Celtic-Plus - Scope and Research Areas 2016/2017

1. PREFACE

In 2003, the major European telecommunications vendors and operators decided to work together and create an ambitious European R&D programme providing the means to tackle issues related to end to end communications. This was to them the best option to address the roadblocks related to a "system view" of communications, in addition to designing and developing technological components. The "Celtic Initiative" as a EUREKA Cluster, which was the outcome of their common effort, became widely recognized in the European ICT R&D environment as a key enabler for ambitious and innovative collaborative R&D projects dedicated to communications solutions. At the end of the first phase in 2011, around 90 R&D projects, involving up to 500 R&D organizations, representing a total R&D budget of over 700 million euro, had contributed to the "Celtic Initiative" Programme. Major achievements were made in service platforms, new multimedia services, and new infrastructure solutions.

By the end of this first period of the Celtic EUREKA Cluster, the main challenges in telecommunications evolved very fast. As IP-Multimedia-Services (IMS) was the key word in the beginning, "Future Internet" became the key research focus area when the second period started in 2011 as the EUREKA Cluster "Celtic-Plus". Until today, Celtic and Celtic-Plus have labelled, funded and performed 143 projects in all their research areas with a total volume of more than one Billion Euro. In 2015, 15 new projects were labelled with a total budget of 154 Mio Euro. By facilitating these collaborative R&D projects, Celtic and Celtic-Plus have made a great contribution to help Europe to stay at the competitive edge of the telecommunications industry.

Celtic 2003- 2015	No. of projects	Effort (Person Years)	Budget (M€)
Finished	103	6,610	708
Labelled and running	40	3,167	335
Total	143	9,774	1,043

Now in 2016, all human activities and business sectors are evolving towards the digital era. The introduction of digital technologies in economic and societal processes is needed. The new ICT infrastructure will be a key asset to support societal transformation, leading to the fourth industrial revolution impacting multiple sectors.

Celtic-Plus positions itself at the heart of the upcoming digital era with its "Smart Connected World" concept. In that new digital era, different actors, whether businesses, communities or individuals, connect with each other, share their contents and want to be aware of their contexts. They are connected to social networks and virtual worlds sharing knowledge within their community while at the same time protecting also their privacy and public safety.

This document, which replaces the "Celtic-Plus Purple Book, version 2013", provides insights into the scope and main research areas, which new Celtic-Plus projects should focus on. The research areas in this document, however, are not binding. Celtic-Plus follows a bottom-up, industry-driven approach, which allows proposers of Celtic-Plus projects to define the content of their project proposals according to their own research interests and priorities.

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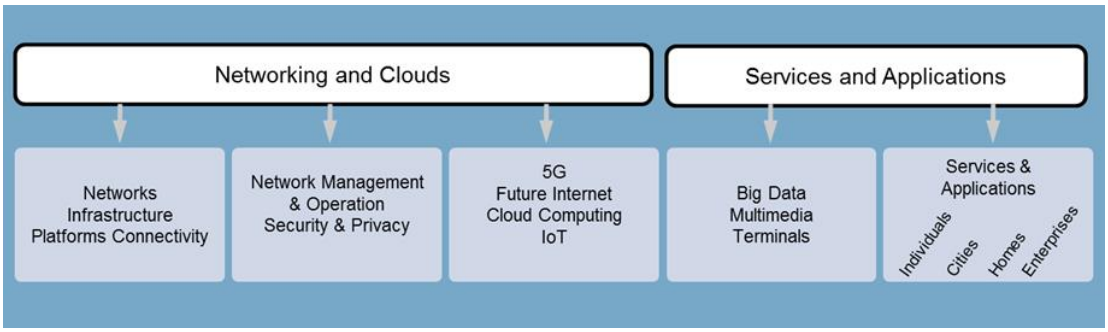
3. EXECUTIVE SUMMARY

All human activities and business sectors are evolving towards the digital era. The new ICT infrastructure will be a key asset to support societal transformation, leading to the fourth industrial revolution impacting multiple sectors. New technologies and solutions at multidisciplinary level are required, to address such issues as developing new applications to reduce the need for travelling, and new technologies for reducing energy consumption, and moreover, to manage and control the best use of energy in other business or private sectors such as health, transport, energy, e-government, urbanisation, knowledge and culture.

The communication technologies, especially the 5G technology, are essential to support a new era where individuals, communities and businesses will see the frontier between physical and digital experience progressively become more transparent. An end-to-end system approach is required in the development of future communications-related solutions that are critical not only to the ICT industry but also to all other sectors. As an example, communications technologies and solutions will support environmental awareness by helping domains such as health or transport better manage and control the use of energy.

Celtic-Plus primarily focuses on two key areas, “Networking and Clouds” and “Services and Applications”.



“Networking and Clouds” tackles the infrastructure and connectivity aspects. Research topics are related to network elements and infrastructures, like wireless, optics and energy efficiency, as well as network architecture and connectivity, like networking and autonomic networks.

“Services and Applications” includes future end-to-end services, like digital citizen, digital home, digital enterprise, digital city, digital school, digital transports, e-health and games, as well as horizontal services, like security, public safety and identity.

This document illustrates the main current research topics and challenges to stimulate the Celtic-Plus community to propose and work in projects covering the most important issues. Those topics include the following areas:

Networking and Clouds
5G, the next generation of ubiquitous network infrastructure
Cloud Computing
Software Defined Networking and Network Function Virtualization
Internet of Things and Industrial Internet
Green ICT
Optical Networks
Satellite network and its convergence with terrestrial networks
Security, privacy, identity, safety and trust
Network deployment, operation and management

Services and Applications
Smart Cities and Smart Homes
Digital Enterprises
eHealth
Big Data
Terminals
Other societal and governmental services

This document also explains the way in which Celtic-Plus works. The R&D work is done in Celtic-Plus projects, which are generated through regular Calls. Normally there is a Spring Call (closing in May) and an Autumn Call (closing in October). The project proposals continue the bottom-up, industry-driven approach following the main research aspects of this document, extended by new challenges that will become important. Celtic-Plus projects are private-public-partnership projects, partly funded by the participating countries. A minimum of two EUREKA countries need to participate in a Celtic-Plus project.

Finally the document contains a taxonomy of the Celtic-Plus research topics. This is important for clarifying, in which topical area, and on which topics the various projects perform their work.

It is planned to update this document once every two years.

4. CELTIC-PLUS IN THE EVOLVING ICT MARKET

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

4.1 Main societal and economic trends

Europe is faced with economic and societal challenges such as ageing of populations, societal cohesion, and sustainable development. Furthermore, all human activities and business sectors are evolving towards the digital era. In the period leading to 2030, the development of a digital society will remain an important factor of globalisation, giving way to a knowledge economy decoupled from geographies. Timely, easy and reliable access to data is a prerequisite for this new economy. Traffic growth will be drastically increased by cloud, mobile, and streaming services, the emergence of the 'Internet of Things' and the nearly real time processing of huge amounts of data.

The development of a digital society will remain an important factor of globalization

With the n*ew* appearing societal and economic challenges, the communication technologies are likely to play a large role and *t*he introduction of digital technologies in economic and societal processes is key to address these challenges. The future information and communication technology (ICT) will require infrastructures that are able to handle an exponential growth of traffic. New ICT will be essential to the creation of knowledge and to safeguard European heritage in a digitalised form, while making all this data more secure (EUREKA Annual Report 2015).

In the next decade, it is expected that the manufacturing industry will evolve towards a distributed organisation of production, with connected goods, low energy processes, collaborative robots, integrated manufacturing and logistics. The automotive and transportation sector will bring to market autonomous and cooperative vehicles by 2020 with significantly improved safety and security standards, as well as new multimodal transportation solutions. Due to the ongoing development of renewables, the traditional power grid will evolve into a smart grid, supporting a much more distributed generation and storage of power with real time dynamic routing of electricity flows using smart meters in houses. Entertainment and digital media sectors are working on the integration of broadcast TV and digital media, including an ever increasing amount of user generated content, high quality media and innovative real time interfaces such as haptics. E-health and M-health will optimise new, revolutionary concepts such as European "Personalised or Individualised Healthcare" and the transition from hospital and specialist centred care models towards distributed patient centred models.

New multimodal transportation solutions

As a result of these transformations, vertical industries shall have enhanced technical capacity available to trigger the development of new products and services. Identifying key vertical sectors' requirements, anticipating relevant trends early and mapping them into the ICT systems' design is fundamental.

Vertical industries will trigger the development of new products and services

People will in the future have multiple sensors and actuators placed on their body and around it (Figure 1). Those things can 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 can also – if allowed - communicate with the city infrastructure providing statistics on the most popular running tracks or health conditions of people in different neighbourhoods, for instance. If a person has a degraded health condition, or there is a health emergency, a doctor can use body sensors and smartphone camera to remotely diagnose the patient and – if needed – send help much faster.

Figure 1: Your application environment following you anywhere (Source: Nokia)

The new ICT infrastructures will be a key asset to support this societal transformation, leading to the fourth industrial revolution impacting multiple sectors. The communication technologies are essential to support the new era where individuals, communities and businesses will see the frontier between physical and digital experience progressively become more transparent.

New ICT infrastructures will lead to a fourth industrial revolution impacting multiple sectors

5G infrastructure will cover the network needs and contribute to the digitalization of vertical markets such as automotive, banking, education, city management, energy, utilities, finance, food and agriculture, media, government, healthcare, insurance, manufacturing, real estate, transportation and retail.

The digitalisation will be the key enabler in the renewal of all industrial and societal sectors and in maintaining the European competitiveness, and as concluded in the European Council conclusions 24/25 October 2013*:* "As part of its growth strategy, Europe must boost digital, data-driven innovation across all sectors of the economy."

4.2 Major technological trends

Future Internet has become, and will be far more so in the future, an engine for innovation, economic growth, job creation and social progress. It is accelerating innovation, reshaping established industries, facilitating new ways of doing business, and transforming social behaviours. At the same time, this increasing diversification of usage patterns and of applications is posing stronger requirements on the underlying networking and computing infrastructures. The use and development of open source software will be encouraged where appropriate to further promote openness and accelerate innovation in Europe through the introduction of novel products and services.

Future Internet

Future European society and economy, and the Future Internet will strongly rely on the 5G infrastructure. The emergence and deployment of the 5G technology is likely to trigger innovation in many industries, thus leveraging sustainable societal change. There is a vision for 5G to become a stakeholder driven, holistic ecosystem for technical and business innovation integrating networking, computing and storage resources into one programmable and unified infrastructure. And how we travel, how we experience our environment, how we control remote environments, how the infrastructure supports us and how we produce goods will all be changed by the 5G connectivity.

5G

The 5G architecture is expected to accommodate a wide range of use cases with advanced requirements, especially in terms of latency, resilience, coverage, and bandwidth (Figure 2). Thus, another major challenge is to provide the end-to-end network and cloud infrastructure slices over the same physical infrastructure in order to fulfil the vertical-specific requirements as well as the mobile broadband services in parallel. However, the deployment of this new generation of mobile technology in the next decade will also likely give rise to uses (and consequences) that are difficult to foresee at the current time. On the basis of the past generations of mobile technology, the

increased networking supported by 5G is likely to stimulate economic growth, not only in the information and communication technology sector, but in many areas of the economy.

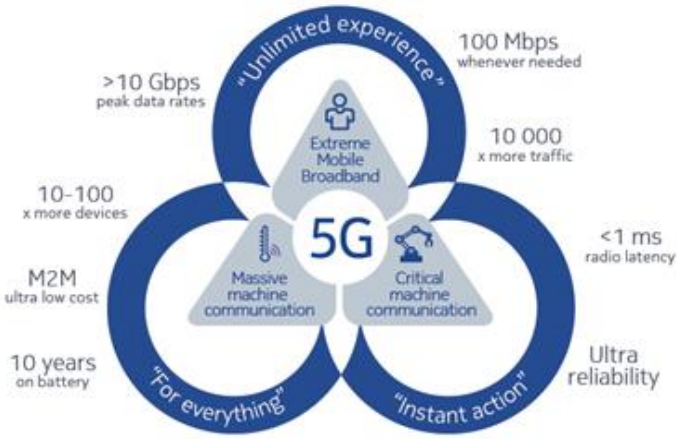


Figure 2: 5G will need to support a wide variety of different users and business models (Source: Nokia)

Software Defined Networks (SDN) and Network Functions Virtualization (NFV), together with Cloud, Edge and Fog Computing, can be seen as facets of a broad innovation wave, called Softwarization, which will contribute to automating processes, optimising costs, reducing the time-to-market, and providing better services. At the same time, the Internet of Things (IoT), Tactile Internet, Machine Type Communications (MTC), Cloud Manufacturing, Cloud Robotics, etc. will generate a new plethora of services and applications, ranging from industrial and mission critical ones to precision agriculture, to Smart Cities, etc.

Software Defined Networks
Network Functions Virtualization
Cloud Technologies
Internet of Things

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. 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.

Big Data

In addition, we will see some specific network platforms for each vertical sector with dedicated features and performance requirements (e.g. high reliability for health or automobile verticals or high density of terminals for smart cities). The use of COTS (Commercial of the Shelf) instead of current proprietary technologies will change the market with these industries having a much greater influence on the development of network services, and their SMEs will be able to innovate and launch new applications leveraging the new capabilities of 5G.

4.3 Overall Scope of Celtic-Plus

In order to respond to all the societal and economic challenges, Celtic-Plus will primarily focus on two key areas, *"Networking and Clouds" and "Services and Applications"* (Figure 3).

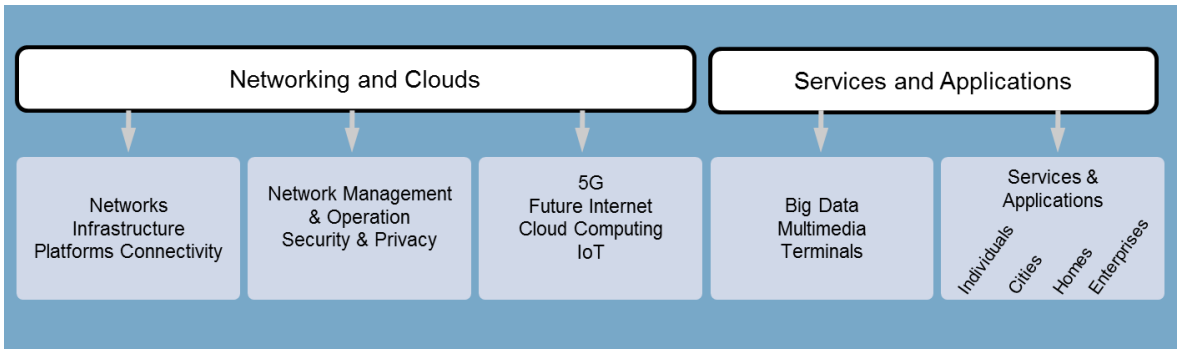


Figure 3: Celtic-Plus focus areas

*"**Networking and Clouds**"* tackles the infrastructure and connectivity aspects. Research topics are related to network elements and infrastructures, like wireless, optics and energy efficiency, as well as network architecture and connectivity, like networking and autonomic networks.

5G is expected to represent a major leap forward from current telecommunications technologies, including revolutionary changes in radio interfaces and spectrum use. On the basis of current trends and potential uses, 5G networks will be faster, always accessible, highly reliable and efficient in handling a very large number of devices (including smart objects in the Internet of Things).By supporting a world in which 'anyone and anything will be connected at anytime and anywhere', 5G is expected to enable new applications in various domains, including entertainment, health, transport and industry.

An important change in the ICT market is the shift from dedicated hardware to software and cloud technologies. Cloud platforms and open source software are also emerging in the mobile networks together with Software Defined Networking (SDN) and Network Functions Virtualization (NFV). SDN/NFV is an attempt to provide better control and automation over the resource management (e.g. network, computing, storage and software) by dynamically allocating the resources to meet the needs of different end users (i.e. consumers and corporate customers). Due to the control plane and data plane split, SDN provides better hardware independence for the operators than before. In addition, NFV and the use of standard data center hardware provides economies of scale in computing and storage resources.

From the business side, the SDN/NFV architecture lowers the initial network investment, energy consumption and network management costs for the operators. At the same time, SDN/NFV encourages openness and competition, as well as promotes new investments into the mobile connectivity and content industry.

Important topics in the Networking and Clouds area include:

- 5G, the next generation of mobile and wireless networks bringing broadband to everybody;
- Cloud computing enabling ubiquitous access for storing and processing data;
- Internet of Things with its sensor networks including billions of sensors and activators;
- Energy efficiency to reduce the enormous amount of energy the current ICT requires;
- Satellite network and its convergence with terrestrial networks;
- Network deployment, operation and management for economically sustainable networks;
- Security, privacy, identity and public safety, including the critical communications infrastructure.

*"**Services and Applications**"* includes future end-to-end services, like digital citizen, digital home, digital enterprise, digital city, digital school, digital transports, e-health and games, as well as horizontal services, like security, public safety and identity. It also includes business aspects, like the evolution of value networks in the telecommunication focus area, forecasting the changes in the value networks and business models. New aspects related to the Future Internet will come into consideration, in particular such issues, which are closer to the market.

Important topics in the Services and Applications area include:

- Smart Cities and Smart Homes, which require a cross-sector approach, supported by the EUREKA Smart City Intercluster MoU;

- Digital enterprises to ensure that European enterprises stay competitive in the global markets;
- E-health solutions in response to the challenges of the aging European population. E-health applications can make use of wearable devices worn by patients in their own home to monitor variables such as blood pressure, pulse and breathing rate;
- Big data, including the related research challenges for, e.g., data capture, storage, analysis, transfer, and privacy;
- Road transport that can become safer and more efficient as connected cars share information in real time with other vehicles;
- New industry and manufacturing services enabled by the Machine Type Communication (MTC). Intelligent connected robots in the Factory of the Future can communicate with each other and parts, to increase manufacturing efficiency, reduce costs and produce individualised 'one-off' products.

5. CELTIC-PLUS MAIN RESEARCH TOPICS AND CHALLENGES

This chapter outlines topical and important research subjects and challenges in the ICT and Telecommunication area. It serves mainly two purposes:

- Complement the scope of Celtic-Plus with concrete and topical items.
- Act as a kind of "stimulus" on important research items for the potential proposers of Celtic-Plus projects.

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

5.1 Networking and Clouds

"Networking and Clouds" addresses everything needed to establish, run, support and secure a communication. The key topics of the current and future Celtic-Plus projects are related to the 5G network architecture, Cloud Computing, SDN/NFV, Internet of Things, Optical networks, satellite communication, mobility, security, scalability, robustness, and energy efficiency.

5G, the next generation of ubiquitous network infrastructure

It is expected that 5G will really bring broadband to everybody, no matter whether in a city, countryside, house, office or on the move. The importance of 5G has been recognised by the major players in Europe, and a Billion-Euro 5G Infrastructure Public Private Partnership (5G PPP) has been initiated by the EU Commission, industry, telecommunications operators and service providers, SMEs and researchers (https://5g-ppp.eu/).

Key challenges for 5G are (source: 5G-PPP):

- *Data Rate: The most demanding vertical use cases are related to Media & Entertainment with maximum values in the order of Gb/s;*
- *Mobility (speed): The most demanding vertical use cases are related to Automotive and eHealth with maximum value in the order of 500 km/h;*
- *E2E Latency: The most demanding vertical use cases are related to Factories with minimum values of 100 µs to 10 ms;*
- *Density (number of devices): The most demanding vertical use cases are related to Factories with up to 100/m2;*
- *Reliability: The most demanding vertical use cases are related to eHealth with values up to 99.99999%;*
- *Position Accuracy (Location): The most demanding vertical use cases are related to Automotive with minimum values in the order of 0.3 m;*
- *Service Deployment Time: Programmable networks and multi-tenant capability in 5G will ensure speedy deployment of services (e.g. 5G Infrastructure PPP targets 90 minutes for service deployment);*
- *Data Volume: Quantity of information transferred (downlink and uplink) per time interval over a dedicated area (e.g. 5G Infrastructure PPP targets a maximum of 10 Tb/s/km2);*
- *Security: System characteristic ensuring globally the protection of resources and encompassing several dimensions such as authentication, dataconfi dentiality, data integrity, access control, non-repudiation…*
- *Identity: Characteristic to identify sources of content and recognise entities in the system. One key parameter to guarantee the fast adoption of 5G is the possibility to access low cost solutions in several use cases of the vertical sectors;*
- *Enabling advanced user controlled privacy.*

This new high-performance network will be operated via a scalable management framework enabling fast deployment of novel applications, including sensor-based applications, with significant reduction of the network management costs.

Cloud Computing

Cloud Computing is an expression used to describe a variety of computing concepts that involve

a large number of computers connected through a real-time communication network such as the Internet. In science, Cloud Computing is a synonym for distributed computing over a network, and means the ability to run a program or application on many connected computers at the same time.

With the success of cloud technology in the enterprise realm, the telecom industry is now looking to the cloud to have the same benefits – economies of scale, cost effectiveness, scalability, lower CAPEX and OPEX. Operators want to exploit cloud technologies in their central offices and network functions to achieve these benefits.

Key research challenges of Cloud Computing are:

- *Availability, accessibility and reliability of the Cloud Computing service;*
- *Interoperability between the Clouds of different service providers;*
- *Cloud management, including maintenance, automatic recovery, etc.;*
- *Security, privacy and data protection (especially across country borders);*
- *Multi tenancy in Clouds;*
- *New business and cost models, and accounting management.*

SDN/NFV

In today's non-virtualised networks, Netwok Functions are implemented as a combination of vendor specific software and hardware, often referred to as network nodes or network elements. To launch a new network service often requires yet another network element, and finding the space and power to accommodate these boxes is becoming increasingly difficult, in additon to the complexity of integrating and deploying these elements in a network. Network Functions Virtualization (NFV) aims to address these problems by evolving standard IT virtualization technology to consolidate many network equipment types onto industry standard high volume servers, switches and storage. It involves implementing network functions in software that can run on a range of industry standard server hardware, and that can be moved to, or instantiated in, various locations in the network as required, without the need to install new equipment.

Software Defined Networking (SDN) provides a powerful complement to NFV's ability to maximum utilization of hardware resources. SDN is an emerging network architecture where the network control is decoupled from the forwarding and is directly programmable. This migration of control enables the underlying infrastructure to be abstracted for applications and network services. It will also open up new opportunities for the traffic, resource and mobility management, as well as impose new challenges on the network security. It is foreseen that the investments on the networks and the operational costs will affected. Furthermore, the value chains may change and new business models emerge.

Key research challenges of SDN/NFV are:

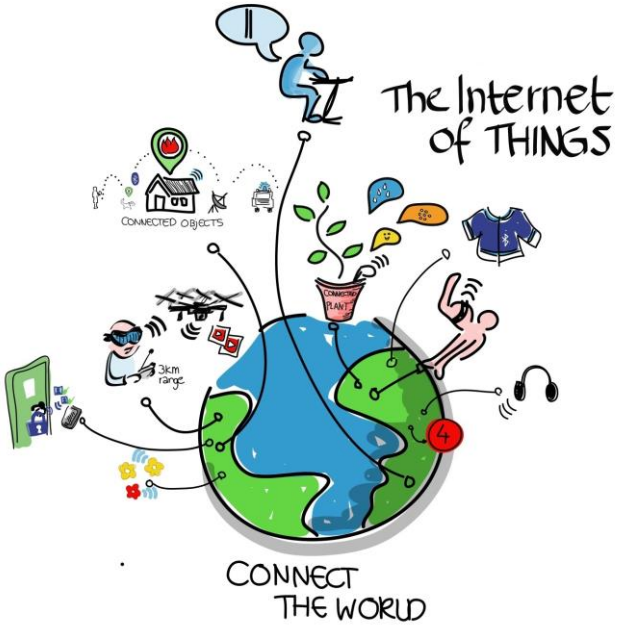
- *Adaptive (de)composition and allocation of mobile network functions (access and core); time critical functions and less time critical functions: network functions for services with tight latency requirement may be centrally located at the network cloud, while more intelligence may be placed at the edge of the network for 'low latency' services;*
- *Joint optimisation of mobile access and core network functions localized together in the network cloud or edge cloud;*
- *A unified management of SDN/NFV based connectivity, with end-to-end security, mobility and routing;*
- *Ensuring the appropriate level of resilience to hardware and software failures;*
- *Solutions to provision SDN/NFV networks across administrative boundaries (e.g. multiple operators, customer networks, datacentres) and interoperability issues between multiple SDN control domains*
- *Managing and orchestrating many virtual network appliances (particularly alongside legacy management systems) while ensuring security from attack and misconfiguration.*
- *APIs for the fast creation of new network information based services*
- *The effects onto the current business models and value chains in mobile networks and on the opening of possible new models;*
- *Integrating multiple virtual appliances from different vendors. Network operators need to be able to "mix & match" hardware from different vendors, hypervisors from different vendors and virtual appliances from different vendors without incurring significant integration costs*

and avoiding lock-in.

Internet of Things, Industrial Internet

Internet of Things (**IoT**) is the network of physical objects—devices, vehicles, buildings and other items—embedded with electronics, software, sensors, and network connectivity that enables these objects to collect and exchange data. IoT allows objects to be sensed and controlled remotely across existing network infrastructure, creating opportunities for more direct integration of the physical world into computer-based systems, and resulting in improved efficiency, accuracy and economic benefit. When IoT is augmented with sensors and actuators, the technology becomes an instance of the more general class of cyber-physical systems, which also encompasses technologies such as smart grids, smart homes, intelligent transportation and smart cities (Wikipedia).

The concept of **Industrial Internet** has recently emerged as a topic of considerable attention. The level of ambition of the concept has been raised to no less than changing profoundly how the manufacturing industries base their operations to ICT by exploiting novel technologies such as sensors, actuators, wireless networks, clouds, computational modeling and simulation, and mobile user interfaces - in short, bringing manufacturing industries and their ecosystems truly to Internet age.



Gartner predicts 26 billion connected devices by 2020 (between the 18 billion predicted by Machina Research by 2022, and Cisco's prediction of 50 billion by 2020). Machina Research expects that connections will be dominated by two sectors: consumer electronics (including cameras, music players and TVs) and intelligent buildings (e.g. security and heating, ventilation and air conditioning- so called HVAC – systems). Short range technology will dominate M2M: 73% of M2M devices will be connected by short-range technologies. In terms of revenue, Machina Research expects an impressive compound annual growth rate (CAGR) of 16%, reaching a total volume of 1.3 trillion US dollar in 2022. Two-thirds of the revenue opportunity is accounted for by devices and installation, and one-third by M2M services.

Key research challenges in the area of IoT include:
(Source: Eurescom Message Autumn 2014: The Internet of Things – an overview by Adam Kapovits)

- *IoT will have very different network and data transmission requirements with regards to connectivity than traditional network clients (e.g. low throughput, low-bandwidth messages from many devices);*
- *Low energy consumption of sensors, activators and related communication infrastructure, incl. radio communication);*
- *Low cost and extreme cost effectivity to permit very high volume deployment;*
- *Small size, simplicity, and ease of deployment and maintenance;*

- *Security (i.e. physical and logical access prevention; device-to-device security);*
- *Reliability and robustness (i.e. sensors must operate for decades without maintenance);*
- *Standards and regulatory frameworks (i.e. connecting millions of objects without roaming restrictions or administrative hurdles).*

Green ICT

Information and communication technology are power hogs. Computers, printers, servers, mobile devices, and telecommunication networks are not energy efficient. Although improvements have been made, the projections show that by 2020 the global greenhouse gas emissions from ICT will double from today's 2 percent to 4 percent.

The largest worldwide emitter is by far the production of electricity, with 30 percent of that power typically generated by fossil fuel sources. And demand for electricity is growing, especially for powering networks. More people than ever are using the Internet and other communication networks; annual growth in traffic doubles every two years. By 2020, 21 billion devices will be connected to the Internet, according to the technology research company Gartner. By 2035, the International Energy Agency projects that total demand for electricity will be almost 70 percent higher than today (IEEE Green-ICT initiative).

The components that make up today's traditional communication networks were built primarily with performance, not energy efficiency, in mind. As more of everything comes online, the energy consumption of base stations, set-top boxes, routers, and the rest of the infrastructure, to say nothing of data centers, is rising—and so is the cost of running a network.

Climate change and environment protection are global concerns. As far as ICT is concerned, energy savings are always twofold:

- Making ICT devices and communication networks more energy efficient, and
- Saving energy in other sectors through applying ICT services and technology.

Key research challenges of Green ICT are:

- *Finding ways to increase the energy efficiency and shrink the carbon footprint of communication and data networks, including the Internet;*
- *Utilise renewable energy for powering the ICT systems;*
- *Research on energy efficient architectures and systems and services;*
- *Smart Energy Grids: ensuring timely support of the energy demand and pursuing maximum exploitation of green energy sources.*
- *Energy distribution in provision of necessary communications infrastructure, including integration of decentralised and renewable sources, and energy consumption optimisation at homes, buildings, factories, areas, etc.*
- *Controlling home appliances (e.g. lights, refrigerators) according to consumer patterns in a most efficient way.*
- *Replacing the physical world through cyber world, e.g. Web- and Video-conferencing instead of physical travel.*

Working towards Green ICT is not only helping our planet to survive, but it can also lead to very positive business and societal effects, and increase the employment rate.

Optical networks

Sustained traffic increase, in the range of 30-40% per year, driven by video traffic, data-mobile applications, and data centres traffic put strong pressure on optical networks to accommodate for this bandwidth demand explosion, while keeping cost and energy consumption at affordable levels. This concerns core networks, metropolitan networks, access networks, as well as intra data center networks, with scales and constraints specific to each segment. Moreover, demand variability associated to the need to optimise resource by reducing over provisioning calls for more agile and programmable optical networks, with a high degree of reconfigurability and dynamic adaptation capability.

Key research challenges of optical networks are:

- *Increase the total capacity per fibre while maintaining system reach;*
- *Advanced digital processing to optimise modulation formats and compensate for*

transmission impairments;

- *Spectral efficiency optimisation;*
- *Improvement of optical layer energy per bit;*
- *Accurate and fast prediction of transmission impairments for path provisioning;*
- *Self diagnosis, protection, restoration and optimization with efficient use of monitoring;*
- *Hitless zero-packet loss adaptive optical interfaces;*
- *Software defined control of optical layer and integration with IP layer.*

Satellite network and its convergence with terrestrial networks

There is still a persisting gap between the two communities, i.e., the satellite and terrestrial networks. 5G is seen as a unique opportunity for integration of the satellite networks with the terrestrial networks as 5G by definition should encompass all transmission technologies. Using satellites can bring unique benefits to 5G and nicely complement the terrestrial solutions (broadcast, large coverage area, very high sharing of the backhaul environment).

The role of satellites in the future communication systems is depicted in Figure 6 below.

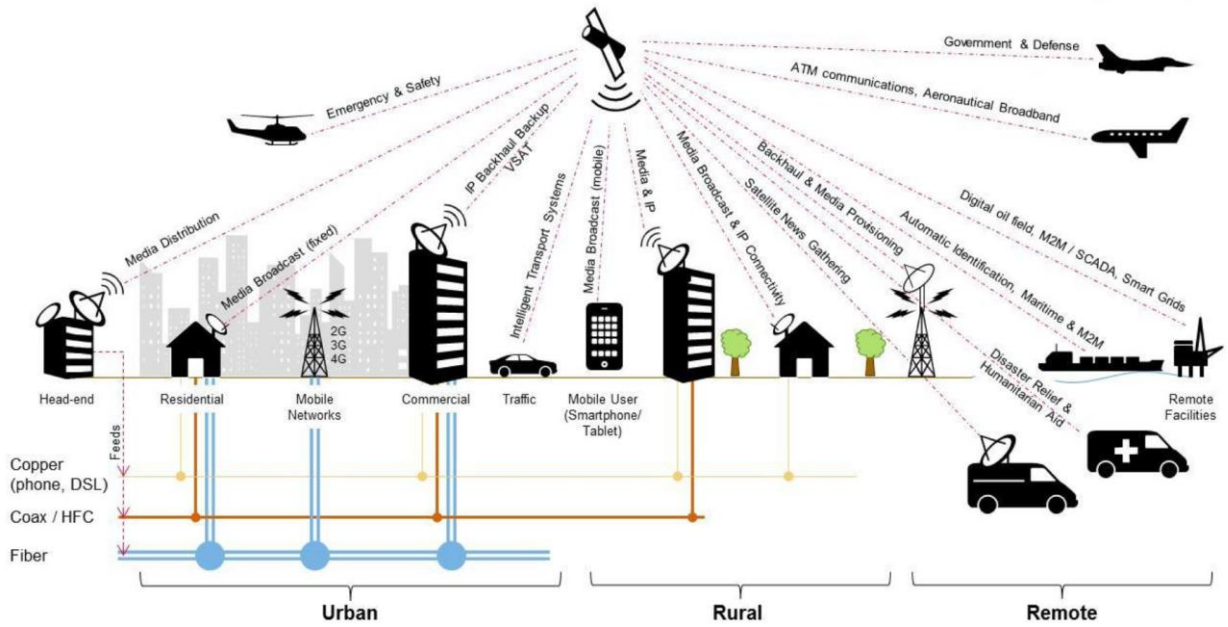


Figure 6: The role of the satellites in the future communication systems
(source: Booz&Co, "Why satellites matter", http://www.esoa.net/news-info-30.htm)

Potential topics of interest on this area:

- *There is a definite need for trialling and demonstrating key 5G technologies incorporating satellite components and using IoT as one of the main application area – the other being content delivery.*
- *Satellite can offer mature technology and solutions (e.g. regarding modems, etc.) that may fit in terrestrial concepts and nicely complement them – connectivity for very high speed mobile nodes (high speed trains, etc.).*
- *The satellite ground segment is currently being re-thought and undergoing the same transformations dictated by software defined networking just as any terrestrial network components.*
- *Early attempts are on their way to make space segment technologies and payloads ready to accept virtual machines, offering entirely new opportunities, including separation, redundancy, testing in lab on the ground and shipping to space new functions.*
- *IP enabled video distribution via satellite is another interesting segment and likely candidate for convergence with terrestrial in the process of CDN (Content Delivery Network) evolution.*

Security, privacy, trust and safety

The future networks are increasingly a part of the critical information infrastructure, and it is clear that Security, Privacy and Trust will be among the key aspects to pay attention to when designing the new network concepts and exploiting the related new technologies. The disruption or destruction of networks would have a serious impact on the vital societal functions and business operations.

The introduction of SDN/NFV and Cloud Computing will not only simplify the network architecture and add flexibility, but will also introduce vulnerabilities inherent to internet and centralized software-based control of the network. Virtualizing or increasing the programmability of networks increase the attack surface for attackers. In Addition, the necessary coexistence with previous generations of cellular technologies, the expected ameliorations in performance, capacity and latency make monitoring and security tasks much more difficult and complex.

Key research challenges of in this area are:

- *The growing popularity of smartphones, rising mobile broadband volume and sophistication of malware exposes mobile-terminals to the attacks of the fixed networks. However, mobile terminals are weakly protected compared to their fixed counterparts i.e. laptops, desktops etc. and are constrained in terms of computing resources, memory and battery lifetime;*
- *Due to their more visible and eventually centralized nature, the controllers in the networks become single points of failure. The operational malfunctioning or malicious software can compromise the whole network by providing access to the control plane;*
- *Optimizing the network resource utilization for security functions: they have to be cost-efficient, simple, and scalable;*
- *How to protect the isolation between multiple services and between different tenants on the shared infrastructure platform;*
- *How to increase the flexibility to adapt the security measures individually to the requirements of the services and to the business policies of the tenants of the shared infrastructure. If this isolation cannot be preserved, a security weakness in one network slice can be exploited to attack a neighbouring network slice. The same is true for the SDN controller, since it is connected to all network slices;*
- *Strong security measures to protect the isolation between multiple services and between tenants operating on a shared infrastructure platform must be mandatory all services and tenants. On the other hand, multi-tenancy / multi-service support must also provide a maximum flexibility to design security measures according to the specific needs of each service or according to the business policies of each tenant.*
- *The need for different levels of security protection are obvious. Highly sensitive service may rely on their own application layer security and thus will only require high availability of the network. On the other hand, there may be services that have very low security requirements (like gathering humidity information from agricultural sensors), which also do not require specific protection. Between the extremes, clearly there will be services that will rely on strong security provided by the network. The security measures have to be adapted to the actual needs of services or business policies of network tenants, without compromising on the security levels of highly sensitive services.*

Network deployment, operation and management

This is the traditional area of the Telecommunication Operators and comprises everything from network architecture via network planning and deployment to operation and management of the networks. The area is extremely wide and has large overlaps with other items discussed below, such as 5G, Cloud Computing, Internet of Things, etc.

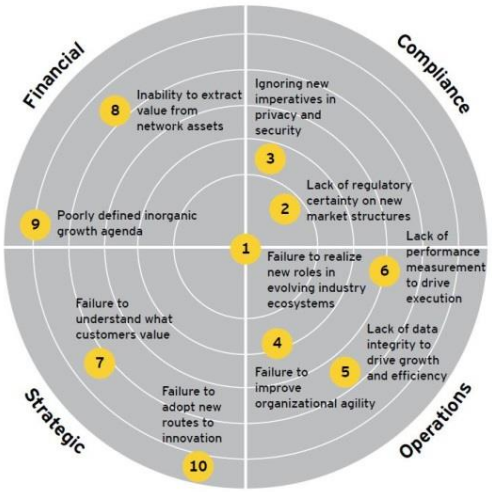
Here we concentrate on the network itself with its control and data planes.

The subject encloses a vast range of challenges. A few of them are listed below:

- Monetizing the telecom infrastructure investments (including decreasing CAPEX and OPEX, and maximising business models).
- Reliability and robustness of networks and services
- Creating trust by assuring security, privacy and cyber-crime prevention
- Reacting fast on newly needed capabilities (new applications drive requirements for new capabilities within the network infrastructure, e.g. multimedia applications require better QoS, and multicasting services)
- Network resilience for time-critical functions
- Improving customer experiences and relationships
- Providing economically sustainable architectures and networks
- Fast, automatic and cost-efficient network operation and management
- Migration to IPv6

The Ernest and Young risk radar 2014 lists the following 10 items as main business risks for telcos:

- Failure to realize new roles in evolving ecosystems
- Lack of regulatory certainty on new market structures
- Ignoring new imperatives in privacy and security.
- Failure to improve organizational agility
- Lack of data integrity to drive growth and efficiency
- Lack of performance measurement to drive execution
- Failure to understand what customers value
- Inability to extract value from network assets
- Failure to adopt new routes to innovation



Source: EY risk radar 2014

5.2 Services and Applications

"Services and Applications" tackles the end-to-end services and applications and their requirements. The key topics of current and future Celtic-Plus projects are Smart Cities, Smart Homes, Digital Enterprises, e-Health, Big Data, terminals, as well as horizontal end-to-end services, like security, privacy, identity, public and data safety.

Smart Cities and Smart Homes

S**mart Cities** is an urban development vision to integrate multiple information and communication technology (ICT) solutions in a secure fashion to manage a city's assets – the city's assets include, but not limited to, local departments information systems, schools, libraries, transportation systems, hospitals, power plants, and other community services. The goal of building a smart city is to improve quality of life by using technology to improve the efficiency of services and meet residents' needs (Wikipedia).

ICT allows city officials to interact directly with the community and the city infrastructure and to

monitor what is happening in the city, how the city is evolving, and how to enable a better quality of life.

Smart Homes is the use and control of home appliances remotely or automatically. Some home automation appliances are stand alone and do not communicate, such as a programmable light switch, while others are part of the Internet of Things and are networked for remote control and data transfer. Any device in your home that uses electricity can be put on your home network and at your command. Whether you give that command by voice, remote control, tablet or smartphone, the home reacts.

Today more than 50% of the world's population lives in urban areas, and that share is rapidly incrasing. This implies big pressures on city infrastructures (transportation, housing, water, power, city services).

ICT research challenges regarding Smart Cities and Smart Homes cover many different areas. Examples for such areas are:

- *Municipal administration services (incl. e-Government)*
- *Mobility and transport*
- *Energy and water management*
- *Health and well-being*
- *Entertainment*
- *Security and emergencies*
- *Home automation*

Digital Enterprises

Digital Enterprise is a concept that is about changing the way organisations use and think about technology – moving it from a supporting player to a leading player in the business. A digital enterprise is an organization that uses technology as a competitive advantage in its internal and external operations. The evolution of digital technology presents opportunities and threats for all businesses.

Digital technology has a great potential to make enterprises more economical ad efficient. A full digital enterprise uses digital technology to integrate their production processes, related information and resources to make their business operating more effectively.

According to the "Strategic Policy Forum on Digital Entrepreneurship" digitalisation has enormous growth potential. According to recent studies, digitally proactive companies can perform ten times better than their peers. But so far, Europe has not met its digital potential. While in 2013 47% of EU citizens were already shopping online, only 14% of small and medium-sized enterprises used the Internet to sell products and services, and less than 2% of European enterprises were taking full advantage of the complete new wave of advanced digital technologies such as mobile communications, social media, the cloud, big data analytics, and the Internet of Things.

Important reasons for these low figures are probably the lack of trust in reliability and security, as well as the complicated systems.

ICT related research challenges in the area of digital enterprises are e.g.

- *Smart transformation of enterprises;*
- *Harmonising the competing and fragmented standards for industrial data;*
- *Security, privacy, and data safety for the necessary trust from the users;*
- *Reliability and robustness;*
- *Ease of use.*

Various other ICT trends and their related research challenges are fully valid to digital enterprises,

such as IoT, Big Data, Cloud Computing, 5G, digital learning, transportation, etc.

eHealth

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."

Healthcare is accounting for 9-10% of national Gross Domestic Products in Europe, a share that is likely to grow further over the next decades. Although the spread of eHealth applications could be instrumental in reducing the societal burden, the results of a recent EU public consultation and study showed that their market uptake has been sluggish and lagged far behind expectations[1]. The most recent "European green paper on m-health" revealed that although m-health is expected to potentially cut costs of healthcare by 15% and increase the effectiveness and efficiency of the delivery of care, a central obstacle to its deployment is the fact that only one third of Europeans have internet access through their mobile phones[2]. 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.

ICT related research challenges in the eHealth sector are:

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

Big Data

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

Europe is not playing a remarkable role in exploiting Big Data globally. 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 organisations involved in data whatever their role, be it producing, analysing, using or creating value from data.

Prof. Roberto V. Zicari from Goethe University Frankfurt analysed the Big Data challenges in an article for the Eurescom Message Magazine as follows (in the list the challenges only from the ICT perspective):

- *Data discovery: this is a huge challenge: how to find high-quality data from the vast collections of data that are out there on the Web?*
- *Volume: the main challenge is how to deal with the size of Big Data;*
- *Variety: combining multiple data sets: the challenge is how to handle multiplicity of types, sources and formats;*

[1] European Commission (2012), Communication from the commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of Regions – e-Health Action Plan 2012-2020 – Innovative healthcare for the 21st Century

[2] European Commission (2014) Green Paper on mobile Health (MHealth)

- *Velocity: one of the key challenges is how to react to the flood of information in the time required by the application;*
- *Personally identifiable information: Can we extract enough information to help people without extracting so much as to compromise their privacy?*
- *The challenges related to data privacy, security, governance, and ethical issues.*

Terminals

There is a wide variety of terminals, from simple telephones over Smartphones to complex multimedia units.

Terminals are usually not much in the focus of collaborative research, because they are mostly subject to manufacturer-internal research. Standardization mostly concerns the access and interfaces to terminals, not the terminals themselves. Terminal standardization at ETSI is done in the ATTM (Access, Terminals, Transmission and Multiplexing) group.

Collaborative research on terminals is mostly related to usability, user friendliness, ergonomics, human centred design, terminals for impaired people, and power efficiency. ETSI has a specific group for usability: HF (Human Factors).

6. CELTIC-PLUS WAY OF WORKING

The strategy of Celtic-Plus is asking projects to primarily focus on two key aspects, infrastructure/networks & connectivity, and end-to-end services & applications, which we call '*Networking and Clouds'* and '*Services and Applications'*. A gradual expansion towards a better integration between these two aspects is at the heart of Celtic-Plus, to help building up a '*Smart Connected World'*.

Celtic-Plus' strategy is continuously adapting to the fast changing technological and societal landscape. To respond to all new challenges, we consider the following way of working:

- Celtic-Plus projects are generated through regular **Calls**. Normally there is a Spring Call (closing in May) and an Autumn Call (closing in October) every year. Proposers of Celtic-Plus projects submit their proposals to a Call. The proposals are evaluated by independent experts, and a Celtic-Plus Label decision is done at a labelling meeting with the Public Funding Authorities and the Celtic-Plus Core Group.
  More details are on the Call information page: https://www.celticplus.eu/call-information/
- The **project proposals** continue the bottom-up, industry-driven approach following the main research aspects of this document, extended by new challenges that will become important. Proposers of Celtic-Plus projects are free to define the content of their project proposal according to their own research interests and priorities. They are not restricted by a specific call text.
- More **flagship projects** with significant budgets and clearly defined research objectives are encouraged. They are supported and agreed between several interested countries already at the definition phase. Flagship projects are supposed to generate significant impacts assuring a strong position and a leading role of the European industry.
- Celtic-Plus projects are private-public-partnership projects, partly funded by the participating countries. A minimum of two EUREKA countries need to participate in a Celtic-Plus project. To clarify whether national funds are available in the different countries, and to speed up the national funding decision, it is highly recommended that proposers contact their national funding authorities very early in the proposal submission process.
  National funding contacts: https://www.celticplus.eu/public-authorities/

7. TAXONOMY OF CELTIC-PLUS RESEARCH TOPICS

CELTIC-PLUS – TAXONOMY OF 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
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
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