability (e.g. with a blockchain approach) and data portability should be made available. In particular localization data or health and financial records pose extremely important issues with regard to privacy.

To take care of cybersecurity issues there is a growing demand for encrypted communication services (such as messaging applications Telegram and Signal for voice and video) and for safe personal data storage.

A need for governance of algorithms is emerging. In the coming years the transparency of existing algorithms will need to be evaluated whereas future algorithms should be designed taking the transparency constraint into account from the very beginning. Certifications or labels for algorithm transparency may be proposed.

Taxonomy

B2 B7 B9 B21 B23

C4 C5 C6

E8 E14

Future Regulation and Ethical Questions concerning the evolving Digital World

Regulation of platforms

Platforms in electronic communications and media markets often meet assumption that they have some anti-competitive effects.

Existing policies (national media policies, European competition policy and also to European electronic communications regulation) are not able to deal with the complexity of platform economics.

One can only observe that the moment there is a lack of sound empirical analysis of what the actual anti- and also pro-competitive effects are of multi-layered platforms. Therefore new theoretical frameworks, methodological toolkits and empirical evidence need to be created for assessing the pro-and anti-competitive effects of multi-layered platforms in media and electronic communication industries.

Privacy and data management

The amount of personal data increased exponentially and, due to cheaper and flexible forms of data storage and increasing computing power, the use of data has grown tremendously in both academia and industry. As such, the perceived value of data is increasing but at the same time, the risks associated with (personal) data are increasing. This is especially clear for personal data where noncompliance will soon imply financial repercussions (the implementation of the GDPR, ePrivacy Regulation and Regulation on free-flow of non-personal data). In short, the increased value of data comes at a price: a virus or a hack can, for instance, directly impact the physical realm and the 'real life' of people. At a high level, this means that the increase of data-driven applications will be met with new means to regulate privacy of these applications.

While the need for such management is widely accepted, very little means exist to manage it, presenting a risk for any data driven applications and the future thereof. This is so because data management is, firstly, not the sole responsibility of one entity, organisation or person but instead a problem of many hands. For example: data protection officers are responsible for compliance but they need their communication departments, engineers and system admins to work together to communicate transparently, to implement privacy by design and to make sure systems are used for their proper purposes.

Secondly, data crosses many disciplines, including the legal, social, technical and organizational realm. In smart city, big data or open data, more and more data processing operations are distributed over multiple actors resulting in possibly joint data controllers or processors and thus many separate organisations that have to manage data collectively.

Thirdly, data challenges often affect stakeholders including data subjects that are not in control of data operations. Data management issues are most often multi-stakeholder problems affecting a wide range of domains and people beyond those who govern, control or own data.

In conclusion, data management processes are subject to various domains - organizational, legal, technical and social – with each their own characteristics, restrictions and (changing) requirements (e.g. in terms of interoperability). Today data management remains fragmented and there is a need to define a data management that will take those four dimensions into account.

Algorithmic transparency

Many stakeholders are involved during the development, selling and implementation of an algorithm. This results in the following value network:

1. Algorithmic development starts not at the algorithm developer but at the data an algorithm developer requires to develop it. The data comes from a data provider who sells training data. (As such, it means that algorithm value chains start with the data subjects who provide their data as training data.)
2. In this example, we assume that the developer is paying the data provider for the data. Next, the developer creates an algorithm which is then benchmarked.
3. A buyer has a particular problem it wants to solve with an algorithm. The buyer buys the algorithm because it fits in terms of accuracy, speed and efficiency in the requirements of the buyer.
4. As the algorithm becomes implemented it receives new information to apply its heuristic to. The outcome of this heuristic affects the person to whom the data refers directly. It also impacts the person to whom the data refers in terms of privacy.
5. In some cases, the algorithm may work with information on behalf of a user that does not refer to the user him/herself.
6. Depending on the contract between developer and buyer, data may be sent back and forth to optimize the algorithm for its new environment or in reaction to unanticipated biases.

Beyond the conventional exchanges that take place in the creation of value, there is a specific need for transparency between each actor involved. While some of these transparency needs can be situated in the domain of good business conduct and would be part of SLA requirements, others will require regulation. The transparency needs and obligations can be mapped as follows, s :

Data provider & algorithm developer: is the data representative for the intended context of the algorithm being developed ? In order to answer that question Data providers need to inform algorithm developers of the data they are selling.

Algorithm developer and buyer: will the algorithm outcomes be accurate enough? quick enough ? efficient enough ?

Algorithm developers sell an algorithm on a market. In order to convince buyers, a developer has to set his or her algorithm apart by defining its unique characteristics. The usual parameters for doing this are accuracy, speed and efficiency. Note that accuracy is context dependent. The algorithm was

created and evaluated with a particular dataset and this can overlap to a certain extent with the data the buyer has. The accuracy of the algorithm can only be assessed by comparing the two data sets or by running tests.

Buyer and user: why am I seeing this result?

If the buyer implements the algorithm into his or her service, then users of the service will use it for a particular goal (e.g. content recommendation, sorting of user information). Users of OTT recommendation engines could wonder how the algorithm works in order to understand the results they see or even to adopt their behaviour. This need is all the more important when outcomes of an algorithmic decision are not accurate.

Buyer and data subject: why am I subject to this result?

In case the user provides personal data, the processing falls under the scope of the GDPR. In case the decision based on this personal data has legal consequences for the data subject, then the data subject should be informed about the logic of the algorithm (automated decision making).

Safeguarding inclusion

The emergence of smart city solutions and the overall ongoing digitization of all life domains have led to both structural mechanisms of empowerment and of disempowerment. Moreover, the level of digital skills, and the ability to use ICTs to one's own social, economic, cultural or political benefit, has proven to define one's capacity to become empowered. High skilled and autonomous individuals and groups, such as for example ICT developers, hackers, open source movements or piracy movements, are increasingly becoming empowered, as they - more than governments and policy makers - are able to question and undermine the traditional and new power institutions in place. High skilled individuals are also increasingly able to shape and use ICTs to their own advantage. Low and unskilled individuals, on the contrary, are experiencing an increased sense of disempowerment as they have no power or influence on the processes of digitization or on the overall presence and integration of ICTs in all life domains. As such, the ongoing and widespread digitization of Western societies, often led by a market driven reasoning of commodification and cutting down costs, is creating - and in many cases reinforcing - existing social and digital inequalities as well as the so-called *Matthews effect* - the rich get richer, the poor get poorer.

It also remains difficult for most individuals - the average and the high skilled included - to have a defining influence on the operational characteristics of the key platforms and services they use online today, to be fully included in the public life via the Internet or to be empowered in the sphere of politics. It is especially difficult for users - and even groups of users - to go against the logic under which the Internet has developed in the recent decades. Obstacles, which users collide against, are a result of processes such as user surveillance, corporate control over the majority of the Internet, privatization, concentration, and commodification of both users and the content (which in most cases was produced by users within these online environments).

The reflections raised above, add to the fact that there is a stringent need to move towards more balanced digital inclusion strategies:

- First, by ensuring more digitally inclusive ICTs through interventions in the design and development process. Foremost, a more stringent follow-through of the European Commission's guidelines on online accessibility, mobile accessibility or overall design-for-all principles is called for in any smart city or ICT-development cycle. Engaging more non-obvious users, such as non-users, low-skilled users or

illiterate users in the ideation and co-creation sessions of the design process, will undoubtedly improve the overall accessibility, usability and inclusive nature of digital tools and services. Every digitization process, for any type of digital tools or service, should be structurally and automatically accompanied by an 'e-inclusion check' that consists of identifying the user groups that are unable to use the digital service at hand, and subsequently, providing the necessary interventions, in collaboration with digital inclusion actors, to re-include these user groups;

- Second, by public policy interventions at various levels through which large-scale mechanisms of digital and social exclusion inherent in Western digital societies are addressed (e.g. universal service to the Internet especially in remote or disadvantaged areas). In addition, public policy interventions should focus on delivering a broad range of formal and informal education and training opportunities, aimed at the population at large, so as to ensure that all individuals are enabled to develop the necessary skills to deal with the ongoing digitization of society.

Taxonomy

B7 B23

C1 C5 C6

E13 E14

CELTIC-NEXT: THIS SCOPE AND RESEARCH AREAS DOCUMENT

When the current Cluster Celtic-Plus started in 2011, there was a decision by the Celtic-Plus Industry Core Group to discontinue the effort related to drafting the "Celtic-Plus Purple Book", that was a detailed and comprehensive document highlighting the technologies that should be pursued by the Celtic-Plus projects. Instead, a short 25-page document entitled "Celtic-Plus Scope & Research Areas" was released. The main reasons behind this important decision were as follow:

- There were other existing detailed reference documents describing technological priorities and roadmap covering areas addressed by Celtic-Plus i.e. ICT and Telecommunications. The Celtic-Plus Core Group members had contributed (and are still contributing) to those documents, and it was considered as an overlap of effort to draft another similar document.
- Celtic-Plus was and is still following a bottom-up industry-driven approach, in line with the main EUREKA principles. This means that a great level of freedom shall be provided to the proposers to address issues of importance to them at a given time. Going into too many details on the issues that should be addressed within Celtic-Plus could have compromised this approach.
- Considering the very fast pace of the technological and business evolution in the domains addressed by Celtic-Plus, it was considered that updating every couple of years a 25-page document could be done, while it was much more challenging with a larger document.

This document, the CELTIC-NEXT Scope & Research Areas, provides initial technological and business directions and orientations for the projects that will request the CELTIC-NEXT label. It is a revised and updated version of the "Celtic-Plus Scope & Research Areas 2016-2017" that is available at <https://www.celticplus.eu/celtic-plus-purple-book/>.

TAXONOMY OF CELTIC-NEXT RESEARCH TOPICS

A NETWORKING
A1 Networks Elements and Infrastructures
A2 Mobile / Wireless
A3 Broadband, fixed networks
A4 Optics
A5 Satellite
A6 Broadcast
A7 Energy efficiency (of networks)
A8 Network architectures and connectivity
A9 Network infrastructure and platforms
A10 Network Management and operation
A11 Autonomic / Open Networks / Ad-hoc Networks
A12 Network evolution
A13 Network Security / Privacy
A14 Network Safety / Robustness
A15 Other network infrastructure aspects
B SERVICES AND APPLICATIONS
B1 Voice Services
B2 Data Services
B3 Multimedia and content Services
B4 Audio/ Video Services (incl. image processing)
B5 Mobile Services
B6 Cloud Services
B7 Security, Privacy related services
B8 IoT related services
B9 Teleworking
B10 Smart City related services and applications
B11 Smart home related services and applications
B12 Smart enterprise / transport related services and applications
B13 Smart traffic / car related services and applications
B14 eHealth related services and applications
B15 eGovernment related services and applications
B16 eLearning / digital school related services and applications
B17 Entertainment services and applications
B18 Gaming services and applications
B19 Location related services (incl. navigation)
B20 Business related services and applications (incl. ePayment)
B21 Societal Improvement
B22 Disaster recovery, safety
B23 Future end-to-end services
B24 Quality related aspects
C FUTURE SERVICE ENABLERS
C1 Future Service Platforms
C2 Future interfaces
C3 Multimedia enablers
C4 Security/ safety, trust and identity

C5	Big Data, Data Mining, Reality Mining
C6	Business and societal issues
C7	Future Displays / Enhanced reality
C8	Artificial Intelligence
D FUTURE INTERNET / CLOUDS	
D1	Technology foundation
D2	Future Internet Use-case scenarios / Test environment
D3	Cloud-related
D4	Internet of Things, including Sensors and Wearables
D5	Internet of Services
E FUTURE USAGE AREAS AND MULTI-DISCIPLINARY APPROACH	
E1	Smart Cities (incl. smart grids, water management, etc.)
E2	Digital / Smart Home
E3	Digital Enterprise including Industry 4.0
E4	Personal Mobility / Transport / Logistics / Food
E5	Smart Learning / Digital School
E6	Smart Car / Smart Traffic
E7	eHealth
E8	eGovernment
E9	Smart Energy (incl. energy efficiency)
E10	Environmental issues
E11	Entertainment
E12	Gaming
E13	Business related Issues
E14	Societal Issues

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