Consultation on Future Network Technologies Research and Innovation in HORIZON2020

29 June 2012, Brussels

Workshop Report

Digital Agenda for Europe

Table of Contents

1. Preface

HORIZON2020 will be a seven-year programme for Research and Innovation (2014-2020) with an € 80 billion budget, implementing the Innovation Union, a Europe 2020 flagship initiative aimed at securing Europe's global competitiveness.
HORIZON2020 is part of the drive to create new growth and jobs in Europe and will focus resources on three distinct, yet mutually reinforcing, priorities, where there is clear Union added value:

- generating Excellent Science,
- creating Industrial Leadership,
- and tackling Societal Challenges,

all essential for the sustainability and long term prosperity and wellbeing of Europe.

The objectives of Horizon 2020 will therefore be addressed through a strong emphasis on finding efficient solutions, going well beyond an approach based simply on traditional scientific and technological disciplines and economic sectors.

Future Network Technologies research in HORIZON2020 will primarily be addressed under the Industrial Leadership pillar. The Industrial Leadership pillar will aim at making Europe a more attractive location to invest in research and innovation, by promoting activities where businesses set the agenda. It will provide major investment in key industrial technologies, maximise the growth potential of European companies by providing them with adequate levels of finance and help innovative SMEs to grow into world-leading companies.

The aim of this consultation is to collect clear and convincing evidence to show that:

- EU research and industrial players are ready in HORIZON2020 to take further long-lasting commitments and be able to develop and deploy leading network infrastructure technologies here in Europe for the benefit of its citizens.
- EU industry will translate successful research and scientific breakthroughs into innovative products, services and systems, which will foster EU economic leadership worldwide.
- EU taxpayers will receive value-for-money from research and innovation: in terms of growth, high-quality jobs and a sustainable life and economy.

The Digital Society enables a whole range of industries to use the network and European industry has a strong position in the global network technologies sector. We need to support all industries using ICT and therefore we need a deep focus on communications as an enabler. If EU will not be in the lead someone else will be. We need to explore new constituencies and methodologies to maximise the impact of research and innovation. The increasing number of connected devices requires enhanced network capacity and performance. This will require significant research efforts into the underlying technologies.

In this context, comments and input on stakeholders' specific areas of interest were requested in order to address and help prioritise in a strategic manner, the needs and challenges in network communications research in Europe in HORIZON2020.

The contributions and the discussions during the consultation workshop were structured around the following questions:

- Which sector are you representing? What are the strengths and size of your market in Europe and/or worldwide?
- How would you describe (in less than one page) your ideas and/or plans for future R&D challenges/topics relating to Network Technologies?

- How do you see the potential role of your organisation in HORIZON2020 in connection to the network technologies design, experimentation and/or deployment? What are your research priorities?
- Which network technologies requirements and expectations, do you consider important to inspire innovation and bring most benefits to your (business) development in the future?
- Which cross sector synergies in relation to the network technologies research are of strategic importance to generate growth in your business sector?
- How do you think that the network research community should best engage with the user community?
- Which constituencies and methodologies in relation to network technologies research are most important to maximise the impact of research and innovation in HORIZON2020?
- How should research developments in network technologies in HORIZON2020 be measured against delivering EU industrial leadership worldwide, sustainable economic growth and high-quality jobs creation in Europe?

This report briefly and crisply extracts the principal points presented, and captures the main issues arising during workshop.

2. Introduction

The consultation workshop on future research challenges in the communication networks area, held at the offices of the European Commission in Brussels on June 29th, 2012, was a step in the process of collecting advice, comments and input on stakeholders' specific areas of interest to address and help prioritise in a strategic manner the needs and challenges in network communications research in Europe in HORIZON2020.

61 contributions were received and 20 leading experts from academia and the ICT industry, who had been selected based on their submitted contributions, presented their ideas in the workshop. Most had prepared a presentation/ position paper responding to the eight key questions above. All gave a presentation of their views, and took part in open panel discussions.

In Section 3 an overview of key trends and drivers from the received contributions is given. In Section 4, the agenda of the consultation workshop on "Future Network Technologies Research and Innovation in Horizon2020" is presented together with the links to the available presentations, followed by a summary of the key points discussed per each panel, as presented by the workshop panellists.

3. Overview of Key Trends and Drivers from the received contributions

Global trends bring in an unprecedented pace of changing and increasing demand and requirements on technologies and solutions for Future Networks. In this consultation three major areas namely Integrated Infrastructure, Smart networks & architectures and Users' Perspectives have been identified as areas where major actions have to be taken towards the Future Internet and where intensive research is required for Horizon2020. An overview of the resulting trends and drivers from the received contributions is presented below:

Integration and Convergence: Development of common/shared infrastructure enabling any-to-any communication independently of the physical access technologies (wireless, wireline), capacity/resource usage, user utility, host/device movement and density, existing infrastructure. ICT networks will be the control and transport plane of other National Critical Infrastructures such as: health and telecare systems, eGovernment, transport systems, energy systems and environmental monitoring systems. Wireless and wired infrastructures need to be better integrated to ensure the required bandwidth is always available, everywhere, at the right cost.

Demands on mobile communication and networks calling for beyond 4G/5G Wireless: The demands placed on mobile communications networks are constantly increasing. The growth in the number of new applications running on the networks shows no sign of slowing and, on the contrary, it is accelerating as ever more mobile devices become the preferred device for Internet access for both people and machines.
Trends like growth of world populations, globalisation, mobility in all dimensions (goods, people, information), technology race, generation gaps, digital and educational dividend, social communities and networking, scarcity of resources, climate change still develop more and more momentum. These global trends are calling and demanding innovation in mobile communications.

Demands on Optical Networks: Optical network technologies will need further development as fibre-optic systems now also start approaching a limit. New research is needed to increase fibre capacity and to provide a dynamic software and control environment around this. A flexible optical spectrum approach, programmable transceivers and switching nodes, and the use of multiple wavelength bands will be prerequisites for these targets whilst still leaving them challenging to achieve. With increasing wireless capacities and smaller cell sites, a close wireless-optical integration and operation will be crucial to adaptively optimize end user experience over a fibre-constrained backhaul-infrastructure. Reseacrh areas include support of multi-Gbps access rate, Spectrum Management, Optical Network and IT convergence, optical network control plane, cognitive, self-managed and energy efficient optical networks.

Demands on Satellite Networks: Demand driven activities enabling, improving and sustaining EU industry competitiveness on the worldwide SatCom market, can be split into five components: broadcast services, backbone, broadband access, communications with mobiles (maritime, aeronautical, vehicle mounted, nomadic and handheld) and Governmental services. Satellite R&D activities include Reconfigurable, resilient and secured broadband connectivity, Enhanced broadcast systems, Integration/hybridising of future SatComs in the Future Internet, Capacity Distribution Scenarios, In-orbit validation of space segment products and technologies, on-board regenerative processor, new Adaptative Coding and Modulation (ACM), Interference Mitigation techniques and technologies enabling in-flight connectivity for passengers in commercial aircraft.

Continuous exponential growth of traffic and Technologies approaching their intrinsic limitations: All network technologies will need further development as we reach the limits of current systems. New research is needed to ensure a thousand-fold increase in network capacity in coming years. Network usage changes, traffic types, traffic rates and flow size distribution changes resulting in new requirements traffic control, Not human generated traffic (for instance from M2M capillary networks) will increase and coexist for network usage, coming along with Massive node deployment. In Wireless networks this goal could be achieved by including the exploitation of new frequency bands and complete revise of frequency allocations and licensing, spectral efficient techniques such as addressing spectrum management with cognitive radio agile radio. Higher spectrum utilization (e.g. bandwidth efficient modulation, out-of-band suppression like FBMC, higher frequency bands, dynamic spectrum access), better spatial utilization (smart antennas, interference control, topology optimization such as heterogeneous networks), and improved overhead ratio (efficient MAC and signalling protocols).

Standardised and interoperable architectures for distributed systems and Heterogeneous networking: As more and more devices are connected to the Internet it becomes essential that they can interoperate not only on the network but also on the service and control layer. Open and standardised interfaces will help but an overall architectural framework is recommended. These kinds of architectures for distributed systems will be the key to enable next-generation services and open up the market for new players. Continuous evolution of mobile terminals and tablets, due to progress of OS, mobile processors and embedded sensors will add further requirements and models for mobile networks. The word of mobile internet and IoT shall meet creating new solution and technological challenges.

Software defined Networking (SDN): SDN represents a change not only in the way networks can operate, but also in the way services and network applications can be designed and deployed. From a decentralized Internet, where relatively low capacity nodes take decisions in a cooperative way, where best effort is still the rule in many cases, we can think in new scenarios where a centralized control and operation system can take a full landscape aware decision and where nodes become fully programmable high-speed forwarding devices. In this view, a SDK is available for producing and deploying services and ad-hoc features needed to run the network and provide new network-based services. The only standard that is currently available for SDN is OpenFlow. It has different functional elements, which range from hardware (like switches) to software like Network Operating Systems and applications with well-defined interfaces between them. This ecosystem is flexible and provides enough space for any extensions needed. This kind of architecture will be the key to enable next-generation services and open up the market for new players in the fields of hardware, software development and network based added value applications.

New applications and content are placing new technical demands on the network. Whereas in the past, increasing the transmission capacity of the networks was the main focus of research, new applications mean that reducing the latency of networks, increasing their energy efficiency, improving utilisation of spectrum and the scalability and stability of networks are the new requirements that future research and innovation must also address. Data and content delivery need further research in order to ensure that they meet the user needs. Research on the issues of intelligent data handling and delivery based on user preferences, and user, device, radio and network contexts offers potential solutions to the challenges. Furthermore, the variety of media consumption, in particular the different types of real-time video and video- on-demand type services, has increased rapidly. Therefore, the classical distinction between broadcast-only networks and (Internet-based) communication networks is no longer valid. Integrated solutions are required which fulfil the customers' media consumption demands on stationary and mobile devices in a cost-, energy-, and spectrum-efficient way.

IoT and M2M: The use of networks to connect machines to the Internet is still in its infancy. Internet architectures should be resilient and trustworthy and designed to support open access, increasing heterogeneity of end-points (multimode devices, people, things) and networks (self-adaptive, self-healing networks, opportunistic networks, networks of networks), with the need of a seamless and generalised handover. Networks will sustain a large number of devices, many orders of magnitude higher than the current Internet, handle the large irregular information flows, and be compatible with ultra-high capacity end-to-end connectivity. Projections suggest that expected rapid growth in the generation of network traffic will be driven by the increasing number of sensors and the use of networks for Machine-to-Machine (M2M) communications.

Security, privacy and trust issues in shared and more autonomous infrastructures: ICT networks, telecoms and content delivery have still to consider important challenges as trust and privacy. As more and more means like electronic signature and digital identity will or are already a basic service to be offered to citizens, reinforcing business dynamicity and growth, trust and related technologies are essential to support such growth of services and traffic. Security of the shared infrastructure becomes a key area of concern, the expansion of the infrastructure together with the increasing complexity of technologies (amplification effects resulting from interactions among components that are sometimes hidden or unknown at design time) makes novel types of anonymous attacks possible. Coping with the security challenges without impacting accessibility, scalability, and privacy of the infrastructure is one of the main challenges of the next decade. Security topics such as beyond DRM, trust, and security, will also remain at the core of the main research areas, especially when it comes to protecting the user while keeping European values such as individual privacy and confidentiality.

Solutions for demographic changes and integration of smart city & smart home networks and applications: In times of demographic change, increasing health care costs and shrinking resources, innovative ICT solutions become more and more vital to ensure high quality of life and future health care. First ambient assisted living (AAL) solutions are available today already, but will be even more beneficial when combining information from smart home and smart city environment (sensor networks, home management systems), thus enabling the home as a location for care and health care. ICT networks will be the control and transport plane of National Critical Infrastructures such as; health and telecare systems, eGovernment, transport systems, energy systems and environmental monitoring systems.

Green industry / life and Energy saving: Energy efficiency is now a primary target for new communication systems and solutions. This work addresses issues such as new applications and technologies for reducing energy consumption, and to actively manage and control the best use of energy in sectors like health, transport, energy, e-government, urbanisation, knowledge and culture. Energy efficient hardware and software algorithms are key parameters in future networks, not only to ensure market success, but also to fulfil green radio obligations.

Proliferation of the cloud concepts beyond pure applications: (a) Technology breakthrough enabling unprecedented scalability, flexible distribution, (b) Networked cloud and (c) Cloud services. Economy of scales both for quick upscaling and downscaling of required processing, storage and network resources 'on demand', pay as you need by means of virtualization.

Societal needs and User perspectives: A connected society: Everybody and everything will be permanently connected to a Network. Network bandwidth and quality will increase significantly. We can summarise this future network paradigm as: *Anything, anybody, anytime, anywhere on any device.* More specifically, needs for networking will increase drastically in coming few years (number of connected objects, higher data rate, pervasive access to information from users, delinearised content, cloud computing etc.). This will make

users' behaviours strongly network-dependent. The future networks will thus have to face future connectivity characteristics and to bind connectivity with smart mediation. A major impact of ICT is that it effects how society and work life is organized and developed. New societal challenges are appearing where communication technologies will have to play a large role e.g. in environmental awareness. The focus of the Internet as a whole has evolved and is now on "people" and "things", and on transporting multimedia "content" and providing "services". New and broader QoS requirements result from new advanced services.

User interfaces and immersive experiences
Effective remote collaboration between professionals requires real-time immersive visualization (e.g. glasses-free 3D), spatial audio and tactile information, to realize a very high quality emulation of the face-to-face interactions in real meetings. The professional worker wants to focus on the content of their work and not on the technicalities of the collaboration and communication tools. Therefore the complexity of the technology should be hidden as much as possible; this requires user-friendly interfaces that support multi-sensory interactions with the display. It also requires network connections with the speed and responsiveness to enable fluid remote interaction, as well as robust technologies to ensure privacy.

User and usage data/content: Data and content delivery need further research in order to ensure that they meet the needs of users. Research on the issues of intelligent data handling and delivery based on user preferences, and user, device, radio and network contexts offers potential solutions to the challenges. Converged service that will give access to all types of information found or to be found on the Internet: health, transportation, pictures, music, movies, power, sensors, social, etc. The Internet of Services is user-centric. The Future Internet infrastructure components must be secured against intrusion, hacks and misuse. The privacy of each actor must be guaranteed and controlled. Content will be transformed into smart content by adding metadata during the content creation process or during exchange. Development of new delivery paradigms is necessary behind current internet/IP model to better match future content-oriented networks, e.g. ICN (Information-Centric Networking) architectures and CDN (Content Delivery Networks). Virtualisation implementation is necessary as they will offer the link to services and data accessible on the Cloud, as well as more adaptive systems and technologies being able to sense their neighbourhood and adapt accordingly and new ways of handling enormous amount of connected devices in a cost-efficient way.

Customer analytics for quality assessment and service management: What can we learn about the user, and about how much she/he likes or dislikes a service, by combining different sources of information from network- and device-based monitoring systems that collect information both about network properties as well as user behaviour? This is an increasingly relevant topic addressed by large non-European companies for a long time already. It requires research and development at European level to exploit the substantial possible economic benefits, by considering the diverse technological aspects underlying different approaches to the topic, and especially addressing the most important show-stoppers such as the related privacy concerns.

New business models, CAPEX and OPEX Reduction: There is a strong need to invent new business models which exploit the value of the infrastructure to the benefit of not only the application sector but of all involved business stakeholders, taking into account cooperation, competition and regulation constraints and the technical impact of network openness and associated interface definitions. An example is that, with networking resource optimisation through intelligent resource and infrastructure sharing CAPEX, OPEX, and costs for energy can be reduced and new business models can be installed. The introduction and adoption of technologies such as clouds, Self- Organizing Networks (SON) and cognitive multi-network access would also represent a major breakthrough towards future business models.

4. Workshop Discussions and Results

4.1. Agenda

Future Network Technologies Research and Innovation in HORIZON2020
Consultation Workshop Agenda
29 June 2012, Brussels
Avenue de Beaulieu 25 – Room S1
9h00 - 9h15 Welcome remarks, Luis Rodriguez-Rosello, European Commission, Head of Unit

9h15 – 11h00 Integrated Infrastructure Panel Session

Chair: Philippe Lefebvre, European Commission
Panel Firestarter: Net!Works ETP Contribution, Werner Mohr, Net!Works Chairman, Nokia Siemens Networks
Panel Opening Statements:

- ASTRIUM (Philippe Boutry)
- COSTIC1004 (Narcis Cardona, COST IC1004 Chairman)
- ERICSSON (Henrik Abramowicz)
- ISI ETP (Nicolas Chuberre, ISI Chairman, Thales)
- DEUTSCHE TELEKOM (Hans Einsiedler)

11h00 – 11h15 Coffee break

11h15 – 13h00 Smart networks & architectures Panel Session

Chair: Rüdiger Martin, European Commission
Panel Firestarter: Alcatel-Lucent Contribution, Didier Bourse, Director, European Research Cooperation
Panel Opening Statements:

- CAON Cluster (Dimitra SIMEONIDOU, Unniversity of Essex)
- DANTE/GN3 NREN (Michael Enrico - DANTE, Mauro Campanella - GARR)
- Steve UHLIG (Queen Mary, University of London)
- Eduardo JACOB (UPV/EHU, University of the Basque Country)
- Olivier MARTIN (Independent ICT expert, exCERN)
- ETNO/ORANGE FRANCE TELECOM (Yvan Meriau, Orange)

13h00 – 14h00 Lunch break

14h00 – 15h45 Users' Perspectives Panel Session

Chair: Andrew Houghton, European Commission
Panel Firestarter: NEM ETP Contribution, Jean-Dominique Meunier, ETP Chair, Technicolor
Panel Opening Statements:

- BARCO (Ronny Dewaele)
- EARPA (Ben Rutten, Technical University of Eindhoven)
- Anders Rockström (KTH - Kungliga Tekniska Högskolan)
- IoT Cluster (Ovidiu Vermesan)
- Celtic Plus (Jacques Magen, Celtic Plus Chairman)
- SINTEF (Arne Lie)

15h45 – 16h00 Wrap-up & Conclusions, Luis Rodriguez-Rosello, European Commission, Head of Unit
N.B. The selected contributions are available online:
http://cordis.europa.eu/fp7/ict/future-networks/documents/h2020-fn-consultation-booklet.pdf

4.2. Integrated Infrastructure Panel Session

The **demands placed on communications networks are constantly increasing**. The growth in the number of new applications running on the networks shows no sign of slowing and, on the contrary, it is accelerating as ever more mobile devices become the preferred device for Internet access for both people and machines. Global market share of ICT sector and several studies regarding traffic growth prove ICT dynamism and the huge impact of communication networks on economic growth and job positions.

ICT will support and will be an important part of the future private and business life – technical research and innovation are needed because new challenges will appear. The current infrastructure and ICT environment will not be able to support these challenges. User community and legal issues will appear, including changes in the community, changes in business and working, regulatory challenges. New business models will come up, while CAPEX and OPEX have to be optimised.

The **technical challenges** will include quality, latency, high sustainable throughput rates, security, and mobility, virtualisation and clouds, context and data processing and optimization of infrastructure/resource usage and service offerings. We are moving from product economy to service economy, so we need to have a comprehensive approach not only focusing on products but also on how to maintain, upgrade, change and charge.

Satellite Communication (SatCom) based services have a role to play to address many societal challenges of the EU: the Digital Agenda per se, but also specific broadband applications enabling a fair access to all European citizen to public services such as e-health, e-education and e-administration. Beside, SatCom services are an obvious tool to support Crisis management and Security issues and a mean for terrestrial network resilience. High quality satellite services in urban areas e.g. TV evolution (delinearized TV and the evolution toward 3D TV) and broadcasting will impact future design. A clear requirement from the EU to achieve seamless integration of satellite based solutions into the global networks would certainly be a strong enabler. Four principles should be followed in order to maximize the impact on Research and Innovation (R&I) actions:

- R&I actions must follow a “demand-driven” approach
- R&I actions must involve the users at all stages of the development
- R&I actions should always have in perspective the possibility of follow-up pilot/demonstration projects
- A pilot/demonstration project should always be implemented with a sustainable perspective, e.g. always involve an operator or service provider to assess the economic model.

In general, the **major network drivers and challenges** that are foreseen can be summarized as follows:

- Traffic will grow exponentially in coming years
- Rapidly changing usage patterns
- Sustainability
- Massive increase of sensors/devices
- Machine-to-Machine (M2M) /Internet of Things (IoT) / sensor-based networks still in their beginning
- Very reliable, robust and highly available systems and networks are needed to support critical infrastructures such as energy, gas, water, health and traffic
- Better usage of spectrum since available frequency spectrum will not grow exponentially like traffic
- High capacity mobile and wireless networks needed
- Cognitive concepts and methods will support more efficient spectrum usage
- Optical networks have to be improved to increase fiber capacity further

- Basic communication systems are reaching Shannon limit on link level, therefore better exploitation of system level to be investigated
- Trust, security and privacy are essential means to support user needs
- Integration of heterogeneous technologies

Based on the above drivers and challenges, the **network technologies requirements and expectations** that come up are:

- Seamless support and integration of heterogeneous networks from wide-area to short-range communication, interworking and traffic off-loading
- More wideband systems for data hungry applications
- The increase of traffic needs to be dealt not only with more spectrum but with better management and advances in technologies and architectures.
- Significantly lower latency compared to today's systems for mission critical applications
- Overall experience in terms of coverage, reliability, availability, resilience, throughput rates per user and latency significantly improved
- Significantly improved energy efficiency of ICT systems and cooperative networks
- OPEX and CAPEX need to be reduced to offer affordable rates for broadband services.
- Decrease of cost of services and devices
- Broadband backhaul systems (e.g. 60 to 90 GHz) for dense cell deployment
- Self-organised and self-managed networks to manage complexity
- Preparation of future standardisation and WRCs for spectrum allocation
- Software defined networking. In future communications we will have a simpler infrastructure part but a more sophisticated control plane that will even allow for terminal side interaction.
- Network Virtualisation
- Integration of IoT and sensors
- Efficiency and security at the wireless terminal side
- Wireless communication for traffic safety and efficiency
- Adaptive, distributed and cognitive mobile systems
- Smart adaptive antennas
- Radio Access Network (RAN) evolution beyond the cellular concept (RAN CLOUD concept)
- Satellite Communication Networks to provide significant contributions in areas where coverage, resiliency are essential, especially for broadcasting/multicasting of media content in real time or non-real time, fast broadband access, M2M, safety communication.

In Horizon 2020, **cross sector synergies** in relation to the network technologies will be of strategic importance. Vendors and Industry should be able to push innovation together with universities. LTE standard is a very good example of collaboration. Communication technologies will increasingly be applied to other sectors in industry and society. In order to enable investment in communication technology for other sectors as much as possible, standardised technologies and systems should be applied. This ensures economy of scale and enables interoperability, which is important for European-wide solutions. Cross sector synergies can be expected in connectivity solutions, cloud computing and IoT solutions. In satellite communication, the integration with terrestrial networks and other satellite applications such as Earth Observation (GMES) and navigation (Galileo) would foster the growth in that domain.

Cooperation between different communities to be involved will be the key to engage with the user community. Both the communications and the user communities have to further improve mutual understanding on the needs of the user community and on the potential offer from the networking community to develop new solutions for societal challenges. User groups need to be involved throughout the research and innovation process to consolidate

the user requirements. Furthermore workshops, networking events and joint projects including both communities will be needed.

In order to **maximize the impact of research and Innovation of Horizon 2020**, relevant stakeholder groups have to be involved to ensure economic exploitation in international standardisation and/or products and systems for new solutions for societal challenges. New value chains that foster innovation should be developed. Collaborative research projects should be used for consensus building, which can be exploited in international standardisation via established channels of partner organisations. There should be no focus on a specific area because world is changing fast. Horizon 2020 should be flexible not to miss the trends; and open to identify new disruptive ideas.

The network technology sector is based on an ecosystem of global companies with globally R&D organisations and SMEs, which provide excellent know-how and expertise. Taking into account the contribution of ICT to economic growth in the EU and the fact that Europe is in global competition for R&D, it is essential to deploy new networking technologies, which are also based on results of **collaborative research in Europe**, by providing reasonable conditions for an investment-friendly climate in Europe. Universities and industry needs to be maintained and strengthened. The regulatory environment is playing an important role in this context.

The **impact on global standards** by anchoring IPRs coming from Europe is an essential condition to ensure an important position of European industry in global competition and high-quality jobs creation in primary and secondary sectors. In order to bridge the gap between research and actual development and deployment it is suggested to make use of public procurement as a means of expediting market uptake and demonstrating product feasibility.

4.3. Smart Networks and Architectures Panel Session

Network technologies requirements and expectations are important to inspire innovation and bring most benefits to (business and societal) development in the future. Global trends bring in an unprecedented pace of changing and increasing demand, and requirements on technologies and solutions for Future Networks. Four major areas, namely Future Wireless Access, Content Distribution, Communications Systems/Network and Optical Networks, have been identified as areas where major barriers have to be brought down towards the Future Internet and where intensive research is required in Smart networks.

For **Optical Networking**, the key research challenges include

- Support of multi-Gbps access rates
- Spectrum management: capacity management and bandwidth granularity Provisioning
- Optical Network and IT convergence e.g. globally accessed clouds empowered by optical network infrastructures
- Optical network control plane
- Cognitive, self-managed optical networks
- Energy efficient optical networking

The CaON cluster has developed a reference model which presents a layered architecture linking optical networks with future services and applications. This model promotes the convergence of the optical infrastructure layers with upper layers and aims to strategically position optical networks as key enabler of Future Internet and cloud networking service deployment.

Software Defined Networking (SDN) represents a change not only in the way networks can operate, but also in the way services and network applications can be designed and deployed. From a decentralized Internet, where relatively low capacity nodes take decisions in a cooperative way, where best effort is still the rule in many cases, we can think in new scenarios where a centralized control and operation system can take a full landscape aware decision and where nodes become fully programmable high-speed forwarding devices. In this view, a SDK is available for producing and deploying services and ad-hoc features needed to run the network and provide new network-based services. SDN concept is still in its infancy and the only standard that is currently available is OpenFlow. This kind of architecture will be the key to enable next-generation services and open up the market for new players in the fields of hardware, software development and network based added value applications.

Current areas of application of SDN range from cloud computing and data centers optimization to ad hoc service provisioning and access network optimization. Future applications are still in the drawing board.

In Europe there are many research institutions, industrial and telecom operators that are already dealing with SDN and this fact should aggregate efforts to multiply results to strength European SDN presence. Products and services should be expected in many areas, i.e.:

- SDN compliant hardware.
- End user/residential access to SDN based Networks and services.
- Software Ecosystem for SDN development.
- Specific application solutions.

Opportunities for the European ICT industry are numerous especially given the irresistible trends towards a “Greener” ICT world, the almost borderless room for innovation in the Over-the-Top (OTT) space, e.g. e-Health, Smart-*, Commodity routers, Large scale NATs, innovative network appliances facilitating interconnections with the emerging IPv6 world, mobile Internet that is still in its infancy with immature protocols and products, innovation in efficient content distribution (Information-Centric Networking, new peer-to-peer schemes).

Many other parallel Internets will appear, e.g. the Internet of Things, Smart Grids, etc., that, if only for cyber-security reasons, will be loosely connected to the "Global" Internet through highly-secured gateways.

In addition, **the standardization process seems to slow down in certain sectors**. The despairing failure of IPv6 deployment, partly due to the lack of suitable migration tools, is one compelling example but there are many others like the implementation of Quality of Service (QoS) and lack of commonly agreed inter-provider mechanisms for automatic charging, bandwidth provisioning, MPLS, etc. Smooth cooperation between ITU-T and IETF is also lacking as exemplified by the endless MPLS-TP controversy. Being too dogmatic and sticking too much to the basic Internet principles like, end-to-end, transparency and end-to-end security, the IETF, that is supposed to provide the basic standards, failed to adapt to the new situation created by the OTT providers. Given the undisputed leadership of the IETF, the only way forward is to strengthen the Internet standards making process through increased European participation.

In a context of digital revolution, the development of internet is core to the economic and technological growth in many application sectors. These ever increasing requirements of connectivity and data transfer will deeply impact the evolution of communications networks and services infrastructure. This will challenge both the traditional business models and uses. Moreover, in this context of increasing complexity, it is essential to ensure safety (resistance to attack and ensuring the confidentiality of exchanged data), dependability (robustness, resilience) and optimal quality of service in multiple and heterogeneous networks that contribute to the services proposed to the user. In this context, the **ideas and plans for future R&D challenges** include:

- Integrate network with Cloud & HPC Services data repositories
- New architecture models should emerge regarding home network
- Develop Software Defined Networking in the broader sense to address Internet flexibility issue (starting with OpenFlow). Apart from S/W Defined Networking, H/W defined Networking should be taken into account
- Support new emerging "real-time" applications with "all-photonic" transmission
- Address scalability issues both in the wide area environment, between a large number of domains, and in the metro and local environment, smart cities, large data centres
- Overcome the dump pipe curse
- Networks that adapt to demand (innovation on the network)
- Cognitive autonomous management solutions for (potentially highly heterogeneous) massive node deployments.
- Evolution towards programmable network nodes, perhaps under the umbrella of the Software Defined Networks paradigm, and introduction of virtualisation in networks will be a breakthrough for the network of the future
- Energy-efficient networks
- Spectrum Management for Optical Networks. Optical Networks and IT convergence
- Seamless access to data & information is the main challenge. Not only content delivery but also data analysis is important.
- Support of test-beds and trials.

The organisation of H2020 itself reflects this core and diffusing character of ICT since relevant budget is allocated to ICT along both "Leadership in enabling and industrial technologies" (LEIT) and also "Societal challenges". Therefore it is obvious that in order to generate growth in the business sector of Smart Networks and Architectures it is important to create **cross sector synergies and collaboration between the following players/activities**:

- Supercomputing and computing grids
- Clouds and large data storage
- Smart cities, sensor networks
- Education and culture
- Retail and trade

- Privacy, identity and trust management
- Security and intrusion detection
- Optical equipment
- Wireless technologies
- Internet policies

It is also vital that there is a constant validation of research directions and results in connectivity and networking services with research and societal needs. **Engagement with the User communities** will be best achieved by working with the e-Infrastructures and communities to understand their needs and involve them in research and development as a collaborator, not just providing "plug on the wall" services.

Traditionally, EU projects in the networking area have not been strongly urged to engage with the public, but focus their attention on the impact for European Industry. The fundamental changes in the Internet lead to fundamental questions about the possible directions in which the Internet might be going, not only at a technical level, but also from a business perspective. These are societal questions asking for answers for the sake of Internet governance, and to ensure that the infrastructure is serving the purposes of the society as a whole, not only of a few business players. Emphasis must also be placed on engagement with users as the focal point of the ecosystem, not only business stakeholders.

User consultation and involvement in the development of networking technology are essential to ensure user requirements are understood and met. Innovation may also stem from direct results of high-end users (e.g. Astronomy, Physics, Biology) who have a history of creating new working methods on the basis of network developments, sharing resources across disciplines and technology domains to create virtual eScience research communities. Research objectives and methodologies need to be sufficiently "open" to allow for this, whilst still responding to future needs and respecting IPR ownership. The involvement of constituencies such as eHealth, education and not-for-profit entities such as humanitarian organisations can ensure economies of scale to the benefit of societies.

Once an invention is born in a research project, especially when it comes to network infrastructure, its **adoption by the market** requires not only a quasi-mandatory standardization step, but also an innovative integration into the existing infrastructures or within a global target architecture, and finally, a comprehensive test to prove that performance is not degraded by a transition to an industrial scale. Therefore infrastructure provider is a very important actor and its collaboration with research centres is necessary. Regulatory bodies should also be involved to accelerate mutual understanding. Last but not least, content providers and data centres are very important in the value chain; user needs and researchers must be involved actively in the process.

Developments in networking should be measured primarily in terms of their indirect impact: advanced networking in research and education networks is essential for top level research and improved higher education, which in turn are two essential elements for industrial leadership, economic growth and high-quality jobs creation.

The success of research developments in network technologies can be measured by:

- Research results produced and contribution to standardization work
- The use of research results worldwide;
- The reduction in the costs of access to high-speed internet and related services;
- The actual usage and usage trend of a network, and its 'value' for business, which can be measured by the impact of having no network connection or a too-low capacity connection;
- Europe's ability to attract and retain networking researchers;
- The number of patents filed, technical standards adopted and peer-reviewed papers and articles published;
- The adoption of results not only by industry but also by the public sector and in society;

- The adoption of research results in smart cities, in particular for gains in transportation and energy efficiency through the use of networks;
- The effect of networking advances on the education sector, in public administration, culture and health.
- Measurement of industrial impact through the use of results in products or marketed services.

4.4. Users' Perspectives Panel Session

There are **big societal challenges** facing the global community. In practically all cases, ICT can significantly contribute to counter these challenges: from humanitarian interventions in cases of natural disaster and the problem of fighting poverty to the alleviation of the effects stemming from global warming or to helping the elderly or people with disabilities to live more safely and have assistance in their familiar environment. Europe has already proven its ICT capabilities in these new domains, and beyond in the classic network technologies such as GSM or DVB, both of which were developed in Europe. Europe is aware of the potential of ICT for industrial export and is already placed at the forefront of applying ICT to new societal challenges. Further research should help to maintain and foster this position in initiatives concerning the application of ICT to energy savings, the ageing population, Internet for all (e-Inclusion), security, health issues, remote collaboration, smart cities, integration of users (user centric approach), smart mobility, and new innovative usages of available ICT. Communication between people is very complex and all the aspects of natural human communication must be addressed to achieve a high quality of experience (QoE) in a remote collaboration setting.

In the not so distant future, **everybody and everything will be permanently connected to a network**. For example, connected 'things' as well as 'people' will be able to provide information that will help to create or enrich content: intelligent objects, while connected people will be able to express and share their experience, attitude. Network bandwidth and quality will increase significantly with fibre networks reaching closer to the end-user's point of access. The applications will also grow tremendously, as will the number of connected things. The need for mobile broadband will grow with the connection of sensors and multimedia technology. Increasing bandwidth capacities of LTE/4G mobile networks will enable users to access high definition and even 3D/holographic content on the move. In addition, increasing uplink bandwidth will allow for new types of services such as online content storage, glasses-free 3D videoconferencing, and tele-immersion. We can summarise this future network paradigm as: "Anything, anybody, anytime, anywhere on any device". Furthermore, In the near future, there will be a burst of glasses-free 3D, immersive and beyond-HD experiences, with interfaces becoming even more intuitive, including speech, tactile and multisensory interactions. The user interface paradigm can be summarised through "Experiencing content is king – rich, connected, immersive, intuitive experiences are the future".

The success of this Internet of services will reside in the European ability to design and deploy **converged service means that will give access to all types of stored and real-time information found or to be found on the Internet: health, transportation, pictures, music, movies, video, power, sensors, social**, etc. The Internet of Services is user-centric and users themselves may be providers of new services. To reach this objective, the Future Internet infrastructure components must be secured against intrusion, hacks and misuse. While technology is going virtual, human is not virtual. The privacy of each actor must be guaranteed and controlled especially in order to allow network authorities mandated by law, to trace illegal behaviours of connected individuals or service providers. Content will be transformed into smart content by adding metadata during the content creation process or during exchange. However, as users will move from one device to another, and also from their home to outside, it is mandatory that their respective smart user profile is transparently accessible from everywhere, for an easy and intelligent usage. Residential gateways at home will play a key role for enabling virtualisation implementation because they will offer the link to services and data accessible on the cloud.

The focus of the Internet as a whole has evolved and is now on 'people' and 'things', and on transporting multimedia content and providing services. One of the keys will be technologies and solutions tackling interdisciplinary domains and more expansion for instance towards services and user-centric solutions, is foreseen. Thus, in terms of **research, network**

technologies requirements and expectations that are identified in this session can be found below:

- The user should not have to configure the network to suit an application and should not even need to know how the signal is routed. To achieve that goal, current network technologies need much improvement. The size and complexity of the internet is growing very fast, both in terms of volume of traffic and number of users (not only human users but also devices). Heterogeneity of devices, technologies and applications make the situation more difficult. Human users increasingly demand services that are real-time, simple, secure and personalised. Transportation of high resolution images will require bandwidth connection of many Gbit/sec at an affordable cost. Quality of Experience (including low latency) is rather important. Networks must be trustworthy, resilient, self-adapted and self-healing. Accommodating all these requirements presents the main challenge for the future Internet. The complexity of the technology should be hidden for the user as much as possible. Multi-modal biometrics should support the user authentication and the user-display-interaction should be based on ease of use gesture-, touch-, and voice control.
- Intelligent delivery of content in general and of video in particular, is an important topic for research as this will impact the majority of the future traffic over the Internet. This includes Delivery-centric network architectures, intelligent adaptation of the content flow, Cognitive video delivery and Interworking between content search and discovery.
- Network technologies allowing adaptive services and tools for dynamic management of automotive control systems and techniques for the verification and validation of the upcoming generation of vehicle electronics and networks: The trend is towards the always connected cars. Traditional top-down executed traffic management from traffic control centre towards variable message signs will evolve towards an in-car centric traffic management system: always connected cars will generate lots of data, which will be wirelessly shared with the car drivers' community, without manual intervention in the traffic control centre, but fully automated disseminated into the car community. This will cause a paradigm shift in traffic management as we know it nowadays. Application example is that information collected from each car will help improve logistics and reduce environment pollution, makes driving more safe, resulting in less casualties, less congestion and less environmental load. Applications will include following the next car, avoiding pedestrians, lane change assistant, dynamic speed adaptation, hazardous location warning, traffic prediction services, etc. Client applications will require fully integrated co-operative road side (receiver/transmitter) units and server side systems and will have an eminent HMI for managing all applications in an effective, comfortable and safe driving service to the user, resulting in increasing wireless and wired bandwidth requirements.
- Security topics such as beyond Digital Rights Management (DRM), privacy, trust and security, will also remain at the core of the main research areas, especially when it comes to protecting the user while keeping European values such as individual privacy and confidentiality.

Cross-sector synergies such as cross-European Technology Platform (ETP) innovation workgroup will be created to combine best practices and facilitate innovation partnerships that use a systems approach to deliver cross-sector innovation. In this context, the existing synergies between the semiconductor industry, communication, network technology and software industry are of strategic importance. The cultural, art and design sectors are also key catalysts in building innovative products and services and increase user acceptance. ICT is a key sector which could also contribute to the growth and maintenance of the worldwide leadership of the European automotive sector, by the provisioning of unique services in the frame of smart mobility. Support of standardization efforts from the relevant bodies is also necessary for all above areas to ensure that interoperability of the different systems and subsystems is addressed in the right way.

Besides the obvious cross synergies between ICT and sustainability research in general, **synergies with areas from social science and humanities** (SSH), in particular those researching individual and group behaviour are of interest. More generally, involvement of user communities is important. In particular those involved in providing societal services, which is very general and spans from health care, education, culture to authorities and governing in general. The value and aim for this collaboration is to achieve more effective and efficient means to produce and provide those services and how to measure their effect/success.

Involvement of new communities, users as well as research communities, do not happen spontaneously but have to be actively encouraged and supported. Such activities could in turn be helped and concerted by activities exploring trends and applications, and arranging some consulting or concertation meetings with relevant communities. User communities could also be involved through user-driven projects and collaboration with other development programs could be pointed out. Discussions forums will continue to exist and strengthen within the ETPs, the Eureka programme and other initiatives. We should have in mind that a majority of innovations are made by users, and not by industry or academia (e.g. in the area of medical equipment 85%). Our focus up to now is too much technology-oriented, so we should let users drive the requirements upstream. Researchers must find a way to listen to user community.

The straightforward **measurement of research development in Horizon2020** will be the uptake and use of developed technologies in a worldwide context. The simple parameter that must be used to evaluate this is the commercial success and continued economic well-being of the European industrial players as a consequence of the research and development performed within the research programmes. A good evaluation criterion for activities in the network field is also the direct measurement of the number of project results application into newer standards, protocols and the provision of new services. Important parameters used can be: number/ type of new or improved products, any directly generated new jobs from project (e.g. spin-offs, etc.) although the impact on employment can be usually seen in a long-term basis, estimated return of investment (RoI), number of generated patents, standards contributions, other publications (including PhDs etc.). A possible step forward may be also to enhance the “peer-review-like” process used today to evaluate project and programs, to also include peers from user communities, other stakeholders and from “cross sectors”.

5. Conclusion

Information and Communication Technology (ICT) remains fundamental to the future health of the European economies. This follows both from the importance of the ICT industries themselves, and from the contribution that ICT makes and will make to the societal and economic goals of the European Union. Network technologies and systems in specific are seen as strategic technologies in the majority of the developed world and in emerging nations, with ambitious R&D programmes. Europe is well positioned on the related markets and represents about 30% of a € 1600 Billions world market for communication services. Global investments in equipment represent a bold market of € 300 Billion worldwide, with European industry well positioned on a number of market segments (wireless, broadband, managed services).

In this context, it is important to keep and reinforce the industrial leadership in Europe for Network communications. Implementation is proposed with a complementary approach, and using a model of infrastructure for innovation, extending the work pioneered in FP7. Horizon2020 programme will be the means to support the reinforcement of the European position of ICT Industry. ICT will be an effective enabling technology in addressing the "Grand

Societal Challenges" of climate change, energy shortage, transportation, health and demographic changes. R&I through Horizon 2020 will contribute to strengthen Europe's place in the ICT sector, thus enabling growth and reduction in unemployment throughout Europe for more than the ICT sector.

This report tries to address all the needs and challenges in Network Communications research in Europe in Horizon2020 in three major areas, namely Integrated Infrastructure, Smart networks & architectures and Users' Perspectives. Based on contributions and discussions during the workshop, network technologies requirements and expectations are presented along with key trends and drivers. In Horizon2020 cross sector synergies in relation to the network technologies research are of strategic importance and will generate growth in the business sector. User consultation and involvement in the development of networking technology is also considered essential to ensure that user requirements are understood and met. It is vital that there is a constant validation of research directions and results in connectivity and networking services with research and societal needs.

.