(NetSoc)

Deliverable D1.3 – Strategic Research and Innovation Agenda – Version 1

Editor:	Halid Hrasnica, Eurescom GmbH
Deliverable nature:	Report (R)
Dissemination level:	Public (PU)
Contractual delivery date:	30 June 2013
Actual delivery date:	23 July 2013
Suggested readers:	Research communities of ICT and vertical/application sectors
Version:	1.0
Total number of pages:	62
Keywords:	ICT initiative, Networked society infrastructures

Abstract

This deliverable represents the updated version of deliverable D1.2 by including the response of the ETPs to the feedback received on the Strategic Research Documents. D1.2 contains a summary of the Strategic research documents from the three ICT ETPs, Net!Works, ISI, and NEM, which are accessible through the ETP websites. D1.2 was aimed at serving as a basis to spur discussion about Strategic Research priorities with various groups and communities. This updated version of the deliverable contains the summaries of the discussion and the positions of the ETPs with respect to the received feedbacks.

Impressum

Full project title: Networked Society

Short project title: NetSoc

Number and title of work-package: WP1 - Identifying Requirements and Challenges

Document title: Strategic Research and Innovation Agenda –Version 1

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Estimation of PM spent on the Deliverable: 4.5

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1 SCOPE AND PURPOSE OF THE DOCUMENT

This deliverable represents the updated version of deliverable D1.2 (Strategic Research and Innovation Agenda –Intermediate Version 1). D1.2 presented strategic research documents from three European Technology Platforms in the ICT area, that deal, among other topics, with communications network infrastructure:

- Net!Works
- ISI
- NEM

The Strategic Research and Innovation Agendas exist as standalone documents and are accessible for the public through individual ETP websites (http://www.networks-etp.eu/, http://www.isi-initiative.org/, and http://www.nem-initiative.org/).

Chapter 2, i.e., D1.2, of this deliverable summarizes these strategic documents to emphasise research and innovation issues in respect to future developments of the future network infrastructure, allowing also an easier discussions on the document with various groups and communities.

Chapter 3 reports the views of the ETPs and the outcomes of the discussion held, on the basis of D1.2, since February 2013 with the major stakeholders, vertical sectors, and expert groups.

2 SUMARIES OF STRATEGIC ICT DOCUMENTS

2.1 Net!Works

2.1.1 Net!Works Strategic Research and Innovation Agenda

Net!Works European Technology platform concerns with technologies for superfast to low information rate connectivity and communications between people, devices, machines, businesses through mobile, wireless and fixed networking media.

Net!Works SRA presented a range of strategic applications and technologies areas for research and innovation in Europe. These areas incorporate grand societal challenges identified in the EU Digital Agenda and believed to be aligned with grand strategy of EC Innovation Union.

This report is based on the previous edition of the Strategic Research Agendas, White Papers and Position Paper [1].

2.1.2 Importance of Connectivity

Information and Communication Technologies (ICT) will continue to be a key driver to the Europe economy as evidenced by the scale of deployment of national infrastructures for the Internet, mobile communications and web services in Europe. ICT is fundamental to connected digital economy beyond just connecting people. It is transformative technology in modernisation and efficiency of other industries such as transportation, health and all utility services. By 2020, globally, more than 7 billion people and in excess of 50 billion “things” will be connected.

The ICT infrastructure is now considered in most countries to be part of the National Critical Infrastructure along with other utility infrastructures such as water, food, transportation, health, government services and energy and electricity as shown in the following figure. In Fully connected digital economy of the future, telecommunication and ICT infrastructure plays important role of transporting and controlling of all the other infrastructures becoming a “Super” critical national infrastructure (Figure 1).

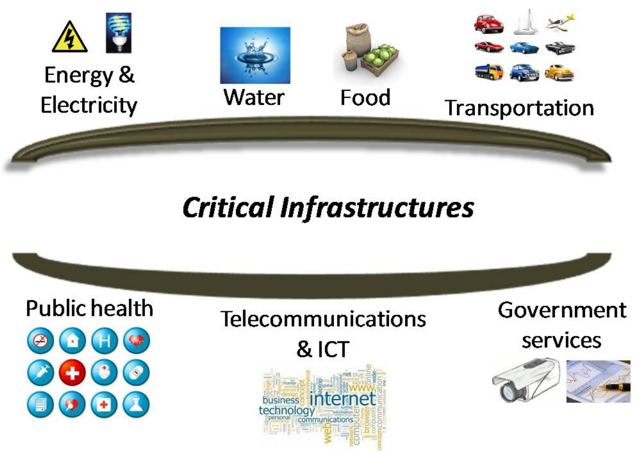

Figure 1: Critical infrastructures as currently identified (EuCo06)

The ICT sector is directly responsible for 10% of Europe’s GDP, with an annual market value of €660 billion and directly accounts for 3% of employment. However, ICT contributes considerably more to GDP by enabling overall productivity growth in other sectors (20% directly from the ICT sector and 30% from ICT investments).

Europe's communications industry has the strength to remain competitive and to establish leadership in a new wave of broadband networking technologies, Internet of Things (IoT) and business innovations. It has the capacity and the know-how to engage in the challenges of transformation and modernisation of other industrial sectors, smart cities and the day to day activities of society in the future connected economy and society.

Figure 2 shows total global connections including machine type communications (M2M) and potential revenue for mobile Network Operator (MNO) are presented in Figure 3.

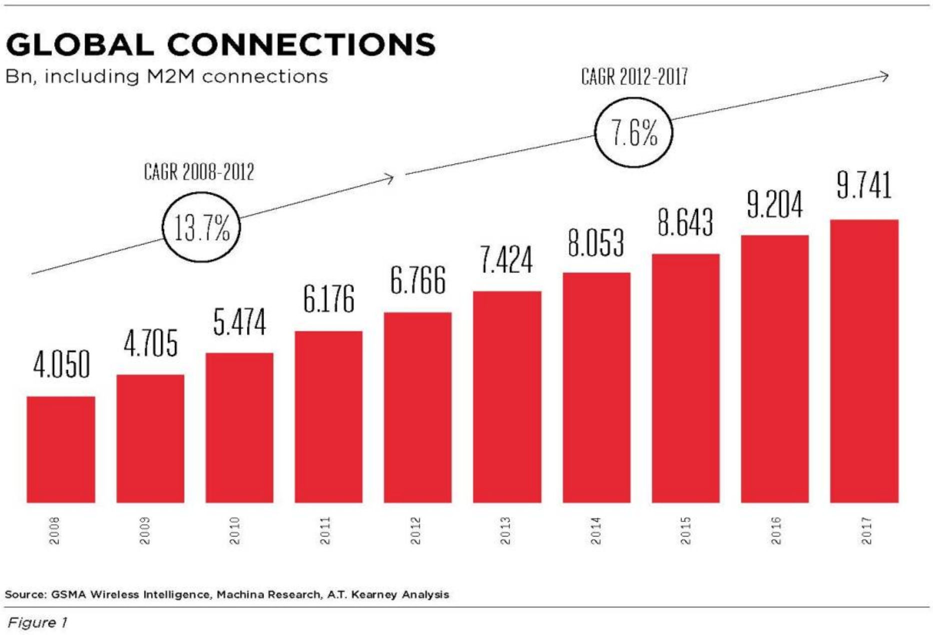

Figure 2: Global connections

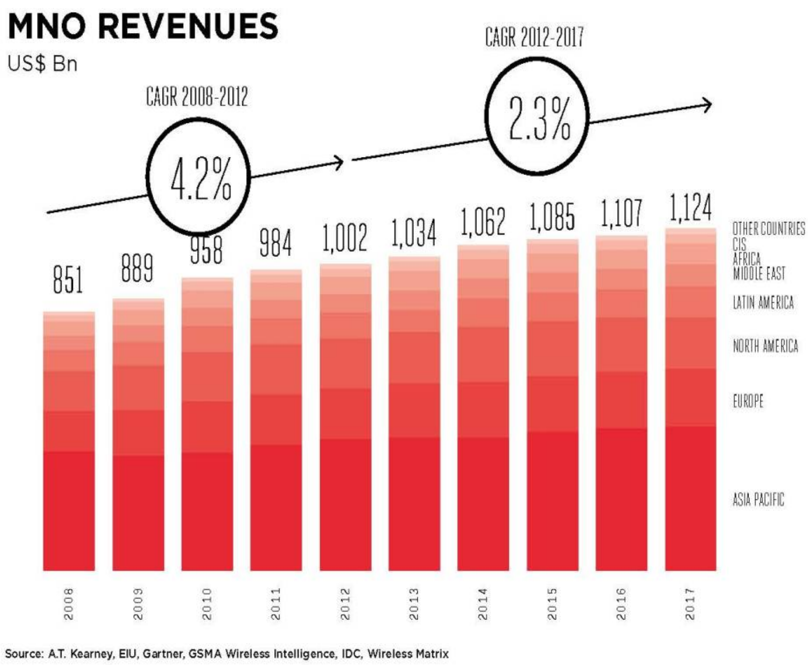

Figure 3: MNO revenues

2.1.3 Trends and Drivers

The number of mobile users and the scale of mobile traffic are increasing at a staggering exponential rate. Cisco predicts that by 2015, global mobile data traffic will increase 26 folds. It will increase by 1000 fold in 2020. These statistics are all relative to the 2010 traffic levels, implying doubling of traffic per year. Moreover, CISCO predicts that, in 2015, every person in the world will have a mobile phone and 2/3 of the world's mobile traffic will be video [2]. In this time scale, one second of video traffic upload on the network will take one person 2 years to watch. Additionally, mobile to mobile traffic is expected to reach 295 Petabytes per month in 2015.

With doubling of traffic annually, the network energy consumption would double annually.

Additionally, in several reports and notably in the EU Digital Agenda [3], emphasis is placed on the role of ICT and its transformational power in the modernisation of other industries. Internet and telecommunications have also been recognised as effective enabling technology in addressing the "Grand Societal Challenges" of climate change, energy shortage, transportation, health and demographic changes. Transporting and controlling of other industries infrastructures bring in new technical, regulatory requirements and in most areas more stringent requirements than Telecommunication and Internet have been designed for. Example of such stringent requirements is utilities service availability/reliability in order of five 9s or higher.

In summary, the telecommunication and Internet infrastructure are gradually becoming "Super" national critical infrastructure paving the way for fully connected digital economy and modernisation of other industries enabling future smart cities, smart services and smart industries. Simultaneously, the mobile traffic demand alone is doubling every year whilst available capacity is only doubling every ten years. Network energy consumption would be increasing linearly to traffic. Ever since second generation cellular standard (GSM) the data rate gap, between that offered in the fixed network and mobile networks, has been increasing from generation to generation. There are new and challenging technical and regulatory requirements from other industries and services. There is emergence of new business models with new players and stakeholder.

Europe ought to have a clear agenda of research and innovation to leverage on this huge opportunity.

2.1.4 Strategic Research and Innovation Areas

The trend and drivers, above, can be mapped into following broad challenges and subsequently several research areas as follow.

I. Spectrum, Capacity and Energy Crunch

II. Tsunami of Data and Internet of Things

III. Emergency Network

The over-arching research, in 2020, across all the above broad challenge areas can be represented with the concept of LE3S.

The **LE3S concept** promotes low **L**atency, **E**nergy efficiency, **S**pectral efficiency, **S**calability and **S**tability.

2.1.4.1 Spectrum, Capacity and Energy Crunch

To have a globally-harmonised approach for specifying and developing mobile broadband Internet networks, ITU-R has established a successful framework by setting minimum requirements for next generation systems. This global effort started with the definition of IMT-2000 systems for 3G standardisation, and recently, 4G systems have been specified, which have to fulfil IMT-Advanced requirements. ITU-R is expected to analyse the demands and requirements for the next generation of broadband wireless systems, in order to guide and harmonise future developments towards 5G.

There are expectations from network operators that new spectrum for mobile services will be allocated at the World Radio Conference (WRC) in 2015. However, it can already be forecast that it will not be sufficient to support the predicted traffic demands for 2020 by some distance. Thus, technologies with increased area spectral efficiency through heterogeneous network deployments with distributed cooperation of devices have to be developed. It is not unconceivable to see yet another new air interface, if significant gains can be obtained by introducing a new access scheme.

- **New Wireless Network Topologies** - The main commonly accepted approach to cope with the spectrum/capacity/energy crunch are denser and denser node deployments and enhanced coordination. However, these require advancements in several other areas to make this feasible both technologically and economically, which are addressed in what follows. Both heterogeneous network topology and network management need to be fundamentally rethought and redesigned for better energy efficiency, dimensioning virtually all quantitative parameters, such as the ratio between large and small cells, form factors, and the number of hops to a node with wire-line and wireless backhaul, in a harmonised and holistic way, and not individually. The backhaul organisation deserves particular attention, especially for cloud computing/processing approaches. Moreover, besides solutions that are theoretically ideal, research should also take practical constraints into account, including constraints to reduce electromagnetic radiation in general.

Switching nodes on and off, depending on the actual traffic, has been the most obvious technique to use, but some critical points need to be addressed in the future. For one, keeping nodes alert while they are asleep (standby) still requires a non-negligible amount of energy. In this context, an entirely passive technology that does not consume any energy at all while being idle would be desirable; this would require a technology leap, as opposed to further fine-tuning of existing ones. A complementary aspect is to switch on nodes before they are actually needed, introducing a proactive element in management, which turn requires statistical insight into the network and user behaviour.

Other priority research areas are:

- **Cooperation between Wireless Network Nodes**
- **Radio Access Resource Sharing**
- **Broadband Radio over Fibre**
- **New Radio Access Architectures** - Current cellular systems are designed with extensive in-band signalling, putting a limit on achievable spectral efficiency. This problem is exacerbated with new trends, e.g., towards smaller and smaller cell topologies, resulting in excessive mobility related signalling. To achieve simultaneously spectral and energy efficiencies, one needs to move away from traditional cellular architectures, and investigate new and alternative architectures where

signalling messages and user data can be supported and optimised for capacity and energy efficiencies irrespective of cell size, which calls for a physical separation between control and data planes. For both on-line spectral and energy efficiencies optimisation in network operation, such new architectures must take users' and cells' active and idle states into account, and manage network resources intelligently and dynamically, whilst maintaining the overall system stability. Physical separation between control and data planes brings about new research challenges, notably synchronisation between these planes.

- **Spectrum Packing between broadcast and mobile communications** - A most prominent component of future mobile traffic increase is expected to be due to video-type services. It makes sense to enhance the existing broadcasting functionality in mobile networks, so that the dense infrastructure of cellular networks can be even better exploited for offering spectrally efficient mass multimedia delivery, thereby also offloading the mobile broadband (unicast) access.

Furthermore, for broadcasting, the introduction of state of the art digital broadcasting technologies, like DVB-T and DVB-T2, enables more dense frequency reuse, thereby leaving less white space between the service areas of a TV channel. With the appropriate dense transmitter network and technology, using, e.g., cellular broadcasting solutions, Single-Frequency-Networks (SFNs) are possible for nation-wide broadcast content; which enables significantly increased "packing" of TV spectrum. This opportunity has been exploited to only a small extent at the ITU Regional Radio Conference Geneva'06 broadcasting frequency re-planning activity. Studies have shown that the secondary use of TV white spaces is possible, however, of limited value for macro cellular networks. Therefore, the prime focus should be on reducing the white space wherever possible, by packing broadcasting channels more densely, so that larger amounts of contiguous spectrum can be re-farmed, and thereby be reused without the burden implied by white space operation. However, many research challenges remain to be addressed mainly towards making mobile broadcasting more efficient, in terms of spectral and energy efficiencies, by using and optimising as much as possible the advanced techniques developed in mobile broadband cellular systems, such as MIMO, diversity and beamforming, thereby reducing the current gaps between mobile broadcasting and mobile broadband. Research should also be focused on the provision of technologies for multicasting at single- and multi-cell levels, and for energy efficiency develop targeted broadcasting technologies, as opposed to current "anytime and anywhere" broadcasting.

The foreseen roadmap concerning wireless broadband for spectrum/capacity/Energy Crunch aspects is presented in Table 1.

Table 1: Technology Roadmap for spectrum/capacity/Energy Crunch

Timeline	In 5 Years	In 10 Years	Beyond 10 Years
Radio	• *data rate*: several 100 Mbps • *bandwidth*: up to 40 MHz • *antennas*: roughly 10 layers spatial multiplexing • *first features of user context*	• *data rate*: up to 1 Gbps • *bandwidth*: at least 100 MHz • *antennas*: tens of cooperative antenna elements • *user context aided RRM*	• *data rate*: multi-Gbps • *bandwidth*: GHz range • *antennas*: hundreds of cooperative antenna elements
Energy	• network architectures are adapted to energy efficiency needs • intelligent switching on/off of resources using current technologies is optimised	• novel transmission schemes and novel form factors for equipment are employed	• technology leaps provide further enhancements
Network	• small cells • cloud RAN • local intra-site CoMP • inter-site cooperation • coverage relays • fast inter-RAT load balancing	• smaller cells • baseband cloud • inter-site CoMP • interlayer coordination • capacity relays • mobile and multi-hop relays • network-controlled device-to-device • inter-system load balancing	• ultra small cells • immersed radio (massive multi antenna) • radio virtualisation • complete inter layer/system CoMP • all photonic RF "leaky RF fibre" • cooperative relays • load balancing with multitude of systems, including full device-to-device

SON	• usage in LTE-A, and in multi-layer and multi-RAT, and SON coordination (light)	• usage in heterogeneous networks, and in E2E, including radio, core, backhaul, and transport • fully coordinated SON at network level (operator domain) • cognitive learning mechanisms for SON improvement • high-level operator goal driven network management using multiple-layer control loops	• CR networks with cognitive learning and reasoning capabilities • automated improvement of management mechanisms • fully high-level operator goal driven E2E network management including all network domains
Spectrum	• opening TV white spaces with advanced cooperative cognitive protocols • geo-location cooperating	• licenses shared by co-operating operators • multi-antenna signal processing • dynamic spectrum access location based • any free portion of spectrum usable • advanced spectrum handover, and spectrum mobility mechanisms regarding inherent QoS.	• dynamic spectrum access • dynamic spectrum management (sensing, sharing, and trading) among operators • cooperative spectrum hole prediction mechanisms in multi-standard stochastic systems • visible light communication
Cognitive Radio	• opportunistic spectrum access in femto-cells	• spectrum usage data bases • cognitive engines for access networks • self-reconfigurable multi standard chips in MIMO systems	• secondary spectrum use supported by sensing • licensed user behaviour prediction in multimedia stochastic networks

The roadmap of developments in the area of networks for wireless-optics communications is presented in Table 2.

Table 2: Technology Roadmap for Networks for the Next Generation of Wireless-Optics Communications

Timeline	In 5 Years	In 10 Years	Beyond 10 Years
Super Broadband	• 1 Gbps • 20 % FTTH	• 10 Gbps • 50% FTTH	• 100 Gbps • 80% FTTH
Physical layer	• photonic A/D and D/A	• 60% of electronic components converted to optical	• 80-90% of electronic components converted to optical
Cognitive RoF Protocol	• transparency • power efficient	• optical cognitive • partial optical handover	• fully optical handover
Energy Consumption	• small percentage of electrical components with optical one • sleep mode implementation	• replacing electrical switches and routers with optical • new power optimisation techniques	• replacement of more electrical devices and components with optical ones
Wireless Optics and new air interface (including femto-cells and home networks)	• new wireless air interface • POF utilisation	• new wireless and optical wireless air interfaces • improvement in POF utilisation	• fully use of POF • integration of wireless and optical wireless

The roadmap of developments in the area of architectures and management of future networks is presented in Table 3.

Table 3: Technology Roadmap for Architectures and Management of Future Networks

Timeline	In 5 Years	In 10 Years	Beyond 10 Years
Software Defined Networks	• Separate resource virtualisation layers operations and optimisation (connectivity, storage, computation, control resources) • Partial network empowerment (i.e., service -, content-,	• Combined approach of CNO with in-network management. • On-demand network provision and operation. • Integrated virtualisation of all resources – operations, optimisation and usage. • Further network empowerment. • Separate in-bound	• SMART software-defined system services of any complexity and any composition • Full network empowerment integrated

	knowledge-, environmental-, energy-, economic-, and social-cognisance).	manageability in all dimensions (embeddiness, automation, autonomicity, extensibility).	in-bound manageability • Combined approach of CNO with in-network management and content centric • Dynamic service aggregation from different providers to create new complex services
Cognitive network operation	• Monitoring for multi-access and multi-path. • Decision in autonomic and near-real optimisation (centralised vs. distributed).	• Monitoring in knowledge management. • Decision in cognitive, self-learning real time optimisation. • Autonomic adjustment based on application requirements.	
Resource sharing across administrative boundaries: modularisation and network virtualisation	• Optimised infrastructure sharing. • Virtualisation of network functionality as well as of computational, communication, and storage resources in order to deliver cost-efficient operation especially in multi-administrative domain environments.	• Modularisation through the separation of functionality into generic self-contained building blocks to support a variety of business models and regional specifics. • Knowledge based virtualisation of network functionalities as well as of computational, communication, and storage resources in order to deliver cost- and energy-efficient operation especially in multi-administrative domain environments.	
Content centric networks	• Content centric optimisation in order to deliver cost- efficient operation especially in multi-administrative	• Cognitive content centric optimisation in order to deliver cost- and energy-efficient operation especially in multi-administrative domain environments	

	domain environments.		

2.1.4.2 Tsunami of Data and IoT

Data continues to be a major area of growth for mobile operators[1]. As Cisco reported in their recent Visual Networking Index (VNI) study [4], the volume of mobile broadband (MBB) traffic has been doubling every year, reaching 1,577 Petabytes per month[2] in 2013 (the equivalent of 500 billion .mp3 files or 800 million hours of streaming HD video[3]) and is forecast to reach 11,156 Petabytes by 2017. The rate of growth is underlined by the fact that total traffic volumes in 2012 were as high as all prior years combined. Furthermore, this growth hasn't been isolated to one area – all regions have been showing impressive growth rates. In absolute terms, however, Asia Pacific is the clear leader and is forecast to account for 47% of traffic by 2017.

Obviously, there is a limit on achievable area capacity using current and future allocation of limited radio spectrum. Management of data in terms of its discovery, storage, distribution and delivery based on a user context is now becoming even more important than ever and goes hand-in-hand with advances in radio access techniques in tacking expected tsunami of data.

Research on the issues of intelligent data handling and delivery based on user preferences, user, device, radio and network contexts offers potential solutions to the challenges.

- There has been many research work worldwide reported on definition and classification of context. However, there is no or little evidence on mechanisms to capture, classify and utilise such information, and how it can be implemented and used in improving a network performance, or in efficient delivery of personalised services. With the increasing deployment of Machine-to-Machine (M2M), and generally Internet of Things (IoT), it is time to start a research on technologies and mechanisms for capturing various context information, whether it is user's, device's, environment's, network's or so on, and demonstrate their utilisation effectiveness in intelligent service/data provisioning, and overall performance improvements in network assets management. Research is required on scalable and efficient networking between IoT nodes, and how such infrastructure-less networks can work with a communication network, Internet and a user device, in a secure, reliable and seamless manner. Another important area of network research is use of context information and their integration technologies for dynamic network resources virtualisation and fast/autonomous network management of resources, service quality and management of self-recovery and healing.
- 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

[1] www.mobileworldlive.com

[2] Equal to 1.6 billion Gigabytes

[3] Assuming .mp3 files are 3 Megabytes each, and an hour of HD video uses 2 Gigabytes of data

dynamicity and growth, trust and related technologies are essential to support such growth of services and traffic.

- The convergence between different National Critical Infrastructures is also a need that requires further research attention.

2.1.4.3 Emergency Network

Current communication architectures are highly vulnerable to major man-made and natural disasters. The man reason for the vulnerability is the fact that all communication networking are network-centric and rely on an infrastructure. In time of such disasters minimum communications is better than no communications. However, instead of developing a separate Public Protection Disaster Relief (PPDR) network, it is essential for public networks have the capabilities to continue their operation even when the infrastructure is destroyed. Discussions about emergency communications usually diverge into discussions about most prominent catastrophes and terrorist attacks, and emergency services personnel (i.e., police, hospitals, fire brigades, etc.). So far, private citizens are not addressed in such situations, which is often a major issue when commercial networks are no longer available due to collapse of the infrastructure (e.g., electricity cuts or broken mobile network). For this, it is important to define an appropriate crisis handling management system for both public and private users. In such situations, private handheld devices can be effectively used to form rapidly an ad-hoc multihop network infrastructure during such incidents, to create connectivity between people, as well as help in improving the coverage of public authorities' network over large geographical areas. Although the target is to provide a system concept for crisis management, as well as critical infrastructure control, the same concepts and solutions may lend themself to other usages and applications. For example, in providing normal communication needs cost effectively to the areas where the basic network infrastructure is non-existent, such as remote locations and areas with low-dense population, and/or in emerging markets where telecom infrastructures do not exist.

This future rapid-deployable network needs to have the capability to support basic communication services (e.g., telephony and narrow band data services), mechanisms to prevent or reduce the impact of disasters (early warning systems), aid in rescue operations, and finally ease the recovery from disasters.

2.1.5 Summary and Recommendations

It is clear that 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. The use of networks to connect machines to the Internet is still in its infancy. Projections suggest that expected rapid growth in the generation of network traffic will be driven by the increasing use of video for communications and the use of networks for M2M communications. New applications are placing new technical demands on the network. Whereas in the past increasing the transmission capacity of the networks was the 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 requirements that future research and innovation must address. Internet and Telecommunication networks will be the control and transport plane of other National Critical Infrastructures, such as: health and tele-care systems, eGovernment, transport systems, energy systems, and environmental monitoring systems. This will make Telecommunication networks National "Super" Critical Infrastructure.

All these matters present many new challenges to the entire business chain in the communications and networking industry.

All the research priorities can be captured in **LE3S concept** that promotes low Latency, Energy efficiency, Spectral efficiency, Scalability and Stability in future network research.

The most important requirement from other National Critical Infrastructures (food, water, transportation, electricity…) is high availability and robustness, much higher than that normally required in communication network designs of usually 99.9% (three 9s). New networking technologies must be developed to ensure high information integrity, network and service **reliability and availability** of more than five 9s, and resilience to potential cyber security threats.

Optical network technologies will need further development, as fibre-optic systems now also start approaching Shannon's limit. New research is needed to increase fibre capacity to more than 100 Tbps in the core, 10 Tbps in the metro, and 1 Tbps in the **access/backhaul** network, 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 optimise end-user experience over a fibre-constrained backhaul-infrastructure. However, as fibre-optic is not universally available, or in consideration of different business models, there is urgency in developing efficient wireless mesh backhaul technologies.

Data and content delivery need further research in order to ensure that they meet the needs of users whilst handle intelligently the expected tsunami of data. 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. Intelligent content delivery requires up to date and relevant context information.

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.

Additionally, it is proposed for Europe to start activity on specification and research into a highly robust, resilient and rapidly deployable emergency network.

2.2 ISI Strategic Research and Innovation Agenda

2.2.1 Aims and Scope

The Integral SatCom Initiative European Technology Platform Strategic Research and Innovation Agenda [5] addresses the overall development of satellite communications in Europe over the next 10 years, highlights how satellite communications can be of strategic relevance for Europe, and identifies medium and long term strategic objectives.

The document is divided into three parts. The first part of the document identifies trends in SatCom architectures and their added value in the context of the relevant European policies (e.g. Digital Agenda, Security and Defence). The second part is focused on the main enablers for emerging SatCom architectures, the related enabling technologies and their impact on the performance, features, and economics in order to highlight how future SatCom can support Digital Agenda objectives. The third part maps the identified enablers and related enabling technologies onto a list of concrete research topics suitable for the next European work programmes and prioritizes them according to the their impact on the European competitiveness development.

2.2.2 European SatCom industry main markets and contribution to the Digital Agenda

The main markets of the European SatCom industry are reported hereunder in decreasing order of generated revenues [6]:

- Direct To Home TV
- Backbone/Backhaul
- Broadband access
- Mobile Satellite Systems
- Governmental systems

The main trends for the next 10 years of the main SatCom market segments are reported in Table 4.

Table 4: Main future SatCom trends

SatCom Market segment	Main trends
Direct To Home TV	HDTV generalisation, nonlinear service, hybrid networks, 3DTV, multi view and UHDTV uptake
Backbone/Backhaul	Flexibility/intelligence
Broadband access	Very high speed broadband, resilience, improved QoE
Mobile Satellite Systems	Mobile Broadband in higher frequency bands especially for professional and governmental services (e.g. Ku or Ka band), security systems in lower bands
Governmental systems	Increased throughput, reinforced security, mobility and dual military and institutional systems

Accordingly, SatCom systems can play a fundamental role in supporting the following Digital Agenda objectives:

- Fast and ultra-fast internet access
- Transportation efficiency and mobility

- Smart Energy grid
- Security
- Climate change
- Digital literacy, skills and inclusion (content)
- Healthcare

2.2.3 Emerging SatCom Architectures

For each market segment, new SatCom architectures will be developed referring to new space segment configuration, new radio interface technologies or even new network integration scenario with terrestrial systems. The main drivers to be considered for the analysis of the SatCom innovation in the future are:

- Performance,
- Quality of Experience (QoE),
- Cost,
- Network integration (satellite with terrestrial systems),
- Flexibility,
- Integration with navigation and observation systems,
- Resilience and Security
- Regulatory frameworks
- In Orbit Validation for innovative space segment technologies/payloads,
- Standards development
- Design of new business model for innovation financing.

2.2.4 Enabling research topics and prioritization

Within the developed context, and with reference to the technical enablers, six main development areas have been identified:

- Space segment,
- Ground infrastructure,
- Radio interface efficiency and robustness,
- Networking integration and convergence,
- Terminals and Services and applications.

Research topics have been prioritized in each specific area. Table 5 reports, for each area, the first four most important topics, in order of decreasing importance. The complete assessment is reported in [7].

Table 5: Prioritisation of specific areas

Research Area	Topic 1	Topic 2	Topic 3	Topic 4
Space Segment High-Throughput, Flexibility and Reconfigurability	Flexibility and Reconfiguration	Capacity and Throughput	Interference and Management	Markets and Resources
Radio Interfaces: Efficiency and Robustness	Interference management techniques	Cognitive radio	Multi beam/feed transmission techniques	Waveform design
Ground Infrastructure: Distributed Processing	Advanced Interference management and cancellation	High capacity feeder links	Distributed radio resource management algorithms	Multigateway architectures
Networking: Integration and Convergence	SatCom Role in Future Internet	Network management harmonization between satellite and terrestrial.	Flexible resource management	Vertical handover techniques between terrestrial and satellite
Terminals: User-Friendliness and Reconfigurability	Fixed Broadband and Broadcast	Collective Mobile Broadband and Broadcast	M2M and SCADA	Consumer and Professional Handheld
Services and applications: Ubiquity and Dependability	Emergency Bidirectional Communications and Backhauling	Ubiquitous Broadband Access	Enhanced Broadcast Experience	Ubiquitous Messaging Services

2.2.5 Summary and conclusions on ISI strategy

ISI vision is to foster the development of innovative SatCom solutions addressing in priority:

- The 2020 goal of all Europeans having access to Internet speeds of above 30 Mbps as set by the European Commission in its European Digital Agenda policy for an Inclusive Growth.
- The improvement of Europe's capacity to prevent and respond to crisis and/or to ensure the security of persons and goods as set by the Europe Commission in its Security and Defence Policy ("There is no development without security and no security without Sustainable Growth", Kofi Annan).
- The Integration of future SatComs providing a flexible and resilient network overlay and/or with cost effective broadcast capabilities to the future Internet for a Smart Growth economy.
- This will enable the development of innovative technologies, products and services up to large-scale pre operational experimentations in the areas of:
- Very high speed broadband access via satellite complementing fibre and wireless networks.

- Reconfigurable, resilient and secured broadband connectivity SatComs to support professional and institutional telecommunication demands (e.g., Private communication networks, Backhaul, Backbone connectivity, public safety)
- Integration/hybridising of future SatComs in the Future Internet to build up smart infrastructures.
- Enhanced broadcast systems, efficiently supporting scalable video quality (3D/HDTV/SDTV), mobility and interactivity.

Satellite Communications belong to both space and ICT enabling and industrial technologies identified in the H2020's industrial leadership part. On one hand, it represents the most important application domain for satellites and on the other hand it is an essential element of any network infrastructure:

- To provide cost effective broadcast and/or data collect capability over wide area.
- To provide connectivity to remote places, vessels or aircrafts.
- To ensure resilience by doubling terrestrial based communications.

Therefore research and innovation activities on SatCom shall be planned under the H2020 part "Leadership in enabling and industrial technologies". SatCom also supports a wide range of applications which contributes to major European societal challenges:

- "Inclusive, innovative and secure societies": SatCom is an essential enabler to fulfill the broadband for all objectives as defined in the Digital Challenges thanks to current (2013 objectives) and future space assets (2020 objectives). It is also an essential element for security missions among which crisis management, transport security, critical infrastructure protection. SatCom integration with other space technologies namely earth observation and navigation, will enable added value services to contribute to a secure society.
- "Health, demographic change and wellbeing": SatCom will help to assist patients under medical treatment in their homes and interconnect hospitals and medical teams in low density populated areas. Moreover, as the need for improving healthcare in rural and low density populated areas intensifies and the importance of bringing the international medical community together in the years ahead grows, SatCom are ideally positioned to facilitate the flow and sharing of medical expertise and information between medical centres.
- "Smart, green and integrated transport": SatCom can be used to alert about events (e.g. accidents, traffic jams, local bad weather conditions) impacting the traffic at regional level and provide guidance to the public and private transport resources, the travellers and decision making tools via fixed or mobile broadcast systems. Satcom can also support asset monitoring anywhere beyond terrestrial reach (low density populated areas, over seas) and hence ensure a permanent status report
- "Secure, clean and efficient energy": SatCom can be used to monitor the power grid and to implement a global and secure energy grid that ensures the energy supply. In particular, it is well suited to optimise the efficiency of the global monitoring and black-out management. Furthermore, telecom satellites can back-up high availability links of the communication and control network in critical parts of the smart energy grids

Within Europe, SatCom research and innovation activities are also supported by European and National Space agencies, however these frameworks differs significantly by the approach:

- The H2020 will help the SatCom industry to establish the eco system for space technologies by undertaking end to end system definition and developments exploiting the technology bricks/segments developed with space agencies support, Trials/Pilots for validation and/or market probing. It is the optimum framework for cooperation with stakeholders from terrestrial ICT networks and for the cross fertilization of ICT technologies from non-space industry.
- European and national space agencies enables the SatCom industry to progress the space technology by carrying out Technical feasibility study on future space segments and providing support to development of space technology and on specific aspects of the related ground segment.

Tentatively a mapping of SatCom research and innovation activities in the institutional framework is summarised in Table 6.

Table 6: SatCom research and innovation mapping

Institutional framework	Possible research and innovation activities
H2020 - Industrial leadership: "ICT"	User and application-centric activities. Advanced system studies, system engineering, software development, hardware development (ground segment), Standardization and regulatory activities, Techno-economical studies, Integration, Trials
H2020 - Industrial leadership: "SPACE"	Space technologies and systems design and development, up to In Orbit Validation. Services validation in relation with the EU flagship programmes.
H2020 - Societal challenges: “Inclusive, innovative and secure societies”	Wide scope of activities while focused on supporting the EU societal challenges: can encompass applied research, processes and methods, social innovation mechanisms, applications and services development, pilot networks.
H2020 - Societal challenges: "Smart, green and integrated transport"	as above
ESA and national space agencies	Technical feasibility study on future space segments, Development of space technology and of specific features of ground segment such as e.g. antennas and RF components

As illustrated above, research, development and innovation activities on SatCom are planned in the Horizon 2020 complementary to activities planned in European and national space agencies frameworks.

Satellite Communication Networks inherently offer three undisputable characteristics:

- All the time: As a dependable solution, SatComs are key elements to ensure a service continuity under natural or manmade disasters.
- Everywhere: Thanks to their ubiquitous coverage, SatCom are the most economical technology to address fixed, portable, nomadic or terminals onboard vessels, trains, cars or aircrafts in low density populated areas for connectivity or broadcast applications.

Based on these key elements, Satellite Communication Networks are expected to provide significant contributions in areas where coverage, resiliency are essential especially for:

- Broadcasting/multicasting of media content in real time or non realtime with caching techniques
- Broadband access: fixed and mobile
- Security missions such as crisis management
- Machine to machine

The SatCom contribution will pertain provided that the industry continue to innovate along the following drivers:

- Firstly, Satellite networks are expected to improve significantly their performances to keep up with the service and economical trends associated set by terrestrial networks
- Secondly, the need for increased resiliency, service continuity drives the SatCom industry to undertake research activities to integrate Satellite component in the global terrestrial networks in a seamless manner so that the end-users benefits from the natural and undisputable SatCom characteristics.
- Thirdly, the evolving regulatory context (towards more flexible spectrum usage) puts additional constraints on the design of future satellite networks.

Based on the prioritization carried presented in the previous section, the research priorities of ISI are organized and grouped among three different lines.

1) Space segment: High-throughput, Flexibility, and Re-configurability

Research efforts aiming at increasing throughput per spacecraft, flexibility in terms of power, bandwidth and frequency allocated to each beam will have to be improved in order to better use the satellite capacity. Dynamic reconfigurability of the coverage area in terms of number and sizes of beams will be another important asset to cover, enabling e.g. to quickly set-up hot-spots over specific regions where high capacity may be needed. This entails the need to pursue the development of reconfigurable antenna systems (passive solutions, as well as active and semi-active with the objective of getting cost competitive offers for the commercial market), allowing small antenna beams and high accuracy pointing, as well as flexible satellite payload RF front-end to efficiently cope with different level of traffic aggregation. Regenerative payloads are an additional step to consider for providing high flexible and reconfigurable satellites systems, suitable for adapting the network for the service scenario needs. The key challenge will be to propose fully in-orbit reconfigurable processors (Software Defined Payloads - SDPs), which would ultimately combine the advantages of fully regenerative payloads with the waveform agnostic flexibility of transparent payloads and with the flexibility/re-configurability of emerging software-defined networks.

2) Ground infrastructure and Radio Interface: Advanced Interference Management

Next generation satellite systems will be based on several hundreds of beams/feeds in order to increase the system efficiency with denser frequency reuse. A key issue in this perspective is the efficient management of interference. Intra and Inter-beam as well as inter-system interference shall be smartly managed in order to achieve unforeseen increase in the spectral efficiency. The research shall be addressed towards applications to multi-beam/multi-feed/multi-gateway satellite systems of advanced concepts like pre-coding techniques, multiuser detection, interference cancellation, and interference alignment and coordination. Generally speaking, new paradigms relying on the idea of exploiting the knowledge of the interference rather than trying to reduce it by bandwidth segregation and/or antenna discrimination shall be investigated. That is, in contrast with traditional interference avoidance schemes (passive treatment of interference), satellite networks shall strive for a proactive treatment of interference. In this course, the latest techniques developed within the terrestrial cellular community on interference management should be investigated in order to maximize synergies between the two realms.

3) Networking: Integration and Convergence

The convergence between fixed and mobile network is progressing rapidly in the world-wide telecommunications network. Satellites are striving to become an important actor in the Future Network Infrastructure due to their unique ability to cover vast regions and sparsely populated areas or areas where terrestrial systems have been destroyed by a recent disaster. A tighter synergy between terrestrial and satellite networks and also among satellite operators would be leveraged through the foundation of network abstraction and virtualisation architectures, which would offer new business opportunities by enabling the real time brokerage and collaborative use of terrestrial and satellite resources and also their integrated management as unified overlays. In this context, novel inter-domain network management paradigms would enable enterprise users and also Virtual Network Providers (network resource brokers) to establish, manage and exploit hybrid terrestrial-satellite virtual network overlays spanning across several satellite and terrestrial operators/physical infrastructures in order to fully meet their customers' needs in terms of geographical coverage and capacity, in cases when the coverage and/or capacity provided directly by a single network operator is either insufficient or uneconomic.

Satellites comprise the following (non-exhaustive list of) primary features which may have a major role in Future Internet: (i) all the time: satellite networks are key to provide service continuity and robustness under disaster cases; (ii) everywhere: especially in rural, low density populated areas, satellites are the most economical access technology and provide the means to access non-traditional networks as SCADA sensor networks and M2M. This induces also the potential of satellites to allow for/or accelerate the high-speed Internet access in developing countries; (iii) native support for wide area broadcast / multicast; (iv) support for inter-planetary communication and deep space networks; and (v) Satellites support security and content reliability on an operational level, since the infrastructure is easy to protect, network management is centralized and under operator control and the access to the network is strictly under control of the network control manager. It is therefore necessary to study the applications and services that are typically susceptible of being used in a satellite network, so that its evolution goes online with the Future Internet guidelines. The development of future satellite systems will not consider only the network aspects as the connection bandwidth required or the necessary traffic engineering, but also higher level factors (such as scalability, security, mobility, etc.) that impose requirements to the lower levels. A promising Future Internet (FI) technological solution that seems pertinent to integration with SatCom networks refers to Information/Content-Centric Networking. It constitutes an alternative to the conventional, IP-based internetworking, with information being identified rather than the host where it resides (which is the case for IP networking). That is, rather than interconnecting pair of end hosts, FI information-centric networks will evolve as a substrate for information dissemination and will be based on named data identifiers instead of end hosts addresses. These identifiers relate to content and/or services. This approach appears to be very promising in the Future Internet. Especially, the Publish-Subscribe Internetworking (PSI) approach seems well suited to SatCom because of the related Broadcast/Multicast nature.

2.3 NEM Strategic Research Agenda

2.3.1 Overview

The NEM Strategic Research Agenda [1] summarizes the challenges and opportunities for the future European research directions in the Networked Electronic Domain in a vision that industry and state authorities might go hand in order to create Digital Europe, resulting in an unprecedented IT penetration within all areas of our society and our daily life.

It describes the main trends whilst it discusses Europe's strengths and determines Europe's diverse cultural heritage as the basis of Europe's knowledge potential. It encompasses a series of precise action lines that may help to catapult Europe to the forefront of IT development. It concludes on innovation partnership as a means to cope with our grand societal challenges.

2.3.2 Where will we go, where are the opportunities from NEM perspectives

2.3.2.1 Connected Society

In the not-so-distant future, everybody and everything will be connected to a network (fixed, mobile, satellite) wherever it is. This new paradigm will open many new opportunities for business, in particular in the NEM sector. For example, "connected things" will be able to provide information that will enrich existing content. People will be able to use any type of device to access any type of content adapted to their situation (at home, on the move, driving a car, in a train, on a plane, etc.), and public live cameras will be accessible by anyone wherever he/she is. Network bandwidth and quality will increase significantly with fiber networks reaching closer to the end user's point of access. 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, 3D videoconferencing, and tele-immersion.

All these network evolutions will help people to share in real time any type of content within their social community, to communicate with remote contacts while feeling as if they are together at the same place.

However, high bandwidth network connectivity will not immediately become available everywhere in Europe due to a number of constraints. The roll-out of fiber networks will be limited by cost factors and LTE/4G coverage cannot be expected to cover all areas of all European countries within the next few years. Consequently, mechanisms able to optimize device connectivity according to the available networks are crucial for a seamless experience from the user's point of view, and unavoidable quality fluctuations need to be minimized.

As the currently growing landscape of application stores continues to evolve, we will see the concept extend towards more online content, applications and service (cloud-based) with pay-as-you-use business models, allowing people to forget about device compatibility, updates, or additional virus protection.

We can summaries this future network paradigm as: *Anything, anytime, anywhere on any device.*

2.3.2.2 Knowledge Society and content availability

An impressive phenomenon of our information society is an ever-increasing amount of new audio-visual content that is available to all. Content is created by professional producers as well as by prosumers or just by Mr. and Ms. Anybody.

High-quality production tools are no longer the preserve of audio-visual (AV) professionals. The advancement in technology is available to all. HDTV cameras are commonplace, the first 3DTV cameras can already be purchased, at affordable prices, by any AV amateur.

However, much content is still only available on a specific display and/or at specific locations. It remains a challenge to turn the request for "anywhere, anytime, any device" into reality. So, content scalability for seamless consumption is still an open issue in order to allow AV access at home, on the move, from the office, in the car, while abroad, etc.

As technical quality is potentially not an issue anymore (today, there is a proliferation of technically high-quality content) the perceived quality of the content comes through its intrinsic value. To distinguish valuable content from junk content is still up to personal judgment, and whether technology may be able to help in this assessment remains to be seen. Whether information in the content is actually true or false is independent of the technical production process, and cannot be related to whether the content has been created by multimedia professionals or as UGC. The research challenge is to assist citizens in finding and selecting truthful and secured content when they wish to do so and preserving their ownership rights; quality content should be available to all, the younger and the elderly, for people with and without special needs.

A policy of all, embracing Digital Inclusion is essential in order to overcome the digital divide and to turn Europe into the most advanced IT area world-wide – for everybody. This is one of our grand societal challenges.

2.3.2.3 User interfaces and immersive experiences

Recent years have seen a plethora of intuitive user interfaces, on various platforms, such as smart mobiles, touchpads and game consoles. The 3D TV is catching up and IPTV is coming to our living rooms. In the near future, we will see a proliferation of 3D, immersive and beyond-HD experiences, with interfaces becoming even more intuitive, including speech, tactile and multisensory interactions.

This shift in the market opens up many new opportunities for business, particularly in the NEM sector. For example, connected TV is becoming a rich open platform, where web style applications are projected to bring another wave of economic growth in the NEM industries. Connected TVs as an open platform will deliver a multitude of new applications and services to the home, particularly for the young as well as for the aging population of Europe and globally.

The 3D and immersive experiences of this future are rich with intuitive interactions and will create new business services such as tele-immersion and tele-medicine, as well as for more traditional entertainment applications. Adding geo-location will enable Augmented Reality applications to become more broadly accepted and used, for example in tourism and cultural sectors.

Intuitive interaction and ease of use is paramount in this future. The younger generations are expecting the same ease of use on their TVs as in their mobiles and touchpads. Multi-touch screens, audio/speech interfaces and more futuristic brain/machine interfaces will create a more direct dialogue between users and the machine, and increase the acceptance of new NEM related services.

In this future, building rich engaging experiences is the key to economic growth. For example, the ability to create shared experiences, on multiple screens at home and on the move, enriched by location-based data to build context, will allow the current content sharing paradigm to achieve its true potential of delivering rich experiences through the networked electronic media of the future. Furthermore, People are more and more interested to share their content not only by posting content on the web but also by discussing it within various communities. Therefore, integration of interpersonal communication and content should be a must.

All these advances will blend the real with the virtual, and unlock the full potential of immersive shared experiences and services with direct application to addressing some of the grand societal challenges of Europe, including the domains of transport and health. Research in immersive technologies as well as in solutions beyond 3D and HD – areas in which Europe has a strong R&D drive – is crucial.

Equally crucial is to increase the speed with which this high-quality European research is taken to the market. We can summarize this User Interfaces and Immersion paradigm through:

Content is king – rich, connected, immersive, intuitive experiences are the future.

2.3.2.4 User and usage data

The success of the Internet is mostly due to its simplicity and its ability to unify. This has been the case with the IP protocol suite at the infrastructure level, and then with the Web at the content level. With fibre to the home and 4G cellular networks, the next challenge is to make it easy for Internet users to access the massive quantity and diversity of information available on the Internet with the best possible quality. The success of this Internet of services will reside in our European ability to design and deploy a converged service means 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 use-centric. It will enhance the users' experience, preserve their privacy, and offer high-quality services that improve life. The development of new business models and opportunities for all actors in the electronic media and content industry relies on our ability to work together to design and exploit the converged service platform. Content here is defined broadly, and encompasses power, entertainment, transportation, personal data, and sensors. We are in a closed-loop situation where network providers need customers to acquire premium content to grow their network, content creators need to bring personalized content to the customers, and customers are demanding an easy way to discover and access quality content and services. Furthermore, the amount of content increases significantly and there is a need to find solution that help people to retrieve consistent information from large data bases – big data search issue.

Content creators and network providers are at the heart of the challenge. There is a need to give Internet users access to a large variety of high-end personalized services and content that will be easy to discover and deliver. This will result in a faster adoption of on demand content, online games, social networks, catch-up TV and other services such as home automation and wellness (health, power).

In order to facilitate universal adoption of online digital services based on the benefit of Future Internet capabilities, it is mandatory that those emerging services and their associated content are provided securely and in a trustworthy way between all the users who act as content providers and content consumers. To reach this objective, the Future Internet infrastructure components must be secured against intrusion, hacks and misuse. 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. This additional information will enable consumers to use any device or application to browse, search, and purchase content from globally distributed collections of content catalogues. 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.

To boost Europe's potential for large deployment of online vital services and content, one can imagine the benefit of having access for users to shared applications for creation and distribution of new innovative services and content. These possibilities will be offered by application services located in the Cloud. The virtualization of resources will strongly impact the capabilities of users to build new innovative offers based on a lower entry ticket because of high utilization and secure sharing of physical resources. Edge devices (like gateways or set-top boxes at home) will play a key role for enabling virtualization implementation because they will offer the link to services and data accessible on the Cloud.

2.3.3 What are the Societal Challenges from NEM view perspective?

The global evolution of people's perceptions regarding networked electronic media technologies (devices, services,…) leads us to a vision of future media:

- More immersive: 3D, holographics for entertainment content as well as video-conferencing and games should take advantage of these new technologies.
- More personalized: people having access to more and more information and access to the right information at the right moment, need more generalized context awareness and information profiling. In addition, information is becoming obsolete very quickly, so there is also a need to propose information rating services.
- More collaborative: people are used to communicate and share content through social networking and to work more and more in a collaborative way. This implies that a combination of content sharing and interpersonal communication services becomes necessary.
- Anything, anytime, anywhere on any device: People use several types of devices depending on location and personal context. There is a need to be able to provide any service on any type of device, whatever the connectivity.
- All these services should obviously be in line with people's behavior :
    - People are attracted by new technologies which answer a need (e.g. iPhone, DVB-T, …)
    - People are becoming Green and will use services which lower energy consumption
    - Elderly people are TV centric in the same way as young people are smartphone centric
    - Wireless technologies are accepted best from a usage point of view but are badly accepted from a health point of view.
    - Future high bandwidth connectivity (FTTH and LTE) will boost NEM applications and will be widely used in Europe

- o Digital Home complexity will need high level Customer Relation Management in order to help people to configure their home network
- o Privacy is a key factor that need to be addressed from a technical point of view as well as from a regulation point of view

2.3.4 What are the links to Grand Societal Challenges from NEM perspectives?

Our European society will face some huge societal challenges in the near future and obviously NEM should help in these fields. NEM is user centric and should take into account the Grand Societal Challenges mainly in:

- Global warming: Due to air pollution (industry, cars, home heating, …) and increasing levels of atmospheric CO2 causing an increase in overall global temperatures, which will have a major impact on our future life (storms, rising sea levels, increasing desertification, …)
- Tightening supplies of energy: Fossil energy will be less and less available; there is a need to find some new resources, but also a need to save energy.
- Water and food: Due to the enlargement of the world population, it is and it will be more and more difficult to have sufficient food and water for everybody.
- Ageing societies: Owing to medical advances, people are living longer and there will be need to help people to stay at home.
- Public health, Pandemics: It is in our basic instinct to live longer and longer, medicine is making great progress but there are always new viruses arising that need great efforts in research but also in public
- Infrastructures which are more expensive and difficult to fund.
- Security: Citizens expect that their environment, which now includes communication and internet as well as their physical safety, will be secure and well protected. This is especially important now that the opportunity for cybercrime as well as physical crime exists.

The Main interest for NEM is Smart culture and knowledge and content: European culture is very rich and European people are so creative that we will be soon overwhelmed by information and archives. With search engines becoming more and more powerful, there will be a need to assist people with content management including helping people to "clean" their information wherever it is stored.

As influential technology platform in networked and electronic media, NEM forms a crucial part of the ICT’s hyper-sector and represents an important critical mass for European research in this field. Consequently, NEM should also contribute to:

- Global warming through new immersive communication applications to avoid travelling
- Ageing society through new multimedia applications helping elderly people to stay at home and to keep in contact with their relatives

How can we ensure content/information availability and the meeting of responsibilities/obligations of companies (public services)?

- In our future society, most interactions with public services will be done through the Internet

- Public content will increasingly comprise of multimedia and should be accessible in any situation
- People should be able to join any public service using synchronous and asynchronous communication services instead of queuing
- Information rating: information still stays on the net even if it is obsolete
- Language translation: one content, many local publications
- NEM can provide solutions to Net-neutrality (access to content for all), to education (mainly eLearning and serious gaming), to health including helping elderly people to remain integrated within the Society, e-Government including open data which will represent a large business opportunity in the future.

3 SUMMARY OF NET!WORKS, ISI, AND NEM DISCUSSIONS

3.1 Net!Works Expert Group and Vertical Sectors discussion

3.1.1 Public Private Partnership programme on 5th generation of mobile communications in Horizon 2020

Extensive consultation carried out with the Expert Advisory Group of the Net!Works European Technology platform results in the " Internet on the Move Research and Innovation Agenda" report (see Annex I). The aim of this report is to assist with the eminent launch of an EU-wide Public Private Partnership programme on 5th generation of mobile communications in Horizon 2020.

The rationale for such a PPP programme is to share investment in research/innovation, mass mobilisation and focus of efforts, stimulation of innovation in Europe and early commercialisation of 5G technologies by Europe industry.

The programme is in line with the implementation of EC Policy on “Innovation Union” with ambition of developing ICT-based solutions to the grand societal challenges including broadband communications to stimulate EU economy as identified in the EU “Digital Agenda”.

In mid-80’s Europe made an epic impact on mobile communication industry and market with GSM under “Phone on the Move”. Now Europe has opportunity to regain leadership, after 10 years of intense competition with other continents, and repeat the success of GSM with this PPP on 5G under banner of “Internet on the Move”.

To create an impactful programme, it is imperative to approach the 5G in a holistic way of joint exploitation between Information Technology (IT), Communication Technology (CT) and Key Enabling Technologies (KETs) [9] strategy as defined in H2020 EC Communications [10]. To further distinguish Europe’s approach to 5G, from the rest of the world, is to research and innovate for an end-to-end system, as was the case in GSM.

It is clear that 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. The use of networks to connect machines to the Internet is still in its infancy. Projections suggest that expected rapid growth in the generation of network traffic will be driven by the increasing use of video for communications and the use of networks for M2M communications. New applications are placing new technical demands on the network. Whereas in the past increasing the transmission capacity of the networks was the focus of research, new applications mean that reducing the latency of networks, increasing their energy efficiency, improving utilisation of spectrum (Area Capacity), and the scalability and stability of networks, are the requirements that future research and innovation must address. Internet and Telecommunication networks will be the control and transport plane of other National Critical Infrastructures, such as: health and tele-care systems, eGovernment, transport systems, energy systems, and environmental monitoring systems. This will make Telecommunication networks National “Super” Critical Infrastructures.

All these matters present many new challenges to the entire business chain in the IT, communications and networking industry. The time scales between mobile standards is getting shorter and it is mainly driven by market demand for "Internet On The Move". If the projections and trends are correct, market may need 5G before 2020 and the system should satisfy the envisaged market demand for at least until 2030.

The following recommendations are provided for 5G development

1. 5G should be designed for market requirements of at least 2030
2. Holistic approach to development of technologies for 5G with close cooperation between IT, CT, HT (Hardware Technologies).5GPPP should cover TRL range up to 7
3. Research into a new air-interface and wireless backhaul and exploration of new frequency bands as in millimetric bands of 60-100GHz.
4. Research into several order of magnitude increase, compared with 4G LTE-A, in area spectral efficiency, energy efficiency and power efficiency
5. Research into Big Data exploitation as an important source of intelligence
6. Incorporation of intelligence for context, spectrum, content delivery network, self-management and optimisation
7. Research into uniform SDN concept covering both radio access and fixed network architecture and micro-servers
8. Develop hardware technologies based on European technologies, with extensive use of SOI technology for development of small form factor RF front-end
9. Develop interoperable solutions based on virtualization through distributed communication and computation in an efficient and holistic way
10. Research into RF solutions for ultra-low power consumption, tuneability and integration
11. Set up a group in 5GPPP to specify new requirements and target metrics for 5G and actively input results of 5G PPP to 3GPPP and ITU-R

3.2 ISI Expert Group and Vertical Sectors discussion

The feedback received from the consultations with expert groups and vertical sectors for the ISI Strategic Research Agenda have been mainly focused on two aspects: the role of satcom in the Future 5G network, and the role of SatCom in the Space Research workprogramme. In the following, the ISI Steering Council position with respect to these two main areas are reported.

3.2.1 SatCom in the Future 5G network

The future common 5G network infrastructure has to be designed to accommodate a growing video traffic which is expected to represent more than 90% of the total traffic and to serve an increased number of mobile and fixed devices also for the Internet Of Things market. The network architecture shall optimise spectrum, energy, and cost efficiency while providing a large range of services including high speed broadband at high service availability. The future common network infrastructure will be based on transport, routing, storage, and computing resources for maximum flexibility towards traffic and service provisioning requirements.

The dependence of the future society on the availability of the telecommunications network will be so dramatic that the first priority of the future networks shall be to ensure Connectivity everywhere and for all European citizens. Furthermore, in case of prolonged failure due to natural disasters or other man-made crisis situations, the effects of lack of connectivity will be nearly as dramatic as the disaster itself. For this reason, the 5G network architecture must include multiple layers, diversified and integrated technologies (wireless, wireline, and satellite) to satisfy resiliency requirements, in order to be able to maintain continuous service provision.

To achieve the above objectives, the network will have to exploit the added value of a wide range of technologies and systems, including satellite communications (SatComs), and this will lead to a disruptive architecture as a key enabler to a “smart” network infrastructure. The 5G architecture design will advantageously leverage satellite network’s inherent cost effective and reliable service delivery over national-, continental or even global coverage. In particular, ISI strongly believes that SatComs are fundamental and well suited to serve the 5G network development and operations through the following functionalities:

- Dimensioning optimization of terrestrial network transport resources up to edge access points by Traffic offload to “one to many” (broadcast/multicast) resources: Content Delivery Networks, Information Centric Networks to convey especially high definition and popular multimedia content
- Extension of the service coverage to un-served or poorly served areas as well as to passengers in trains, aircrafts, vessels with Backhaul service to local 5G wireless/mobile network
- Sustainable throughput at high service availability in under served areas with access combining satellite with wireline and/or wireless technologies
- Wide area data collect service provisioning especially to monitor and control critical infrastructures (e.g. 5G network, Smart Grids, transport, etc.)
- Public safety communications provisioning via combination with wireless technologies

Satellite communication systems, as an enabling building block of the future 5G network, shall be therefore addressed in :

- Network infrastructure architecture options between different scenarios and their respective impact on the spectrum, energy and cost efficiency as well as resiliency in the support of the roles identified above;
- Demonstration of system concepts, network technologies and service architectures to support the requirements (e.g. performance, flexibility including impact associated to software defined network, virtualization, self organization concepts) of SatComs serving the 5G network.

3.2.2 SatCom in the Space Programs

Satellite Communications are also a fundamental element for Space activities which are horizontal enablers for many services and products of everyday life, e.g., weather forecast, earth observation, communications, disaster prediction and recovery, etc.. Therefore, there is a strong need to ensure that Satellite Communications research and development are integrated and harmonized in the larger framework of Space research Activities. In this direction, discussion with SatCom Exper groups and interested sectors, e.g., European Space Agency, highlight the following fundamental elements to be addressed within the H2020 Space workprogramme:

- the creation of a specific *SatCom Strategic Research Cluster* aimed at preventing the risk of dilution and absence of vision within the *Future technologies* theme;
- the development of topics not addressed in European Space Agency ARTES or National Space Agencies framework such as, but not limited to,
    - terrestrial technology spin-in,
    - disruptive technologies,
    - non dependance and critical technologies (FP7 Space follow-up)
    - Technologies for Safety/Security applications
- the need of addressing those topics, already covered by the European Space Agency ARTES program but relevant for those EU Member States that have not subscribed the ESA ARTES program and that, as such, might suffer of a lack of competitiveness;
- the creation of a focused *SatCom Strategic Research Cluster* addressing the *Digital Agenda and Security Societal challenges* as well as the overall SatCom industry competitiveness, covering
    - multimedia services,
    - broadband access,
    - safety communications,
    - aeronautical communications,
    - data gathering.

In the above described perspective, the following research topics have been identified by the SatCom expert group and approved by the ISI Steering Council:

- Payload
    - Photonics technology for space;
    - Optical feeders;

  - Large Ka-band antenna system (with dish larger than 5m);
  - Tx/Rx active antenna technology building blocks;
  - Technologies to support flexible requirements of SatCom integrated in future networks (see also section 3.2.1);
  - Standardisation of payload architectures, e.g., generic and hosted payloads
- End-to-end
  - Automated mission management, i.e., optimization, reconfiguration;
  - Scalable Service oriented architectures;
  - Service enablers for integrated Satcom, Earth Observation and GNSS systems;
  - Engineering tools fro design and assessments, e.g. simulation tools, emulators, etc.;
  - Technical enablers to increase the security of future Satellite Communications networks;
  - Energy efficiency ground segment technologies for sustainable development;
- Enablers
  - Non dependence and critical technology development for SatCom satellites;
  - Innovative governance model for hosted payload, i.e., coordination action;
  - Innovating financing schemes for European SatCom infrastructures;
  - Innovative industrial process.

3.3 NEM Expert Group and Vertical Sectors discussion

NEM took the opportunity of this period to tackle further two subjects of interest for the NEM community : the open data topic and the creative industry sector, identified as two vertical sectors to look at more specifically. NEM organized to this end two dedicated workshops: one on open data May 10, 2013 during the Future Internet assembly in Dublin and one on creative industry May 30 in Brussels.

3.3.1 NEM and open data

NEM took the opportunity of the Future Internet Assembly (FIA) in Dublin May 8th -10th , 2013 to submit a workshop proposal dedicated to open data, which what accepted by the FIA organization. In fact, Future Internet offers the ground for accessing new content in a way that third parties exploitation and utilization can offer new innovative services. Open data belongs to this new content category and it is rather important to better know the borders, the access mode, the business models, the challenges in front of us.

This session organized May 10th 2013 had the objective to offer answers in questions arising for these Open Data tasks and at the same time to share a common vision on Open data. Questions were around:

- What is the definition of Open data ?
- Who are their providers ?
- Which are their access APIs ?
- Which are the key issues for their utilization ?
- Which are the most suitable business models ?

The audience (around 25 people) concerned:

- Researchers and developers from industry and academia engaged in Future Internet programs and projects, e.g. FI PPP program, FP7 Media projects, etc.
- Innovation leaders and entrepreneurs interested to know more about Open data and the usage
- Open data providers and stakeholders such as cities, ministers, local government and relevant authorities.

This workshop was the opportunity to set up the open data scene and get views from recognized experts, feedback from an experimentation conducted at Santanders (Spain), and different views trhough a round table and exchanges with the workshop attendees:

- Jean-Dominique Meunier, NEM Chairman, presented the NEM European Technology Platform dedicated to Media & Content. He outlined that Open Data subject is new to NEM community and most probably source of lot of opportunities. He was thanking the European Commission for allowing NEM to tackle this subject in a FIA workshop and to address several questions : is it linked to big data ? is it metadata ? How to have access to them /How to use them ? What is the EC position ? What' about standardization ? What are the experimental test feedback How Citizen are appropriating them ?

- Prof. Stefan Decker from Digital Entreprise Research Instituted, National University of Ireland Galway , pointed out that many open data initiatives are now existing in Europe : ie Apps4Fingal for creating apps which provide info particular at cities and at local level; also transport and travel info has exploited open data. There is open data movement in various fields : Archives / Europeanna/Libraries are now starting to publish their content in an open data format. Sciences also provide open access and open data (biology, climate change, open EI, etc). A network of knowledge is developed with RDF/Vocabularies - Examples given from Wikipedia/gov.ie to prove information aggregation, from Data catalog vocabulary emerging and SPARQL He concluded that a Network of Knowledge is more than just data, it It is people, communities…, And then it assists humans, organisations and systems with problem solving, enabling innovation and increased productivity
- James Clarke, from Waterford Institute of Technology – TSSG, Steering Board member of NEM made a presentation on open data challenges including those in related to trust and security. Privacy-by-design and privacy-by-default and security and trustworthiness issues were raised , where applicable in open data (secure protocols, cyber forensics, crypto, ..). The need to ensure that the Open Data Directive is in sync with the Data Protection Directive was emphasized. Trustworthiness and a compilation of related open data projects and initiatives were highlighted, summarized and discussed.
- D. Iñigo de la Serna Hernáiz, Santander City Mayor from, Spain, presented SmartSantander project and its services along with its social innovation and new business models priorities. Smart Santander aims at providing a European experimental test facility for research and experimentation on architectures, key enabling technologies, services and applications (i.e., augmented reality, participatory sensing),for the Internet of Things (IoT) in the context of the smart city. 20,000 IoT devices were installed.
- The panel discussion allow the attendees to rise some specific issues such as how to control access to data (and recommend not to deliver raw material), how to encourage generic applications (and encourage going to standardization), how to balance close or open approach (and what are the corresponding added value and markets). Tools availability such as the one that FIRE projects can offer (in delivering open data) is key in the experimentation to conduct and as support for standardization.

The output of this workshop on Open data is clearly an opportunity for the NEM community to issue a position paper identifying the research trends and activities that would deserve attention in the future EU policy and research program(s). There is a need to ensure that Open Data Directive is in sync with Data Protection Directive. Key messages can be highlighted so far:

- Network of Knowledge is more than just data
- Stimulating Social Innovation through the Open Data Paradigm
- Privacy-by-design, privacy-by-default, security are key issues to tackle
- Open Data business model(s) remain to be invented
- Let's try to avoid over-regulation in the open data. Otherwise we would be killing the paradigm before making it a reality.

3.3.2 NEM and creative industries

NEM organized May 30 in Brussels a dedicated workshop on Creative Industry with the support of European Commission DG Connect Unit G1 (Converging media and content) and Unit G2 (creativity).

It was an opportunity for all the participants to present their community or organization, and the business and technology challenges they are facing. Participants were from the following organizations :

- CAP DIGITAL, www.capdigital.com,
- Cluster Audiovisual, www.madridnetwork.org,
- Images & Réseaux, www.images-et-reseaux.com,
- Imaginove, www.imaginove.fr,
- IMINDS, www.iminds.be/en,
- EGDF, www.egdf.eu,
- Ficam, www.ficam.fr,
- BBC, www.bbc.co.uk ,
- DIGINEXT (French), www.diginext.fr
- Italdesign Giugiaro (Italian), www.italdesign.it/home-eng
- Orange, www.francetelecom.fr ,
- Rovio, www.rovio.com ,
- NEM www.nem-initiative.org ,
- European Commission, DG Connect, Unit G2 (creativity),
- European Commission, DG Connect, Unit G1 (Converging media and content),

This workshop will be followed by a second workshop planned July 3rd in Paris, the target being to discuss more in detail how to contribute to the H2020 program (business challenges, technical challenges and priorities, specific issues to address) and what kind of efficient governance to put in place to translate the concept of being a cluster of clusters for the benefit of all those content communities including creative industries.

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[9] http://ec.europa.eu/enterprise/sectors/ict/key_technologies/index_en.htm
[10] COM(2012) 341- A European Strategy for Key Enabling Technologies-A Bridge to Growth and Jobs

A.1 Annex 1 - Internet on the Move Research and Innovation Agenda

A.1.1 Introduction

This section is the results of extensive consultation carried out with Expert Advisory Group of Net!Works European Technology platform. The Technology platform is supporting industry and academia with strategic research and innovation on connectivity and communication technologies for superfast to low information rates between people, devices, machines, businesses through mobile, wireless and fixed networking media in realising digital market, improve citizen's quality of life and modernisation of other industries which are considered as national critical infrastructures.

The aim of the report is to assist with the eminent launch of an EU-wide Public Private Partnership programme on 5th generation of mobile communications in Horizon 2020.

The rationale for such a PPP programme is to share investment in research/innovation, mass mobilisation and focus of efforts, stimulation of innovation in Europe and early commercialisation of 5G technologies by Europe industry.

The programme is in line with the implementation of EC Policy on "Innovation Union" with ambition of developing ICT-based solutions to the grand societal challenges including broadband communications to stimulate EU economy as identified in the EU "Digital Agenda".

In mid-80's Europe made an epic impact on mobile communication industry and market with GSM under "Phone on the Move". Now Europe has opportunity to regain leadership, after 10 years of intense competition with other continents, and repeat the success of GSM with this PPP on 5G under banner of "Internet on the Move".

To create an impactful programme, it is imperative to approach the 5G in a holistic way of joint exploitation between Information Technology (IT), Communication Technology (CT) and Key Enabling Technologies (KETs) [4] strategy as defined in H2020 EC Communications[5]. To further distinguish Europe's approach to 5G, from the rest of the world, is to research and innovate for an end-to-end system, as was the case in GSM.

It is also important, from the start, that the protocols be designed in a way that the network operation does not fully depend on an infrastructure, thereby providing a highly resilient and reliable communication infrastructure that would continue on providing service in cases of possible disasters or system malfunctions.

The 5G system deployment target date should be set for before 2020 and the system should be aimed at serving the fast growing demand for "Internet on the Move" for at least until 2030.

A.1.2 Vision 2030

A.1.2.1 Connectivity is the Oxygen of Digital Economy

[4] http://ec.europa.eu/enterprise/sectors/ict/key_technologies/index_en.htm

[5] COM(2012) 341- A European Strategy for Key Enabling Technologies-A Bridge to Growth and Jobs

Information and Communication Technologies (ICT) will continue to be a key driver to the Europe economy as evidenced by the scale of deployment of national infrastructures for the Internet, mobile communications and web services. ICT is fundamental to connected digital economy beyond just connecting people in a "Hyper Connected World". Its transformative power in modernisation and efficiency of cities and other industries such as transportation, health and all utility services as acknowledged in EU "Digital Agenda".

Currently the ICT sector is directly responsible for 10% of Europe's GDP, with an annual market value of €660 billion and directly accounts for 3% of employment. However, ICT contributes considerably more to GDP by enabling overall productivity growth in other sectors (20% directly from the ICT sector and 30% from ICT investments).

The following figures show total global connections including machine type communications (M2M) and potential revenue for Mobile Network Operator (MNO).

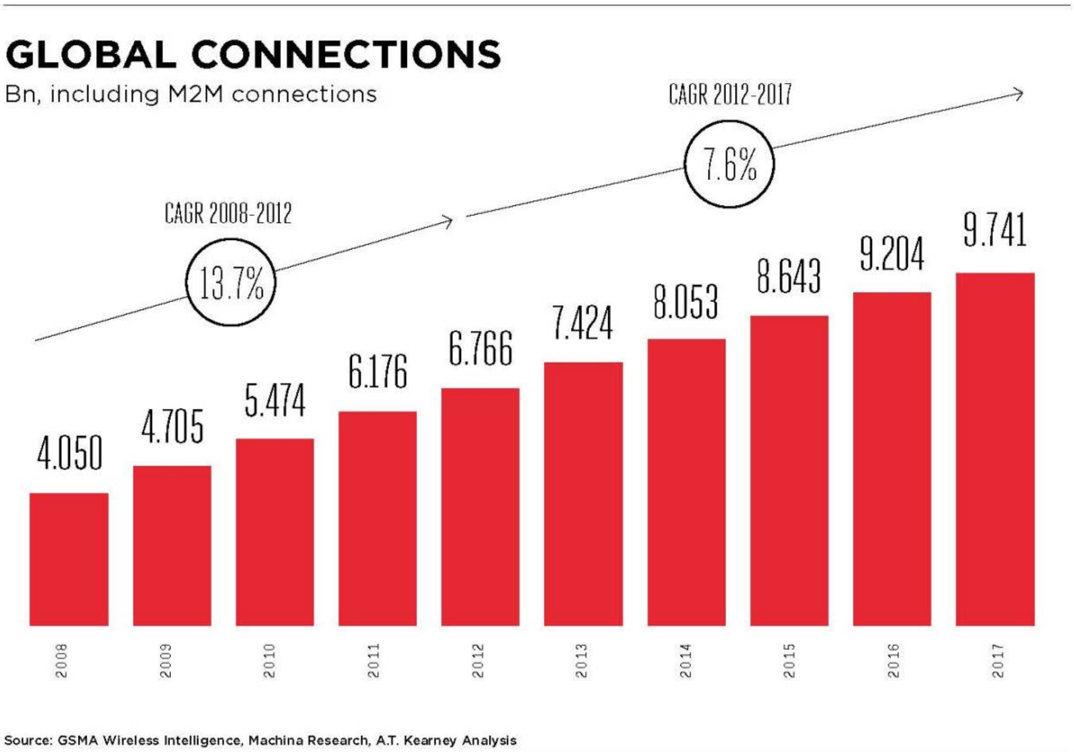
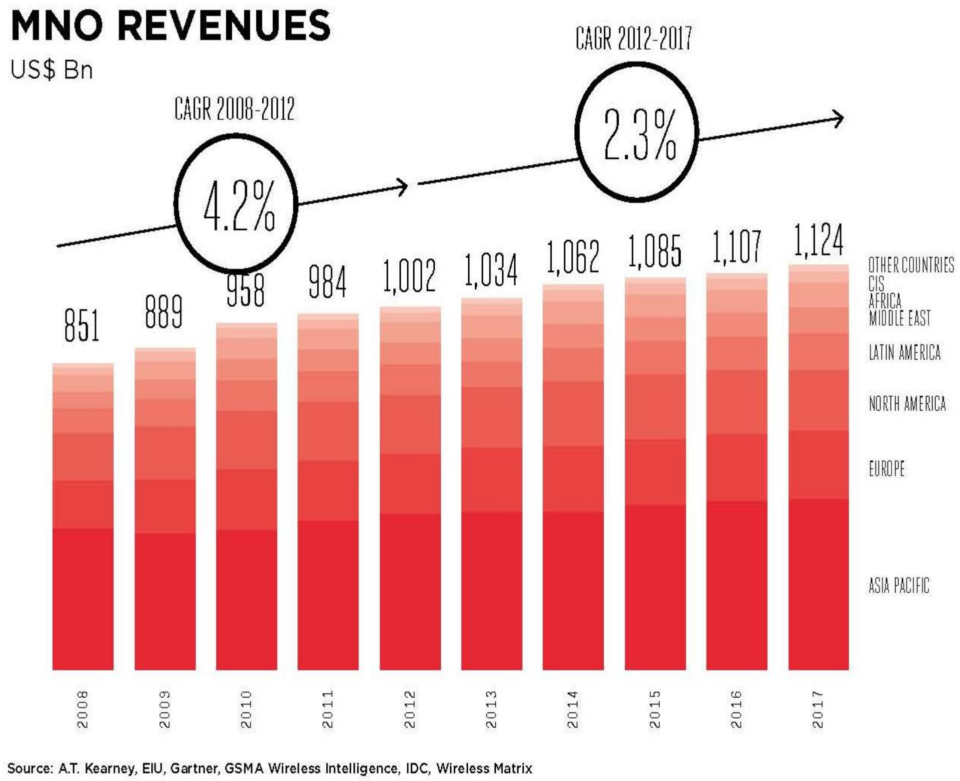


Figure 1



By 2020, globally, more than 7bn people and in excess of 50bn "things" and by 2030 all mobile devices will be internet capable with more than 500bn "things" connected to the Internet.

The number of mobile users and the scale of mobile traffic are increasing at a staggering exponential rate. Cisco predicts that by 2015, global mobile data traffic will increase 26 folds. It will increase by 1000 fold in 2020. These statistics are all relative to the 2010 traffic levels, implying doubling of traffic per year. Moreover, CISCO predicts that, in 2015, virtually every person in the world will have a mobile phone and 2/3 of the world's mobile traffic will be video[6]. In this time scale, one second of video traffic upload on the network will take one person 2 years to watch. Additionally, mobile-to-mobile traffic is expected to reach 295 Petabytes per month in 2015. If the trend holds same pace, the mobile data traffic will be 1,000,000 times that in 2010.

With doubling of traffic annually, the network energy consumption would double annually if no other measure is taken.

On the other hand, Internet and telecommunications have also been recognised by EU Digital Agenda[7], as effective enabling technology in addressing the "Grand Societal Challenges" of climate change, energy shortage, transportation, health and demographic changes. Transporting and controlling of other industries infrastructures bring in new technical, regulatory requirements and in most areas more stringent requirements than Telecommunication and Internet have been designed for. Example of such stringent

[6] Cisco Visual Networking Index (VNI) Global Mobile Data Traffic Forecast for 2012 to 2017. Cisco, 2013

[7] http://ec.europa.eu/information_society/digital-agenda/documents/digital-agenda-communication-en.pdf

requirements in utilities service availability/reliability in order of five 9s or higher and should be considered as one of the important targets for 5G.

A.1.2.2 When should 5G research and standardisations start?

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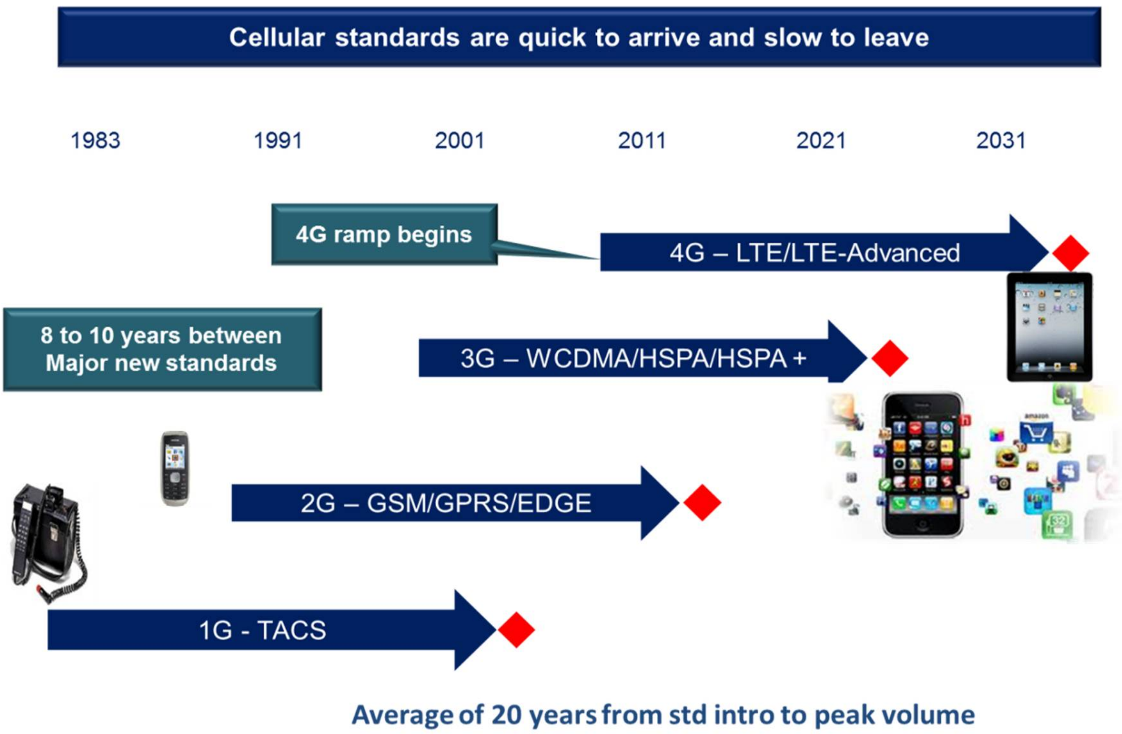
The mobile communications is one of the fastest growing industry in the world. Its success is based on the fact that it is a global standard that enables economy of scales, interoperability and adoption. There is a trend between research, standardisation and deployment of different generations of mobile cellular systems.

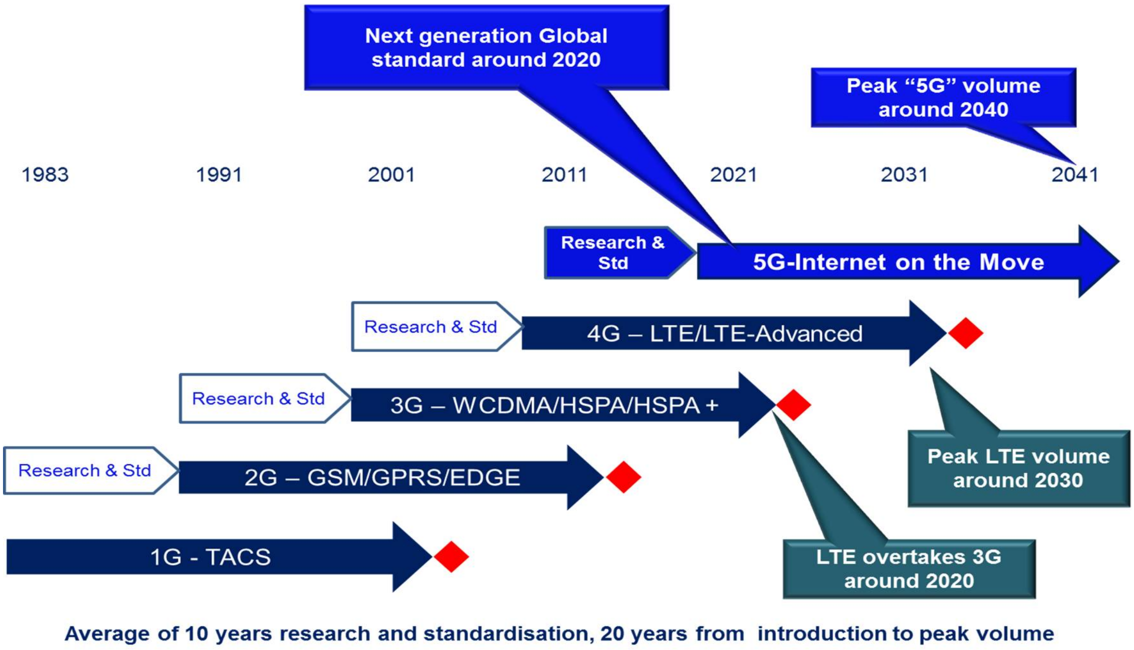
Every generation of system takes about 20 years to peak after being introduced to market and it is preceded by about 10-12 years of research and standardisation activities.

Looking closely at timescales between different generations of standards, from introduction of the first generation mobile systems in mid 80's to 4th generation in 2010, it appars that 2013 is the right time to start research and standardisation processes for 5G.

Further observations of the trend reveals that the time between introduction of one generation and next one seems to be getting shorter from one generation to the next one starting with 12 years between 1G and 2G, 10 years between 2G to 3G, 9 years between 3G and 4G. Following this trend and fact that 4G was introduced in the market in 2010, it appears that market demand would push for availability of all 5G technologies before 2020.

A.1.3 Mobile Standards Evolution

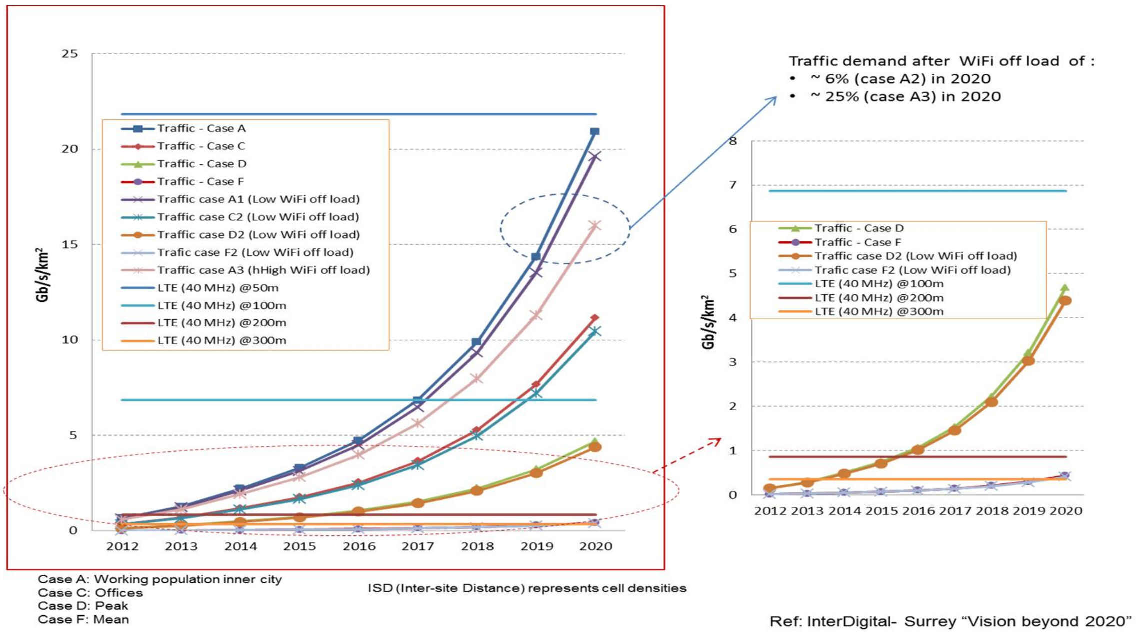




A.1.3.1 What happens if we do not have 5G?

Tsunami of expected mobile data traffic by 2020 can not be supported in highly dense urban environment where traffic and users density is the highest amongst all different environment categories. The figure below is only an indication of traffic demand against offered capacity for a high density environment which is typical of most of the Western Europe capitals, Tokyo, New York or so on.

A.1.3.2 Capacity Crunch



From consumers' point of view, the availability of mobile broadband services will be highly patchy similar to a large train station or conference venues served by WiFi technology today.

From mobile operators business point of view, they will not be able to meet quality of experience (QoE) their customers enjoy today from mobile system, as there is not sufficient radio frequency spectrum available to serve the demand. In WRC'15, maximum available new spectrum to mobile communications is expected to be in order of 500MHz which is similar to existing amount of allocated spectrum. With current technology and its enhancements, 4G can only provide two to three times more capacity even with extremely small cells. It is important to note that highly dense cells has its own economic and capacity limits and can not be relied on to meet expected demands in 2030.

A.1.3.3 What is 5G and how is different from previous generations?

Based on the trend of mobile evolution, shown above, 5G technologies must be developed in support of market demands beyond 2030 in mind. If the same pace of increase of data traffic volume is kept, 5G should be designed for 1,000,000 fold traffic growth compared with that in 2010.

5G is about sustainability of mobile broadband business and, unlike previous mobile generations, should not be driven by higher speed only. 5G is about utilisation of existing, additional radio spectrum and unification of licensed and license-exempt frequency bands. The focus should be to develop technologies in response to the capacity and spectrum crunch in a cost effective manner. The new 5G system has to provide Area Spectral Efficiency (ASE) (b/s/Hz/m^2) of several orders of magnitude compared with that offered by 4G whilst being several orders of magnitude more energy efficient compared with today's technology from operational cost perspective. To be more specific 5G is not about link spectral efficiencies (b/s/Hz) like previous generation of mobile systems.

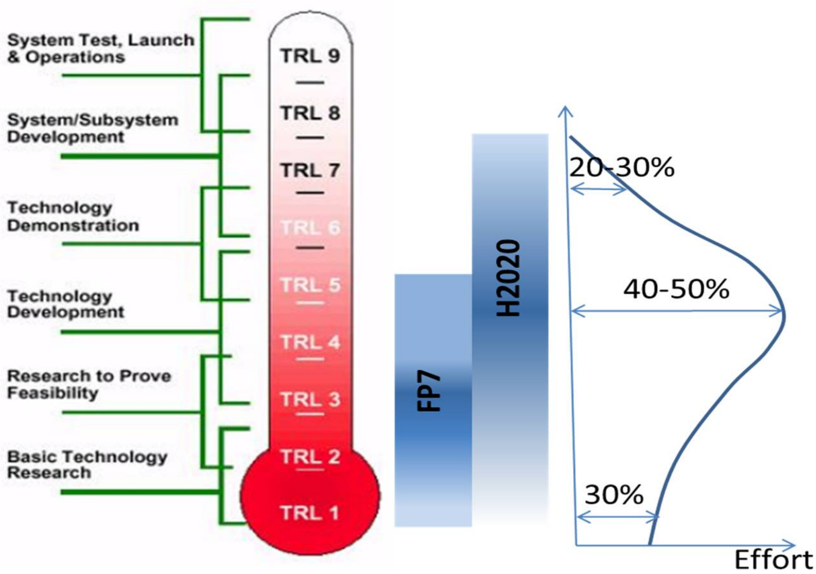
From the start, 5G should be designed to support billions of machine type communications (M2M) in mind rather than as an add-on feature. It is equally important for 5G system to be highly resilient and scalable in face of natural or man-made disasters so communications can be uphold without a fixed infrastructure.

According to market demand, broadband part of 5G should provide "Omni-present Internet on the Move" rather than just in indoors or some specific hotspots only. For 5G PPP to have a desired impact, Europe should approach 5G in a holistic way as the capacity crunch challenge can not be achieved by advance radio technologies alone. The 5G PPP programme should be structured and organised based on tight cross-fertilisation of the following 3 pillars of technologies complemented with experimental pilots and extensive standardisation/regulatory activities. With this PPP Europe would have opportunity to drive the requirements and targets in ITU-R, 3GPP and ETSI on 5G.

Essential Enabling Technologies for Internet on the Move

All the identified strategic research and technologies are based on these three pillars in next sections.

Compared to FP7, 5G PPP in H2020 will include higher Technology Readiness Level (TRL) activities with the aim of stimulating innovation in Europe. Some activities should be related to demonstrations and assessments of 5G technologies in real environments, through pilots integrating results from a number of cooperative projects. The following figure illustrates the scope of 5G PPP in comparison with the previous framework programme. It is proposed to cover TRLs up to 7 (namely, system prototype demonstration in the planned environment). A proposal of effort allocation is also shown suggesting 20-30% for high TRL activities, 40-50% for medium range of TRLs and 20% for low TRLs.



Technology readiness levels/functional maturity of technologies for 5G PPP

A.1.4 Strategic Research and Innovation Areas

A.1.4.1 Pillar 1: Communication Technologies

The mobile broadband networks and Internet are now “Super” national critical infrastructure paving the way for fully connected digital economy and modernisation of many industries enabling future smart cities, smart services and smart industries. Simultaneously, the mobile traffic demand alone is doubling every year whilst available capacity is only doubling every ten years. Network energy consumption will be doubling every year in linear relationship with traffic increase, thereby doubling networks operation cost with energy bills. Mobile networks and mobile users and devices are main sources of “Big Data”[8] consisting of “small data of large volumes” as in M2M and “large data” from video and image based applications. Allocated spectrum is becoming highly fragmented and scarce to the extent that most large capital cities will ran out of capacity as early as 2018. Signalling architecture in mobile networks is still based on GSM and is now becoming major capacity bottleneck particularly for small cells. Considering future video based applications and shortage of the radio spectrum, it does not make sense to have separate radio spectrum for broadcast and mobile networks. There is also no business or technical justification for separation of licensed and licensed-exempt bands. Ever since second generation cellular standard (GSM) the data rate gap between that offered in the fixed network and mobile networks, has been widening from generation to generation. There are new and challenging technical and regulatory requirements from other industries and services. There is emergence of new business models with new players and stakeholders.

All these are some of main rationale and research challenges for 5th Generation mobile broadband system in a uniform mobile, broadcast and licence-exempt bands as well as investigation in suitability of new frequency bands such as millimetre bands in 60 to 100 GHz.

Each of the above issues is briefly expanded upon as follow.

A.1.4.1.1 New Air-Interface

ITU-R is expected to analyse the demands and requirements for the next generation of broadband wireless systems, in order to guide and harmonise future developments towards 5G.

There are expectations from network operators that new spectrum for mobile services will be allocated at the World Radio Conference (WRC) in 2015. However, it can already be forecast that it will not be sufficient by any means to support the forecast traffic growth for 2030. Thus, technologies with increased area spectral efficiency (area capacity) through advanced radio for both access and backhaul, heterogeneous network deployments with distributed cooperation of devices, have to be developed. There is a need for new air-

[8] http://www.bbc.co.uk/iplayer/episode/b01sb437/Click_27_04_2013/

interface suitable particularly for small cells which can operate across licensed and license-exempt bands with distributed protocols between network and devices. Justification for new air interface is not yet higher spectral efficiencies as current 4G standard is within 10-20% of Shannon capacity limit. New air-interface should have as minimum following salient properties:

- Very low control signalling overhead for management, relaxes the stringent time-frequency control inherent in OFDMA
- Flexible implementation of carrier aggregation across highly fragmented spectrum including license-exempt band
- Highly energy efficient
- Allow full-duplex operation
- Sub-millisecond Air-Interface latency
- Support fast and reliable spectrum sensing for opportunistic spectrum sharing with and without database support
- Support distributed MAC between network and mobile device
- Support of device to device communications
- Scalable for Machine type communications
- ….

Cells-cooperation for joint processing is needed in support of expected vastly increased transmission rates in 5G enabled by large scale active antenna systems and usage of wider spectrum. The performance of cells-cooperation would be greatly limited by inherent transmission delays and delay uncertainty between packets for joint processing. Novel access point architectures and time synchronisation techniques between distributed access points should be investigated as a key enabler in exploiting potential gains offered by cells-cooperation.

A.1.4.1.2 NEW NETWORK ARCHITECTURES

Commonly adopted approaches to the spectrum/capacity/energy crunch are denser and denser node deployments and enhanced coordination. However, these require advancements in several areas to make this viable both technologically and economically. Both heterogeneous network topology and network management need to be fundamentally rethought and redesigned. In small cell scenarios with inexpensive base stations the backhaul architecture becomes an important issue and deserves particular attention, especially in support of mass processing.

Current cellular systems are designed with extensive in-band signalling, putting a limit on achievable area capacity. This problem is exacerbated with new trends of smaller and smaller cell topologies, resulting in excessive mobility related signalling. To achieve simultaneously (link and area) spectral and energy efficiencies, there is a need in moving away from traditional cellular architectures, and investigate for new and alternative architectures where signalling messages and user data can be supported and optimised irrespectively of cell size, thereby providing another degree of freedom in network resources management and operations. This calls for a physical separation between control and data planes. The separation between these two planes should be an end-to-end architecture spanning radio access, backhaul and fixed network in an intelligent and novel software defined networking (SDN). For both on-line capacity and energy efficiency optimisation, network management must take into account users and network's various states such as active and idle states and manage network resources dynamically, whilst maintaining the overall system capacity and operational stability. Physical separation between control and data planes brings about new research challenges, notably synchronisation between these planes.

"Always-Online" state is one of the most important requirements for Mobile Internet. Current protocol designs of state machine of mobile networks is similar to the one used for fixed access internet resulting in excessive signalling overheads, energy and other resources inefficiencies. Particularly in case of smart phones periodic application-level heartbeats trigger a terminal to frequently switch between idle and active states. 5G should be designed with support of "User-Centric protocol state machines" where application level connection can be kept without excessive signalling in switching between idle and active states.

A.1.4.1.3 Spectrum Packing between Licenced and Licensed-exempt Bands of Broadcast, Mobile Communications and WiFi

A most prominent component of future mobile traffic increase is expected to be due to video-type services. It makes sense to enhance the existing broadcasting functionality in mobile networks, so that the dense infrastructure of WiFi and cellular networks can be even better exploited for offering spectrally efficient mass multimedia delivery, thereby also offloading the mobile broadband (unicast) access. Furthermore, for broadcasting, the introduction of state of the art digital broadcasting technologies, like DVB-T and DVB-T2, enables more dense frequency reuse, thereby leaving less white space between the service areas of a TV channel. With the appropriate dense transmitter network and technology, using, e.g., cellular broadcasting solutions, Single-Frequency-Networks (SFNs) are possible for nation-wide broadcast content; which enables significantly increased "packing" of TV spectrum. This opportunity has been exploited to only a small extent at the ITU Regional Radio Conference Geneva'06 broadcasting frequency re-planning activity. Studies have shown that the secondary use of TV white spaces is possible, however, of limited value for macro cellular networks. Therefore, the prime focus should be on reducing the white space wherever possible, by packing broadcasting channels more densely, so that larger amounts of contiguous spectrum can be re-farmed, and thereby be reused without the burden implied by white space operation. However, many research challenges remain to be addressed mainly towards making mobile broadcasting more efficient, in terms of spectral and energy efficiencies, by using and optimising as much as possible the advanced techniques developed in mobile broadband cellular systems, such as MIMO, diversity and beamforming, thereby reducing the current gaps between mobile broadcasting and mobile broadband. Research should also be focused on the provision of technologies for multicasting at single- and multi-cell levels, and for energy efficiency develop targeted broadcasting technologies, as opposed to current "anytime and anywhere" broadcasting.

A.1.4.1.4 Pillar 2: Information Technologies

Data continues to be a major area of growth for mobile operators[9]. As Cisco reported in their recent Visual Networking Index (VNI) study[10], the volume of mobile broadband

[9] www.mobileworldlive.com

[10] Cisco Visual Networking Index (VNI) Global Mobile Data Traffic Forecast for 2012 to 2017. Cisco. 2013.

(MBB) traffic has been doubling every year, reaching 1,577 Petabytes per month[11] in 2013 (the equivalent of 500 billion .mp3 files or 800 million hours of streaming HD video[12]) and is forecast to reach 11,156 Petabytes by 2017. The rate of growth is underlined by the fact that total traffic volumes in 2012 were as high as all prior years combined. Furthermore, this growth is not confined to one area – all regions have been showing impressive growth rates.

In addition to mobile data traffic there will be huge amount of data generated from smart cities applications such as intelligent transportation, environment monitoring, e-health and telecare, smart energy grid networks and all utility services in general through Machine type communications (M2M) connecting "Things" generating what is commonly refered to as "Big Data". All these are applicaion areas and identified as "Grand Societal Challenges" that should be supported by 5G technology.

Obviously, there is a limit on achieveable area capacity from radio perspectives. Information Technology has an important role in handling of expected tsunami of data in several ways as well as new network architectures using distributed micro-servers for high scalability, energy efficiency, resilience to failures and reduced latency by bringing data to proximity of users.

The traditional model of single ownership of all network layers and elements is no longer a viable business model and sharing of the assets "Infrastructure sharing" is the way forward. To have a control over cost and its reduction in terms of network capital and operational costs, Radio Access Network (RAN) Virtualization and Sharing are the most promising technologies for 5G.

A.1.4.1.5 BIG DATA

Mobile devices, customers, networks are the main sources of big data. Information content of such data, at present, is not effectively utilised. It is a common problem that digital systems, architectures, and services are designed "outwards" from what is technologically interesting rather than from "inwards" from a proper understanding of customers and application needs and expectations. This ranges from quasi-standard settings at the architecture level, protocols to lack of "consumer and user trials communities" on which new products and services can be tested. The information content in Big Data should be utilised for several purposes such as capturing user, device and network contexts dynamically and use these information for appropriate content distribution, and caching of large data such as videos as well as small data but in large volume from M2M type communications in an intelligent and unified content delivery networking (CDN) architecture. Utilisation of Big Data can also help in efficient operation of self-organisation networking (SoN) and cognitive use of the radio spectrum from network operation point of view. Capturing the network, user, device contexts is essential in efficient delivery of contents in "Application aware networking", as well as "Network aware applications". Ignoring data/content available in Big Data and its expolitation, and focusing 5G PPP only on radio research and innovation, could result in shifting capacity bottleneck from radio access to the fixed network.

Research on the issues of intelligent data handling and delivery based on user preferences, user devices, and radio and network contexts offer potential solutions to the challenges.

[11] Equal to 1.6 billion Gigabytes

[12] Assuming .mp3 files are 3 Megabytes each, and an hour of HD video uses 2 Gigabytes of data

A.1.4.1.6 5G AND GRAND SOCIETAL CHALLENGES

5G architecture should be designed with technical requirements imposed by the EU Grand Societal Challenges. These are challenges faced in environment, health, transportation, energy and many more applications and services specific to smart cities, smart homes, and smart factories and so on.

Fundamental to many of these challenges is development of a suitable monitoring, measuring and control system that helps removing current boundaries between real and cyber worlds. There is a need for embedded cognition/intelligence into web-based service in a decentralised control and monitoring system. The intelligence will enable autonomous communications and interactions between real/physical objects "Things" and cyber world. Near real-time interactions is essential for creating perception of seamlessness between the two worlds.

The intelligence would facilitate appropriate data gathering including "context" and its conversion into machine-interpretable information for the purpose of self-control as well as autonomous execution of complex tasks in interactions with smart objects, smart services and smart network.

Research should leverage on existing standards and Open concepts (Open Data, Open Content and so on) and develop new ones if necessary.

A.1.4.1.7 MICRO-SERVERS TECHNOLOGY

Development of 5G will require a tremendous increase in processing power and energy efficiency of the computing engines. In addition to Big Data, baseband processing, intelligent spectrum analysis and selection will require fast responses from the computing elements as well as for network management. To reduce latency and increase bandwidth, processing should be carried out as near as possible to data sources. For example, in a smart city, M2M communications will require distributed processing schemes instead of a global centralised large data centre to perform all the operations. The large data centres are still required, but a hierarchy of "micro-servers" should be used for filtering and processing of information in an energy efficient and fast manner. Low level decisions and processing should be executed locally as opposed to flooding of the network channels. The hierarchy and overlapping of communication and processing will increase reliability, safety and privacy. Privacy is upheld as important information is communicated on need-basis only and is generally locally processed that results in control of overall latency.

A.1.4.1.8 RADIO ACCESS NETWORK VIRTUALIZATION AND SHARING

The current limitations of 3GPP systems have to be significantly enhanced as already recognized by some early activities in standardization groups as in the 3GPP SA1 RAN Sharing Enhancements Study Item where, for instance, automated means (no human intervention) in allocation of RAN resources dynamically and on-demand.

Virtualization and multi-tenancy, a crucial need for today‘s operators, is a major challenge. In this scenario different operators are able to deploy and control virtual access networks over a shared infrastructure comprising several different access technologies. Additionally, by implementing wireless functions in the cloud and virtualisation of resources the radio protocol stack will be significantly simplified. In this respect the peer connection between different wireless nodes will turn into connection between different Virtual machines (VMs) in the cloud. As the result there will be no more needs of tunnels and protocol stacks between different nodes (peers). The technical challenges can be summarised as:

- Operator-facing interfaces: Particularly for the virtual operators to provision a degree of control over customers and resources comparable to what is achievable today with dedicated infrastructures,
- Resources guarantee: Mechanisms and policies that guarantee slicing of resources and isolation among different customer groups, whilst providing the ability to leverage on statistical multiplexing so as to improve the overall system performance.
- New Radio protocol stack: Taking advantage of cloud network architecture and virtual machines

A.1.4.2 Pillar 3: Hardware Technologies

Advanced technologies envisaged for 5G would require research into new generation of hardware designs. It is important for Europe develop such technologies for greater impact from 5G PPP and readiness for commercial exploitations. To this end, close links and interworking should be established with EU initiatives on Key Enabling Technologies [KETs] and multi-KETs, namely micro/nano-electronics, advanced materials, photonics, and advanced manufacturing. In fact, 5G should be considered as a driving application of KETs and related stakeholders should be involved in early stages of 5G definition to ensure a good matching between KETs and 5G roadmaps.

Among the critical enabling hardware technologies that 5G PPP should develop are advanced RF and digital architectures and components ones as outlined and justified below.

A.1.4.2.1 RF CHALLENGES

RF in future 5G for broadband as well as machine type communications pose unprecedented challenges. In this future hyper-connected world, RF front-end technologies based on advanced CMOS process have to be targeted, providing simultaneously cost efficiency, innovative RF architecture, very high level RF performance and low power consumption. The emerging CMOS FD-SOI (Fully Depleted Silicon On Insulator) which is a European technology could be a starting point. In FD-SOI transistors can run about 30% faster than traditional CMOS and are about 50% more efficient in terms of power consumption, with much lower leakages. In addition, operations as low as 0.5V are possible compared with state of the art 0.8V, allowing flexibility and real-time trade-off between performance and power consumption. The FD-SOI technology currently targets digital part, and analog/RF solutions are still to be developed.

Europe should take the lead in developing high performance RF front-end by exploiting the best in the class, European developed technologies such as FD-SOI, combining high integration between digital and analogue parts with very low power consumption.

A.1.4.2.2 ULTRA LOW POWER CONSUMPTION FOR IOT AND M2M

Internet-of-Thing (IoT) and its subset M2M are enabling technologies in addressing “Grand Societal Challenges” and will make extensive use of wireless sensors technologies. RF communication solutions for improving battery life to ensure autonomy of up to 10-20 years should be the target of research. Current solutions do not come anything close to this requirement unless a large and costly battery is used. Actual solutions range from Photovoltaic (PV) cells to vibration harvesting. Future directions will take advantage of better efficiency in terms of more current for the same weight or larger bandwidth of vibrations being captured and/or new sources like thermo-electricity systems.

However, the gap between the µW range from the harvested energy and the mW one for the electronics and more specifically the RF communication is still too large. To this end, the power consumption of the RF front-end must still be further reduced, and below 1 mW for a receiver is a must-have target. In that scope, these front-ends will require to be more flexible and able to run with power consumptions in the hundreds of µW range.

Moreover, major power saving can be expected if the linearity of the RF front-end is alleviated through Low Noise Amplifiers (LNA) and mixer specifications, ADC resolution, and a-priori knowledge on the quality of the received RF signal.

A.1.4.2.3 POWER AMPLIFIER ON CMOS

Energy-efficient RF front-end (FE) has become a paradigm in RF system development. The transmitter section of the RF FE uses Power Amplifiers (PA), filters and RF switches to make it possible to address the many standards and frequency bands in cell phones or handheld tools (tablets, PC, …). In the future, they will have to cope with even more fragmented frequency bands of 5G, from below 1 GHz, TV broadcast and white space, all the way to below 5GHz including licensed and license-exempt bands in a non-contiguous manner. This imposes great challenge in reducing the form factor whilst being highly power efficient. On the other hand, seamless connectivity will be mandatory as well as easy swap from one standard / band to another. Therefore, real multi-mode / energy-efficient / cost-constrained solutions are major technical challenge. The key challenge in the future will be to improve the efficiency of the PA whatever the conditions in which the handheld is in, and whatever the standard it covers.

Secondly, the cost of the RF FE solution has to be improved. Today RF FE is composed of many different blocks connected together on costly modules aggregating hybrid technologies. Better integration is expected by the use of valuable full-CMOS integration of various blocks, corresponding to various standards onto the same die.

Thirdly, better integration of the RF FE module will also help the overall performance by reducing the traces and paths between the blocks, thereby optimize the energy efficiency at the most demanding side of the RF communication. Here, 3D integration combined with full-CMOS devices has to be investigated.

Following the PA at the very end of the RF FE are the filters. Since the 3G deployment and more intensively with the 4G, the complexity of the filtering stage has grown up due to the intensive extension of frequency bands in use. In addition to complexity, it also impacts the PA performance by multiplying the paths and switches to consider. Current filter solutions still rely on single band bulky SAW/BAW[13] filters and new bands means extensive duplication of filters. A potential solution is to add tuneability to the filters. Two main advantages of using these acoustic wave-based devices are miniaturization and power consumption reduction. Nevertheless, this added flexibility on the front-end must be correctly managed by the embedded processor or directly at the front-end level by an automatic process. Here, the development of the technology must be done considering the possibility of the front-end in terms of detection of events/behaviours and its ability to correct/compensate/switch passive filter response.

[13] SAW : Surface Acoustic Wave / BAW : Bulk Acoustic Wave

Related multi-standard integration with broadband and narrowband communication will also lead to tuning at the antenna level, where reconfigurability will be mandatory: radiation pattern, impedance and bandwidth. The small form factor antenna leads to narrow band behaviour, which is not always required by the application. Therefore, the management of the antenna tuning and performance will have to be done in conjunction with the PA overall performance on the transmitter side, and with the LNA on the receiver one. As above-mentioned, the PA characteristics are strongly related to the matching with the following stages, i.e. filtering ones and antenna. Thereby, the adaptation of the antenna will not be possible without considering the PA functioning.

A.1.4.2.4 NEW FREQUENCY BANDS IN MILLIMETRIC RANGE

Recently, millimetric wave (mmW) communications in the 60 GHz bands have attracted interest in finding solution to spectrum crunch. Thanks to available large bandwidth and efficient modulation schemes, communication up to several Gbps is a practical.

Main current application is in indoors, as a solution to cable replacement in displaying high-definition video on a large TV set for instance, and in complementing WiFi. In future, the high data rate in mmW bands will evolve to support indoor applications in both up- and down-link directions. Even though the communication range is limited, due to short wavelength, it enables development of small antenna which can be trimmed to operate highly directive beam forming.

The mmW frequency bands are good candidates for outdoor broadband communications. The main driver is high throughput requirements for backhauling and radio access which can be satisfied using 60 to 80 GHz frequency bands. These bands are ideal for future small cells where radio propagation can be contained within a cell easier than lower frequency bands enabling more spatial re-use of spectrum.

Last but not least, millimetre waves present the important characteristic of not penetrating deeply through the skin and are interesting for minimisation of the electro-magnetic field exposures.

mmWave technologies for mobile communications is an early stage of research. Significant research should be undertaken to improve the integration of RF front-end to address high-volume / low-cost in CMOS technology, e.g. by using the European FD-SOI technology to enhance the digital process and reduce the overall power consumption.

A.1.4.2.5 USE OF INNOVATIVE EMBEDDED AND LOW POWER COMPUTING TECHNOLOGIES FOR 5G

Inexpensive Micro-server technology play a key role in reducing overall latency and increase bandwidth, by enabling processing to be carried out as close as possible to data sources. The evolution of components should be complemented with advanced technologies for micro-servers to reach such targets including: processors, memory, interconnect and storage. Candidate technologies that need to be further investigated are:

- Multicore chips realized e.g. in FDSOI (Fully Depleted-Silicon On Insulator) technology. This will leverage the extended performance/power range offered by the FDSOI technology nodes to reach high performance/energy ratio on a large range of compute loads.
- 3D stacking to increase bandwidth between compute engines and memories. Stacked processor and memory using the WideIO standard shows more than 4 times energy bandwidth improvement over state of the art system. Dense 3D

interconnects shows possibilities to reach above 450 GB/s between memory and processing.

- Silicon interposers allowing to efficiently pack and interconnect dies in a small form factor, allowing merging of heterogeneous techniques including photonic interconnect, reaching new performances in bandwidth / energy efficiency.

Solving some important challenges of advanced computing systems is essential for the success of 5G. Higher levels of energy efficiency can be achieved by using heterogeneous hardware in combining parallel processor cores with accelerators. Efficient programming of these structures is a major challenge, where computing resources are required to be virtualized to process a large range of tasks, independent of underlying hardware, and even allowing dynamic task allocation and migration to truly virtualize network and computing resources. Research is needed for efficient distributed virtualization solutions with resilience, data security and protection.

A.1.5 Pilots

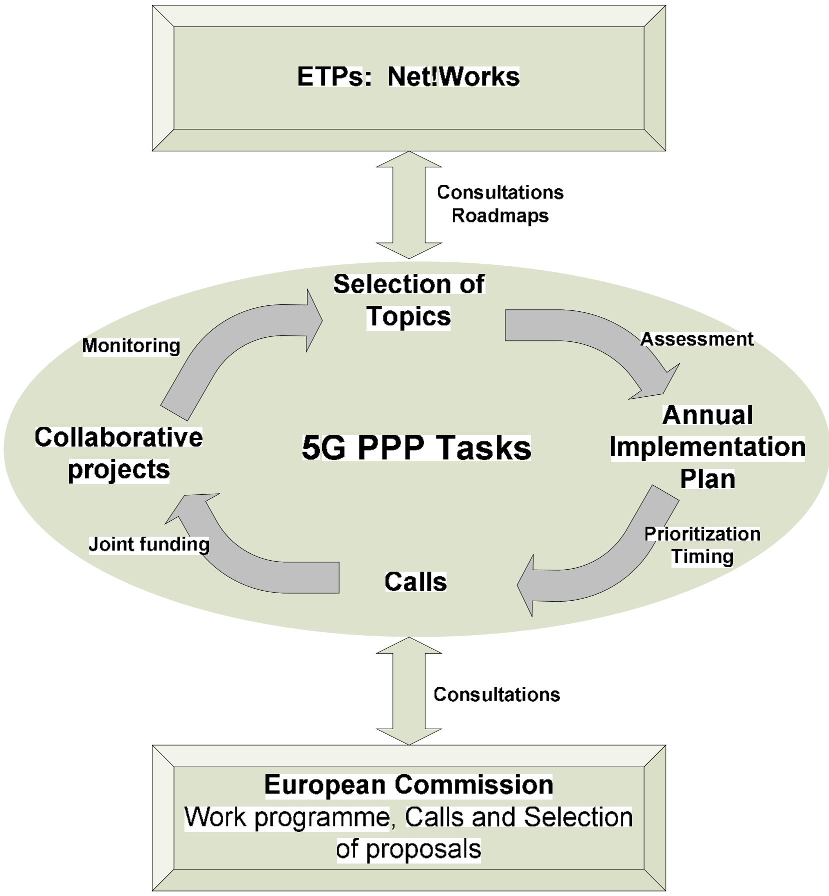
Europe has been excellent in generation of concepts, knowledge, standardisation and that needs to be complemented with testing and optimisation in real world environment to bridge the gap to commercialisation.

In 5G PPP demonstration and optimisation of generated technologies should be carried out through a number of specific and complementary pilots in Europe with experimental facility of sufficient scales and leveraging on already developed Pilots funded by EU and National programmes such as SMART-SANTANDER (for M2M), FI-WARE (for Core Network) in Spain and 5GIC in the UK. 5G PPP should also identify appropriate locations for new topic specific pilots such as CDN, SDN and so on.

A.1.6 Governance of 5G PPP

The following diagram illustrates the running of the PPP and its interactions with the ETPs and the European Commission.

The activities of the 5G PPP in terms of performance in meeting set milestones should be regularly evaluated. Such evaluation needs to be carried out both internally and externally. The internal evaluation should be based on the comparison of current project activities and results with the original annual implementation plan. The required steps of project monitoring and program assessment should be fully integrated in 5G PPP programme feedback loop. These monitoring and self-assessment should be core task of the governance organization. The external evaluation assesses whether the impact of the 5G PPP is progressing towards the original objectives set by the European Technology Platforms and the European Commission. It may give directions for necessary adjustments in case of major deviations or changing framework conditions. Such external evaluation has to be based on evident facts about project results and credible information about their use in the innovation chain. It can only be carried out by an independent entity which is well accepted by both the public and the private sides. It will collect information on specific projects on a trust basis, and anticipate their contribution to the goals of the 5G PPP. The findings will be published in a generalized manner as an annual progress report which may also give advice to the European Commission.



A.1.6.1 Why a contractual PPP?

- To ensure a lasting commitment from the industry and the European Commission to address the shared objectives, with the ambition to deliver results in a timely and continuous manner;
- To guarantee critical mass of funding for topics that are of strategic importance for Europe, tackling specific societal challenges and aiming at industrial leadership;
- To drive forward innovation, by integrating in a ring-fenced programme research activities together with actions necessary to accelerate the implementation of research results, towards the deployment of innovative solutions and pushing for production within the Europe;
- To set up a collaborative process where private and public actors are putting together their specific competences;
- To maintain transparency of the priorities setting and openness for participation in the programme to any interested stakeholders, qualities which cannot be otherwise fulfilled. This is a particular need for the telecommunications industry, which includes several competitors and which is based on fragmented supply chains including SMEs;
- To guarantee flexibility and an ability to adapt the technology coverage of the programme according to research findings, allowing the budget to be always oriented towards the best usages according to real industry situation and the state of the art research;

- To ensure a lasting cooperation of the industries concerned (operators, equipment manufacturers, …) with academic and research institutes.

A.1.6.2 Benefits of using a Contractual PPP instrument

- Secured commitment of industry and the EC to meet critical societal and industrial policy objectives;
- Builds on success of the past European initiatives on 2G, 3G and 4G;
- Open to the participation of a wide stakeholder group, including newcomers and smaller players, and enabling also a wide inclusion of particular experiences from all EU countries;
- Emphasis on defining clear directions and priorities through Roadmaps which have gained wide consensus through the activities of the Net!Works Technology Platform;
- Appropriate structuring of programmes and individual projects in order to guarantee adequate coverage of all research priorities and provide potential synergies in order to enable the predetermined targets and milestones to be achieved;
- Facilitating the collaboration between competitors on a wider range of topics, thus strengthening the competitiveness of the EU industry as a whole;
- High degree of accountability, through the continuous review and monitoring of progress over the course of H2020, being a clear task of the 5G PPP, using the roadmaps;
- Continue to take advantage of excellent expertise and experience of Commission in its management of collaborative R&D programmes, in view of their policy frameworks;
- Greater focus on the integration of supportive measures like standardization or training and education through dedicated actions.

A.1.7 Summary and Recommendations

It is clear that 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. The use of networks to connect machines to the Internet is still in its infancy. Projections suggest that expected rapid growth in the generation of network traffic will be driven by the increasing use of video for communications and the use of networks for M2M communications. New applications are placing new technical demands on the network. Whereas in the past increasing the transmission capacity of the networks was the focus of research, new applications mean that reducing the latency of networks, increasing their energy efficiency, improving utilisation of spectrum (Area Capacity), and the scalability and stability of networks, are the requirements that future research and innovation must address. Internet and Telecommunication networks will be the control and transport plane of other National Critical Infrastructures, such as: health and tele-care systems, eGovernment, transport systems, energy systems, and environmental monitoring systems. This will make Telecommunication networks National “Super” Critical Infrastructures.

All these matters present many new challenges to the entire business chain in the IT, communications and networking industry. The time scales between mobile standards is getting shorter and it is mainly driven by market demand for "Internet On The Move". If the projections and trends are correct, market may need 5G before 2020 and the system should satisfy the envisaged market demand for at least until 2030.

- Recommendations

I. 5G should be designed for market requirements of at least 2030

II. Holistic approach to development of technologies for 5G with close cooperation between IT, CT, HT (Hardware Technologies).5GPPP should cover TRL range up to 7

III. Research into a new air-interface and wireless backhaul and exploration of new frequency bands as in millimetric bands of 60-100GHz.

IV. Research into several order of magnitude increase, compared with 4G LTE-A, in area spectral efficiency, energy efficiency and power efficiency

V. Research into Big Data exploitation as an important source of intelligence

VI. Incorporation of intelligence for context, spectrum, content delivery network, self-management and optimisation

VII. Research into uniform SDN concept covering both radio access and fixed network architecture and micro-servers

VIII. Develop hardware technologies based on European technologies, with extensive use of SOI technology for development of small form factor RF front-end

IX. Develop interoperable solutions based on virtualization through distributed communication and computation in an efficient and holistic way

X. Research into RF solutions for ultra-low power consumption, tuneability and integration

XI. Set up a group in 5GPPP to specify new requirements and target metrics for 5G and actively input results of 5G PPP to 3GPPP and ITU-R

A.1.8 Acknowledgement

We would like to thank and gratefully acknowledge valuable inputs received and the hard work of the following persons, in no particular orders, from the Net!Works Expert Advisory Group (EAG).

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