Future Internet X-ETP Group

Future Internet Strategic Research Agenda

Version 1.1
January 2010

eMobility (Connect to the network community)

NEM NETWORKED & ELECTRONIC MEDIA

NESSI

EPoSS European Technology Platform on Smart Systems Integration

ISI

PHOTONICS21

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Research topics	ETP Leader
1. Routing and addressing scalability and dynamics	
1.1 Scalability of routing system (nodes/hosts, address/AS, etc.) and dynamic of routing system: robustness/stability and convergence properties [Deterministic communication]	eMobility
1.2 Information-driven routing (e.g. semantic routing, but other paradigms are also under investigation in the scientific community [Routing & addressing based on metadata]	eMobility + NEM
1.3 Addressing and routing information management (renumbering, allocation, etc.) [Enhancement of existing functionnalities]	eMobility
1.4 Routing system security	eMobility
2. Resource (forwarding, processing, and storage) and data/traffic manageability and diagnosability	
2.1 Configuration and upgrade management (and their resulting cost) knowing that in practice continuous patching results in relative decreasing gain but increasing complexity	eMobility
2.2 Problem (e.g. anomaly, inconsistency) detection and root cause analysis (as the current paradigms, techniques and toolset for debugging the Internet are limited)	eMobility
2.3 Interactions Traffic source/sink(application)-Network resource sharing	eMobility
2.4 Radio network	eMobility
2.5 Optical network	PHOTONICS
2.6 Satellite network	ISI
2.7 Exaflood management	EPOSS, NESSi
2.8 Provide a flexible infrastructure to support networked economy	NESSi, ISI
3. Security, privacy, trust, and accountability	
3.1 Security, privacy and trust	NEM, NESSi, ISI
3.2 Accountability	NEM, NESSi
4. Availability, ubiquity, and simplicity	
4.1 Resiliency against normal accidents and failures	eMobility
4.2 Fast convergence/recovery of routing system	eMobility
4.3 Global connectivity coverage availability	eMobility, ISI
4.4 Global connectivity coverage reliability	eMobility, ISI
4.5 Quality Of Experience	NESSi
4.6 Seamless continuity between all networks	eMobility, ISI
5. Adaptability and evolvability to heterogeneous environments, content, context/situation, and application needs	
5.1 Semantic web	NEM, NESSi
5.2 Seamless Localization	eMobility, ISI
5.3 Industrial mobile networks	eMobility, NEM, ISI
5.4 Adaptive interactions	NESSi
6. Operating system, application and host mobility / nomadicity	
6.1 Cloud OS	NESSi
6.2 Embedded OS	NESSi, EPOSS
6.3 Cloud Computing	NESSi
7. Energetic sustainability	
7.1 Energy efficient systems	eMobility, ISI
7.2 Energy Efficient radio tranceivers	eMobility
7.3 Energy Efficient Protocols	NESSi
8. Conflicting interests and dissimilar utility	
8.1 Stakeholders positioning	eMobility, NESSi
9. Searchability/localisation, selection, composition, and adaptation	
9.1 Search Engines	NEM
10. Beyond digital communication: semantic, haptic, emotion, etc.	
10.1 3D Communication	NEM
10.2 Behaviour communication	NESSi
11. Internet by and for People	
11.1 Contribution to the Grands Societal Challenges	NEM
11.2 The enabling e-Applications	NEM
11.3 Ensure social, economical, legal and cultural viability	NESSi
12. Internet of Contents and Knowledge	
12.1 Virtual environment	NEM
13. Internet of Things	
13.1 Intelligence/smart	EPOSS
13.2 Harsh environment and integration into material	EPOSS
14. Internet of Services	
14.2 Open Service Platform	NESSi

Editor and co-authors acknowledge and thank the contribution and reviews of their colleagues from organizations and from ETPs.

CONTENT

List of Abbreviations

3DTV	3D Television
A/V	Audio/Video
ACM	Adaptive Coding and Modulation
AI	Artificial Intelligence
AS	Autonomous System
ASIC	Application Specific Integrated Circuit
ASN	Autonomous System Number
BAN	Body Area Network
BGP	Border Gateway Protocol
BTS	Base Terrestrial Station
CDN	Content Delivery Network
CPU	Central Processing Unit
CR	Cognitive Radio
DAB	Digital Audio Broadcasting
DAD	Duplicate Address Detection
DARPA	Defence Advance Research Project Agency
DIDL	Digital Item Declaration Language
DoA	Direction Of Arrival
DSLAM	Digital Subscriber Line Access Multiplexer
DTN	Delay Tolerant Network
DVB	Digital Video Broadcasting
DVF	Design Web Format
DWDM	Dense Wavelength Division Multiplexing
EE	Energy Efficiency
EMTEL	EMergency TELecommunication
EoIP	Everything Over Internet Protocol
EPOSS	European Platform On Smart System
ESA	European Space Agency
ETP	European Technology Platform
ETSI	European Telecommunication Standardisation Institute
FI	Future Internet
FRR	Fast Re Routing
FSO	Free Space Optics
FTTH	Fibre To The Home
GEO	Geostationary Earth Orbiting
GMES	Global Monitoring for Environment and Security
GNSS	Global Navigation Satellite Systems
GNSS	Global Navigation Satellite System
GPON	Gigabit Passive Optical Network
GPS	Global Positioning System
GSM	Global System for Mobile
HDTV	High Definition Television
HSDPA	High Speed Downlink Packet Access

HTML	Hyper Text Mark-up Language
HTTP	Hyper Text Transfer Protocol
HW	HardWare
IFDMA	Interleave Frequency Division Multiple
IGES	Initial Graphics Exchange Specification
InP	Indium Phosphide
IoT	Internet OF Things
IPTV	Internet Protocol Television
ISI	Integral Satcom Initiative
ISL	Inter Satellite Link
ISP	Internet Service Provider
ITS	Intelligent Transport System
LAN	Local Area Network
LBS	Local Based Services
LED	Light Emitting Diode
LEO	Low Earth Orbiting
LNA	Low Noise Amplifier
MAC	Multiple Access Control
MEMS	Micro Electro Mechanical Systems
MEO	Medium Earth Orbiting
MHP	Multimedia Home Platform
MIMO	Multiple Input - Multiple Output
MPEG	Moving Picture Expert Group
MPLS	Multi Protocol Label Switching
MTTR	Mean Time To Restore
MUD	Multi User Detection
NAT	Network Address Translation
NEM	Networked Electro Media
NESSI	Networked European Software & Service Initiative
OBP	On Board Processing
OCA	OnChip Antenna
OECD	Organisation for Economic, Cooperation and Development
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
OFDMA	Orthogonal Frequency Division Multiple
OPLL	Offset Phase Locked Loop
OS	Operating System
OTT	Over The Top service provider
P2P	Peer-to-Peer
PA	Power Amplifier
PAN	Personal Area Network
PEP	Performance Enhancing Proxy
PN	Personal Networking
PON	Passive Optical Network
PPP	Public Private Partnership
QOS	Quality Of Service
RAM	Read Access Memory
RAN	Radio Access Network
RED	Random Early Detection
REM	Random Exponential Marking
RF	Radio Frequency
RFID	Radio Frequency Identification
RRM	Radio Resource Management
SAE	System Architecture Evolution

SCADA	Supervisory Control and Data Acquisition
SDR	Software Defined Radio
SDTV	Standard Definition Television
SiP	System In Package
SLA	Service Level Agreement
SNR	Signal to Noise Range
SOA	Service Oriented Architecture
SRA	Strategic Research Agenda
SSL	Secure Sockets Layer
STEP	? (P 72)
SW	SoftWare
TCP	Transport Control Protocol
TLS	Transport Layer Security
TRX	Energy efficiency of radio transceivers
TSD	Trust Security and Dependability
UMTS	Universal Mobile Telecommunication System
UWB	Ultra Wide Band
VD	Vision Document
VHDWDM	Very High Density Wavelength Division Multiplexing
VoIP	Voice Over Internet Protocol
VPN	Virtual Private Network
VRML	Very Reality Mark-up Language
WDM	Wavelength Division Multiplexing
WLAN	Wireless Local Area Network
WSN	Wireless Sensor Network
X3D	Extensible 3D
xDSL	Digital Subscriber Line
XML	Extensible Mark-up Language

Executive Summary

This document constitutes version 1 of the Strategic Research Agenda (SRA) of the Future Internet (FI) Cross-European Technology Platforms (X-ETPs) Group. This SRA reflects a comprehensive collection of active and upcoming developments in the Future Internet research world, while clearly aiming towards the realisation of the FI Vision. The document takes as starting point the X-ETPs FI Vision Document (VD). The main objective of this SRA is to provide a well structured and consistent publication that reflects and covers a broad set of FI aspects. The document is up-to-date with regards to new developments and evolutions of research topics addressed by the FI community. The aim is to define short, medium and long-term research challenges and identify future important trends before they have started entering hype mainstream, in order to help the European ICT community to gain a leadership position.

Introduction

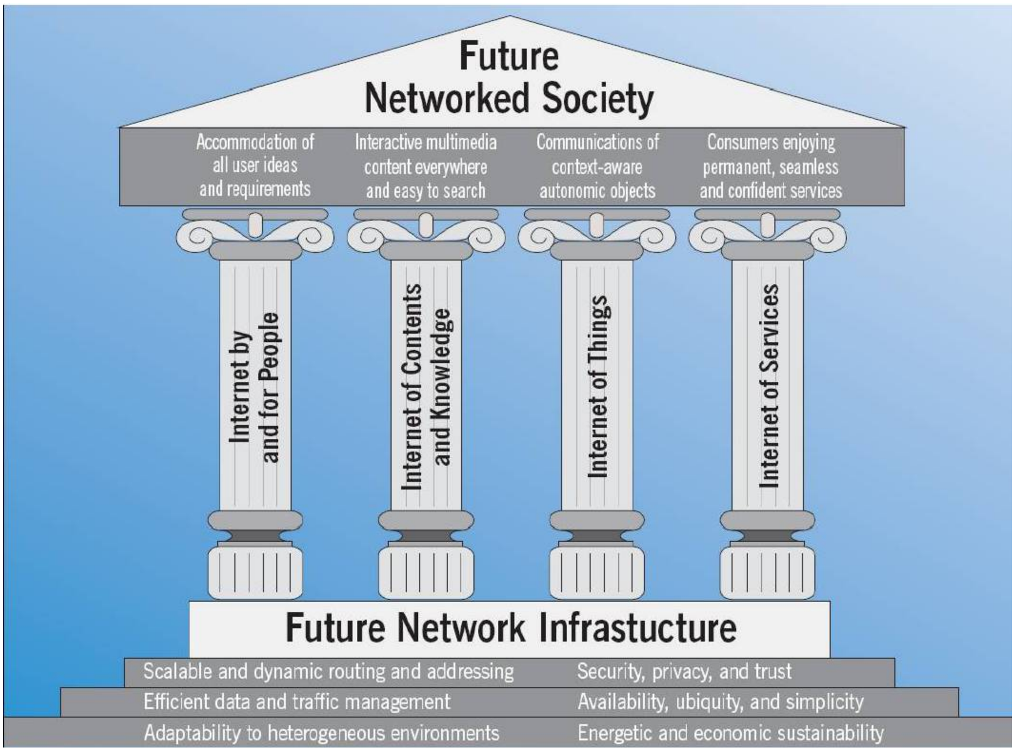
This document constitutes version 1.1 of the Strategic Research Agenda (SRA) of the Future Internet (FI) Cross-European Technology Platforms (X-ETPs) Group. To address the Future Internet (FI) and its related challenges, ICT ETPs (eMobility, NEM, NESSi, EPOSS, ISI and Photonics21) have set up a common working group with the objective to define a vision and provide recommendations to the European research for the next 10 years. The 6 ETPs comprise a large set of European and European-based organizations (more than 1000 members: manufacturers, operators, SMEs, academics) and bundle competencies on networks, devices, content, and services, which in turn cover most of the aspects of the FI.

This version 1 of the SRA aims at identifying short, medium and long terms research challenges of the FI. The associated topics could be used to set up specific research projects and targeted cross-domain and multi-disciplinary projects.

This SRA does not intend to cover the full space of the FI, neither does it intend to supersede the existing SRAs of the different ETPs. Furthermore, this first version claims not to be exhaustive in terms of FI cross-domain topics. However, this document covers the main technological challenges that are perceived as crucial and that justify the initiation of more systematic research. Also, these challenges are relevant to more than one ETP. In substance, this SRA reflects the overall cross-domains work of the X-ETPs FI working group and translates the ambition to create bridges between the different research silos. The defined research topics require competencies from eMobility, NEM, NESSi, EPOSS, ISI, and Photonics21. One additional outcome of this work is the possible enrichment of the individual ETPs SRAs.

The document takes as starting point the X-ETPs FI Vision Document (VD – version 1.0, released in January 2009) and in particular section 2.4 "Key Technological Challenges" and the appendix "Working Document - Technological Challenges". A first incomplete version was published in July 2009. The current version (1.1) has the objective to bring the latest research topic list regarding the FI work program.

The below key FI technological challenges have been identified in the X-ETPs FI VD and are listed with the objective to drive/orient stakeholders R&D so that their investment can position them as actors for their resolution. They cover the 4 FI pillars and the FI foundation.



The following 14 challenges cover cross-pillar (and referred to as cross-cutting) and network-foundation challenges, as well as generic challenges for the FI (no claim is made here that this list is exhaustive). For each of these challenges, pointers to the "Technological Challenges - Working Document" (TC-WD) of the X-ETPs FI VD are provided. Key specific challenges families have also been identified per pillar:

1) **Routing and addressing, scalability and dynamics:** Network foundation - Reference TC-WD section 1.5.
2) **Resource (forwarding, processing, and storage) and data/traffic manageability and diagnosability:** Network foundation – Reference TC-WD section 1.3.
3) **Security, privacy, trust, and accountability:** Generic challenge (security built-in at design time) – Reference TC-WD sections 1.1 and 1.2.
4) **Availability, ubiquity, and simplicity:** Cross-cutting challenge covering Network foundation as well as Internet by and for People, Internet of Services, and Internet of Content and Knowledge – Reference TC-WD sections 1.4, 2.1, 2.2 and 2.4.
5) **Adaptability and evolvability to heterogeneous environments, content, context/situation, and application needs (vehicular, ambient/domestic, industrial, etc.):** Cross-cutting challenge covering Network foundation as well as Internet by and for People, Internet of Services, Internet of Contents and Knowledge, and Internet of Things – Reference TC-WD sections 1.4, 1.7, 2.1, 2.2, 2.3 and 2.4.
6) **Operating system, application and host mobility / nomadicity:** Cross-cutting challenge covering Network foundation as well as Internet by and for People, Internet of Contents and Knowledge, and Internet of Services – Reference TC-WD sections 1.6, 2.1, 2.2 and 2.4.
7) **Energetic and economic sustainability:** Generic challenge with societal and economical impact.
8) **Conflicting interests and dissimilar utility:** Generic challenge (intelligence at execution time) involving policing aspects.
9) **Searchability/localisation, selection, composition, and adaptation:** Cross-cutting challenge covering Internet of Contents and Knowledge, and Internet of Services. – Reference TC-WD section 2.2 and 2.4.
10) **Beyond digital communication: semantic (intelligibility of things and content, language, etc.), haptic, emotion, etc.:** Cross-cutting challenge covering Internet by and for People, Internet of Contents and Knowledge, Internet of Things, and Internet of Services – Reference TC-WD section 2.1, 2.2, 2.3 and 2.4.
11) **Internet by and for People:** Accommodate anticipated and unanticipated people and community expectations together with their continuous empowerment, cultural acumen, and self-arbitration (by recognizing that access and use of information as well as associated processing means are common non-discriminatory universal rights).

12) **Internet of Contents and Knowledge:** Access by advanced search means and interact with multimedia content (e.g. 3D and virtual reality) that can be created, and manipulated by professionals and non-professionals and be distributed and shared everywhere on any terminal per needs.
13) **Internet of Things:** Context-aware autonomic objects able to generate automatic code and human-controlled behaviours, exploiting peer-to-peer bio-inspired communication models.
14) **Internet of Services:** services are part of the new capabilities that the Future Internet will bring into the everyday life of citizens and businesses of organisations. In this perspective, "Internet of Services" encompasses also non-electronic services that operate in the real world and that citizens and communities exploit in their lives and businesses. As key element, service "consumers" look for the ***perfect interactivity***. With "perfect" we mean here permanent (i.e. and interactivity that has no time limits), transparent (i.e. the service consumer is only concerned with the benefits of the service he/she is using), seamless (i.e. the interaction is performed using the "typical" devices of the context), and trustworthy.

The main objective of this SRA is to provide a well structured and consistent publication which reflects and covers the broad set of Future Internet aspects. The document is up-to-date with regard to new developments and evolutions of research topics addressed by the Future Internet world. The aim is to define short, medium and long-term research challenges and identify future important trends on the horizon before they have started entering hype mainstream, in order to help the European ICT community to gain a position ahead of the market.

For each technological challenge the document addresses systematically (1) state of the art, (2) target, and (3) topics and key issues to be addressed. According to the 14 challenges families, the version 1.1 of this SRA instantiates the following themes:

1) **Routing and addressing, scalability and dynamics**:
    a. scalability of routing system,
    b. information-driven routing
    c. addressing and routing information management.
2) **Resource and data/traffic manageability and the ability to diagnose**:
    a. configuration and upgrade management
    b. problem detection and root cause analysis
    c. network resource sharing and control
    d. seamless continuity between all networks
    e. event-driven architecture
    f. radio networks
    g. optical networks
    h. satellite networks
    i. exaflood management.
3) **Security, privacy, trust and accountability**:
    a. security
    b. privacy
    c. trust
4) **Availability, ubiquity, and simplicity**:
    a. resiliency against normal accidents and failures
    b. fast convergence/recovery of routing systems
    c. global connectivity coverage availability
    d. availability and reliability even in critical emergency situation
    e. quality of experience.
5) **Adaptability and future-proofness**:
    a. web 3.0
    b. seamless socialisation
    c. industry mobility
    d. adaptive interaction
6) **Operating system, application and host mobility / nomadicity**:
    a. cloud OS
    b. embedded OS
    c. cloud computing
7) **Energetic sustainability**:
    a. energy harvesting

   b. energy storage
   c. energy-efficient protocols.
8) **Conflicting interests and dissimilar utility**: Stakeholders positioning.
9) **Searchability/localisation**: Search engines.
10) **Beyond digital communication**:
   a. 3D communications
   b. behavioural communication
11) **Internet by and for people**:
   a. **e**nabling e-applications
   b. social, economical, legal and cultural viability
12) **Internet of contents and knowledge**: virtual environment or virtual and augmented reality.
13) **Internet of things**:
   a. intelligence/smart and
   b. harsh environment and integration into material
14) **Internet of services**: open service platform.

It has to be noted that several specific sub-sections are identified as "To Be Completed in Version 1.2". The editorial team has identified the related technologies as important and relevant to this SRA, for further completion in the Version 1.2. The Version 1.2 will also be up-dated and completed in order to include new topics that are addressing the FI.

Research Topics part

1.1 Routing and addressing scalability and dynamics

1.1.1 Scalability of routing system

Resulting from its expansion, the Internet routing system needs to accommodate an increasing number of sites/Autonomous Systems (AS) resulting into an increasing number of routes. This situation is exacerbated due to site multi-homing and AS multi-homing (resulting into an increased meshedness) as well as traffic engineering (by means of prefix de-aggregation). The currently observed routing table (RT) growth rate ranges between 1.2-1.3 per year: in January 2006, the number of active RT entries was about 175k entries and beginning of 2009, it is expected to reach 300k. Depending on extrapolation model, by January 2011, the RT size of a core router would reach about 400 to 500k active entries. Worst-case projections predict that routing engines could have to deal with an order of 1 Million active routes within the next 5 years. Thus, while the routing system actually prevents from any host specific routing information maintenance (routing state), carrying an increasingly larger amount of routing state updates in the routing system is expensive and places undue cost burdens on network administrative units that do not necessarily get value from RT size increases. Note that these numbers do not fully account for the deployment of mobile devices. Thus the observed trends can be further exacerbated by millions of embedded IP-addressable devices coming from building and manufacturing automation as well as control networks, i.e. for urban traffic management, smart energy or other so-called Supervisory Control and Data Acquisition (SCADA) applications.

Moreover, the impact on routing system dynamics (robustness/stability and convergence) resulting from inconsistencies (software and configuration problems, routing policies, etc.), instabilities, and topological changes/failures is progressively becoming a key concern for the operational community. Indeed, inter-domain routing scalability properties do not only depend on the routing algorithm used to compute/select the paths but also on the number of inter-domain routing messages or updates exchanged between routers. Between January 2006 and January 2009, the prefix update and withdrawal rates per day have increased by a factor of about 2.25-2.5. Routing updates require processing, and result in routing table re-computation/re-selection that can lead to convergence delay and instabilities. In this context, a fundamental dimension to take into account is the dynamics of the routing information exchanges between routers, in particular, the routing topology updates that dynamically react to topological structure changes.

The Internet routing system architecture is thus facing performance challenges in terms of scalability (the Internet routing system must be able to cope with the growing number of routers, address prefixes, autonomous systems) as well as dynamic properties (convergence, and stability/robustness) that result into major cost concerns for network designers (resulting from the impact of address prefix de-aggregation) but also system designers (in particular, for what the concerns the inter-domain routing protocol of the Internet Border Gateway Protocol (BGP). The former exacerbates the limitations of the current Internet routing system as documented, e.g., in [RFC4984]. Nowadays, the routing system must not only scale with increasing network size and growth of the Internet but also with a growing set of constraints and functionality: routers shall cope with growing routing table size even if network itself would not be growing, i.e., ***the Internet routing protocol must not only scale with increasing network size***.

In a wireless context, and as long as improvements in technology enable the deployment of large-scale networks, relevant issues to study include state information to be stored and control overhead needed to exchange routing tables as well as to measure the parameters of interest to make routing decisions.

1.1.1.1 State of the Art

Prominent research efforts have been conducted to overcome current Internet routing system limitations. Nevertheless, none of them provide scaling guarantees, and many of them represent only short-term fixes addressing the symptoms instead of the root causes i) existing routing protocols compute/select shortest paths in the topology. This leads to routing table sizes that cannot scale better than linearly. In a wireless context, routing schemes exploiting other kinds of information, such as geographic position, have been proposed.

1.1.1.2 Target

New inter-domain dynamic routing paradigms compared to the current policy-based shortest AS-path vector routing shall be investigated that provides the following properties:

- **Scalability** (measured in terms of memory/storage space consumption by the routing tables, i.e., the number of bits of routing information stored locally for the routing scheme): routing table size scaling better than Ω(n log n), i.e., sub-linear routing table size scaling (preferably Ω(log n)), where n is the number of (abstract) nodes. Note here that the number of reachable nodes, n, that the routing scheme shall support is at least of the order of 109. So, at least 3 order of magnitudes higher than the current routing protocols support today.
- **Quality** (defined in terms of stretch -of the routing scheme-: ratio between the cost/length of the routing path -as produced by the routing scheme- and the minimum cost/length path for the same source-destination pair): bound the stretch of the routing paths as produced by the routing scheme to a relatively small constant factor[3] that does not grow with the network size.
- **Reliability**: fast routing state convergence upon topology (and/or policy) changes while minimizing communication costs (in terms of number of routing update messages and resulting processing) needed to maintain coherent and timely non-local knowledge about network topology.
- **Name-independence**: accommodate routable addresses/labels assigned independently of the topology (otherwise need to split topology-dependent locator and topology-independent identifier parts in the addressing architecture). In turn, this property would facilitate support of dynamic multi-homing/mobility by the routing system.
- **Specialization**: take benefit of Internet topology properties (some of which characterize scale-free graphs) so as to optimize the routing scheme for such topologies.
- **Policy**: enable each network administrative partition to apply its own routing policy without requiring explicit exchange of these policies (or their exposure to a third party) neither mandate homogeneous policy rules for the routing scheme to properly operate.
- **Security** is also a critical element to be considered when designing a routing scheme (see Section 1.1.3).

There is no real phasing in the research process. Instead, two main research directions can be considered depending the terms:

- Phase 1 (short- to mid-term): mitigate significantly the current inter-domain routing system limitations, and, in wireless networks, intra-domain ones too
- Phase 2 (long-term): by that time it can be expected that research on new routing paradigms will provide for a suitable answer to the challenges outline here above.

1.1.1.3 Topics and key issues to be addressed

The most fundamental issues faced by the Internet architecture are the scalability and quality (stretch, convergence, and stability properties) of its inter-domain routing system. Solving these issues requires to address multiple dimensions altogether i) the routing table size growth resulting from a larger number of routing entries, and ii) the routing system dynamics characterized by the routing information exchanges resulting from topological or policy changes. Both dimensions increase memory requirements but also processing capacity of routing engines.

Solving the scalability of the Internet routing system taking into account its dynamic is challenging. Indeed, routing convergence time should not be delayed whereas scalability improvement implies minimizing the number of routing information messages exchanged to prevent routers overload (in order to eliminate "path exploration" effects). Also, addressing routing stability consistently with planned BGP routing policy implies eliminating non-deterministic and unintended but stable routing state resulting from policy interactions.

The routing schemes shall fulfil the properties listed here-above by while preserving the Internet routing system existing but critical characteristics such as "organic deployability", and support of "implicit policy routing" but also operate under dynamic network conditions. The latter means that upon topology and/or policy changes, the affected routing table entries shall be updated after performing routing path re-computation/selection. On the other hand, when designing new routing scheme, it is important to emphasize that a fundamental and unavoidable trade-off shall be taken into account between the stretch induced by the routing algorithm, the routing table size it produces (measured in terms of locally consumed memory space), and the cost of communication (the number of routing update messages that need to be exchanged between routers to converge after a topology change).

In addition to the above issues, different types of scalability concerns may also be the focus of research in the wireless context, such as intra-domain control overhead for measuring the parameters of interest for making routing decisions.

1.1.2 Information driven routing

Internet routing system shall be capable to consider associated routing information (referred to as meta-data) and metrics for path calculation such as the link quality, security level, energy consumption, priorities or location. Additionally, an efficient way of addressing groups of "users" by pointing at (groups of) terminals/devices is required in many applications that rely on a one-to-many data exchanges.

1.1.2.1 State of the Art

Routing table entries are calculated by shortest path algorithms towards destination either by accounting for the link cost (intra-domain routing) or the AS-path (inter-domain routing).

Distributed services, i.e. Content Delivery Networks (CDN), Peer-to-Peer (P2P) or mobile services cannot take full advantage on all underlying features of the network. Routing protocols base thus their decision (e.g. route computation and selection), purely on networking properties.

1.1.2.2 Target

The short-term objective (3 years) is the development of a routing scheme applicable to an Internet interconnecting from computers to sensors and that is evolvable flexible enough to add the mid-term objectives later on. Such routing scheme is expected to meet the properties identified above in Section 2.1.2.

An important mid-term objective (2015) is the usage of meta-data describing the properties of higher and lower layers to optimize the network operation and especially the forwarding/routing.

In between it is expected that dedicated research will be conducted to determine the cost/gain and cost/performance ratio of the proposed routing scheme compared to the current Internet routing system.

1.1.2.3 Topics and key issues to be addressed

The main new or additional requirements and concepts and protocols should provide location-based addressing, efficient addressing concepts for user/device groups, scalable and high-performance messaging, routing considering lower layer capabilities as well as auto configuration and network service assembling.

- **Location-based**: In Future Internet use cases which contain large scale control systems and thus a huge number of sensors, not only the sensor measurement itself is required but also the information from which sensor the information originates respectively which sensor(s) to poll to get the relevant information. Thus suitable addressing schemes and allocation processes are also required.

- **Identifier-based**: In the Internet today, multiple devices with specific properties can only be addressed either by using multicast addresses or by addressing each and every instance (unicast). None of these methods can provide an efficient way to communicate to these devices based on their identification or their attributes. Another issue is the current semantic overload of the IP addressing scheme that result in overlapping network graph termination point identifiers (referred to as topology-dependent locators/addresses) with host identifiers that are invariant with respect to the node attachment to the graph. This overload has lead to an increased number of prefixes into routing tables as node identifiers are invariant. From this perspective it is still open issue whether the routing system shall be able to route on host identifiers or locators (topology dependent addresses) and if such duplicity exists, efficient location management schemes (either centralized or distributed) should be designed for mapping purposes.

- **Meta-data based**: Instead of using only one metric-parameter to describe routing topology or path to destination additional metadata could be used that contain additional information about e.g. energy consumption, delay, link stability, packet corruption-loss (the latter are typically affecting wireless links). An advanced routing process should take – or at least be able to take – all this information into account when determining the routing path subsequently used to forward traffic. This means that the routing engine must have a real-time view on the situation of at least parts of the network, and it must be able to apply different decisions for data flows with different requirements.

- **Role-based**: For wireless networks with a high number of nodes with varying link conditions a flexible concept for the role of a node in such a network is necessary (e.g. access point, relay, router, gateway). For such a network a role-based addressing scheme has to be developed also for efficient routing schemes which balance the traffic according to the available node resources. For networks which cover large geographical areas with varying node densities routing schemes which also provide efficient short cuts based e.g. on location information are necessary.

1.1.3 Addressing and routing information management

Migration from one addressing space to another (IPv4 to IPv6 to cite the most prominent example) has clearly demonstrated the lack of renumbering mechanisms to allow for a transition from one address space to the other - in particular for customer edge equipment. As such renumbering tools were lacking to allow migration process to be operated rapidly without configuration errors (e.g. address and subnet duplicates) - IPv6 DAD feature is a detection tool.

1.1.3.1 State of the Art

Renumbering operations are performed using either non-standard ad-hoc tools. There is no know renumbering procedure or tool that can efficiently cope with the number of IP termination points as currently deployed across the Internet.

1.1.3.2 Target

Addressing and routing information management is a short-term objective aiming at providing the toolset for renumbering and addresses allocation. As such the target is to investigate the space of possible solutions and derive a small set of candidates. Without such tools any routing scheme that would require transition from one address space to another would not be deployable.

1.1.3.3 Topics and key issues to be addressed

New routing paradigms relying on new addressing space (being either locator or identifiers - or both -) or existing routing designed with new addressing schemes (e.g. separation of the location and identification function of the IP address) will require migration from the currently used schemes. In this context, renumbering tools will be required. On the other hand, there is still no routing state and information base transfer tools for fast migration beside use of MIB modules.

1.1.4 Routing System Security

1.1.4.1 Introduction

Security constitutes a critical element to be considered when dealing with the current Border Gateway Protocol (BGP) inter-domain routing system of the Internet or designing a new routing scheme. Indeed, one of the areas of vulnerability for large scale Internet environments lies in the area of inter-domain routing. Routing protocols, and in particular, inter-domain routing protocols are subject to attacks and threats that can harm individual users or the network operations as a whole.

Common attacks that can harm individual network operations as a whole in particular, the routing system, include:

- **Falsification**: an action whereby an attacker (the originator or a forwarder) sends false routing information leads to usurpation of some network resources and related routers, deception of routers using false paths, and disruption of data planes of routers on the false paths

- **Interference**: is a threat action whereby an attacker inhibits the exchanges by legitimate routers by adding noise, by not forwarding packets, by replaying out-dated packets, by inserting or corrupting messages, by delaying responses, by denial of receipts, or by breaking synchronization
- **Overload**: is a threat action whereby attackers place excess burden on legitimate routers by attackers triggering a router to create an excessive amount of routing state that other routers within the network are not able to handle.

Routing protocols are subject to threats at various levels. A threat is defined per [RFC4593] as a potential for violation of security, which exists when there is a circumstance, capability, action, or event that could breach security and cause harm. Threats can be categorized as threat sources, threat actions, threat consequences, threat consequence zones, and threat consequence periods. Security threats to BGP point-to-point sessions can thus be classified as follows:

- Threat source: any host in the Internet that can reach one of the BGP peers. A threat source can also be a wire tap agent, either passively listening to the BGP session, or actively modifying BGP data in transit.
- Threat action: sending of forged BGP packets, or sniffing BGP traffic.
- Threat consequence: break of confidentiality by wire tapping, break of integrity by faking BGP messages or hijacking a session, or denial of service, for example by sending fake TCP reset control packets, terminating a BGP session abnormally.
- Threat consequence zones: the BGP peering session itself, the BGP routing tables on the affected peers, or potentially larger areas of the BGP routing system.
- Threat consequence period: depending on the attack and the implemented counter measures, a threat might be preliminarily mitigated by changing the MD5 key, unless it is a threat against MD5 itself, in which case the threat period is indefinite.

Other type of attacks from legitimate BGP speakers which are trusted (implicitly or explicitly) occurs when the source of the attack in this case could be either a misconfiguration, or an attacker gaining illegitimate access to a router, for example through SSH brute force attacks.

1.1.4.2 State of the Art

Limitations of current BGP session security mechanisms (between BGP peers) include:

- The use of static keys, which tend to be changed infrequently, and often not at all. However, the relative complexity of changing MD5 keys on all BGP peering sessions, specifically when securing sessions to routers maintained by two different organisations, means that keys are often not changed at all. This makes long term brute force attacks feasible.
- The key change process needs to be coordinated between both sides of the BGP session, making this an operationally expensive exercise.
- The keys are typically chosen by humans, and expressed in ASCII; therefore, the entropy is typically small, making the keys easier to determine.
- Dependence on the MD5 algorithm, which brings two problems: MD5 is not considered strong enough for the future as documented in [RFC4278]
- Security architectures should also allow a choice of algorithms, to have an alternative in case serious vulnerabilities are discovered in an algorithm.
- When confidentiality of BGP routing information is required can only be achieved today by securing the BGP session with IPsec.

1.1.4.3 Target

Coping with the routing system security requires to:

- Design and specificy extensible inter-domain routing security architecture that must be capable of supporting incremental additions of functional components

- Design and specificy routing functionality modules within this architecture to address specific secure routing requirements detailed here above.

- Use certification objects within this secure routing architecture for supporting i) the distribution of authorization and ii) authentication of the originated routing information. Indeed, the basic security questions that can be posed regarding routing information are whether the originating Autonomous System (AS) is authorized to advertise an address prefix by the holder of that prefix, whether the originating AS is accurately identified by the originating AS Number (ASN) in the advertisement, and the validity of both the address prefix and the ASN.

- Related to the previous point, one of the main targets is the level of trust than can be ascribed to attributes of a route object in terms of their authenticity, including consideration of the AS Path attribute.

- Address the specific the security requirements for single BGP sessions, i.e., the connection between two BGP peers, implies i) to ensure unicity of BGP speaker Identity, ii) to support means for BGP peer authentication, iii) to provide methods to ensure integrity of routing message exchanged between speakers, iv) to have mechanisms to encrypt BGP messages in transit (so as to ensure confidentiality), v) to detect and protect against anti-replay attacks (methods to detect and prevent replay of BGP routing messages), and vi) to protect the BGP session against denial of service attacks, targeting the availability of the BGP session.

- The newly proposed security concepts/principles/models and corresponding components/mechanisms shall be designed modularly and shall assume weak coupling with the routing protocol specifics/underlying communication mechanisms. This, in order to be re-usability beyond specific policy-based shortest-AS path vector routing such as BGP

1.1.4.4 Key issues and topics to be addressed

Approaches to routing system security shall enable each network administrative partition to apply its own security rules (because various parts of the network may require more or less stringent security rules) starting from a common baseline without mandating homogeneous security rules for the routing scheme to properly operate.

The routing system security (and its model) must support altogether:

- To ensure **deployability**: an incremental deployment model which will provide some benefit for participants (e.g., routers, network partitions)

- To ensure **robustness**: the ability to maintain and return to a significantly converged state without the need to rely on systems external to the routing system, i.e., reduce reliance on external systems to the greatest extent possible,

- To **prevent performance degradation**: routing scheme convergence speed, with a security system in operation, should deliver equivalent performance than the same routing scheme running without the security system in operation. It is worth noticing that resulting from the routing update exchanges, updateful routing schemes are more prone to security attacks and threats than updateless routing schemes.

1.2 Resource and data/traffic manageability and diagnosability

By resources, we mean either system resources (CPU, memory, storage and information/data processing) and network resources (forwarding/switching capacity, queuing capacity, link/medium capacity).

1.2.1 Configuration and upgrade management

Configuration and upgrade management becomes a common practice whereas the practice of continuous patching results in relative decreasing gain but increasing complexity.

Configuring networks is a complex and costly task is that error-prone when performed manually. Indeed, nowadays, networks can comprise from hundreds to thousands of devices that require manual configuration, equipment-by-equipment. Current configuration task is usually performed using a trial-and-error approach by means of a diversity of vendor-specific languages. Each of these languages has different syntax, and semantic, in addition to support different features. Also, a lot of code duplication results from manual configuration operations. As main consequence, network misconfigurations are frequent. Human factors, is the biggest contributor to misconfiguration that is responsible for 50 to 80 percent of network device outages. In 2002, R. Mahajan et al reported that 0.2 to 1 percent of the BGP table size suffer from misconfiguration. Such misconfigurations have led and still lead to large- scale problems (e.g., YouTube in 2008). Moreover, management costs keep growing due to the increasing complexity of network architectures.

In Industrial scenarios those problems arise in the commissioning phase, the roll-out of a properly planned network still requires many manual steps leading to potential mis-configurations. In the operation, replacement of defect devices, upgrades and installation of additional equipment is a costly and error prone task.

1.2.1.1 State of the Art

Two techniques are currently used to mitigate these effects:

- **Static analysis:** uses pattern matching on configurations to detect misconfigurations and compares configurations to given specifications. This technique is effective to detect some critical problems but requires a priori specifications of what a valid network is. It also suffers from disparity of languages when analyzing heterogeneous networks.

- **Data mining:** performs statistical analysis directly on configurations and infers network-specific policies, to subsequently perform deviation analysis. This technique is completely independent of a priori validity specifications but is too verbose (resulting from non-error messages). It also shows the same kind of difficulties than static analysis when analyzing heterogeneous networks.

To solve the heterogeneity problem, both techniques can be enhanced by means of an intermediate representation of the configuration but this technique does not relax the burden associated to the configuration phase itself. However, in both approaches, the network configuration validation is still performed a-posteriori.

1.2.1.2 Target

This objective is to apply well-proven software engineering techniques to network configurations. The expected benefit is to exploit a well-proven formal process to validate network configurations. The processes described may require further adaptation in order to cope with the specifics of the different platforms comprised in the Internet infrastructure.

1.2.1.3 Topics and key issues to be addressed

In order to reach this target, there is a need to address the following topics:

- **Automation of network configuration**: configuration of network parameters is frequently a high-skill, error-prone manual task. There is increasing need to automate configuration by identifying and incorporating best practices.

- **Validation of network configuration**: using a high-level vendor-independent representation (i.e., abstraction) of a network configuration, the proposed technique makes use of a Rule-based validation process and Generation process to produce configuration of each device in its own configuration language.

- **Network and system self-management**: in order to lower the level of required skills and effort to manage such networks. These management systems shall support highly distributed architecture to cope with the size of and with the high level of dynamics in and between the networks.

- **Auto configuration and network service assembling**: Internet of Things requires highly dynamic and flexible network domains. The handling of such systems is just feasible if the network configuration is automated and adaptable to the actual situation.

- **Auto-configuration and self-management mechanisms in wireless/radio networks**: to autonomously deal with dynamic configuration changes (for example, small footprint networking technology), including multi-mode multi-band radio, radio resource management, instant network composition and decomposition, automatic roaming agreements, interworking between new and legacy management systems, multi-hop radio networks, software configurable radio interfaces, multi-link phones (terminal, router and repeater functions and flexible quality of service).

1.2.2 Problem detection and root cause analysis

Increasing importance of diagnosability is caused by a performance drop resulting from an growing Internet infrastructure and associated (system engineering) complexity. The root cause is the "absorption" by the systems (routers but also other networking equipment) of the network technologies limitations and continuous "patching".

Indeed, existing solutions are no longer adequate to allow for correlation of a priori unrelated events that may impact (some part of) the infrastructure e.g. routing system.

1.2.2.1 State of the Art

Most diagnostic systems are designed on an ad-hoc basis, reactive to already encountered situations (predictive and proactive capabilities of most existing tools are limited if not inexistent).

1.2.2.2 Target

The medium-term objective is to provide for the necessary automation of problem detection and identification (ranging from anomalies to attacks).

The long-term objective is to devise a system able to suitably respond to these problems (without oscillatory or coupling effects).

1.2.2.3 Topics and key issues to be addressed

Processing of network monitoring data to detect root causes of problems are subject to five main challenges:

- Inherent complexity in precisely characterizing an event,
- The correlations and trends between events are hidden within large amounts of data that are associated to these events,
- The conditions are changing over time (this is particularly the case for the routing environment characterized by the variability of topology but also routing policy),
- The amount of available data is too large for handling by human intervention,
- New events are constantly detected and discovered.

In that context, several issues require specific attention:

- **Routing**: analysis of BGP update messages (e.g. BGP bogon messages) to deduce the source of anomalies or to act to counter failures is notoriously difficult. There is still need for research on root cause analysis techniques to facilitate troubleshooting - a good example is the problem induced by more specific address prefix compared to a destination prefix already present in the routing table.
- **Traffic**: distributed anomaly detection and root cause analysis (as the current paradigms, techniques and toolset for debugging the Internet are limited).
- **Security**: distributed attack and intrusion detection mechanisms.

1.2.3 Network resource sharing and control

The end-to-end and fate resource sharing principles are generally regarded as the key ingredients for ensuring a scalable and survivable network Internet design. This principle ensures that the network provides a general service and that remains as simple as possible (any additional complexity is placed above the IP layer, i.e., at the edges) so as to ensure evolvability, reliability and robustness.

On the other hand, requirements for maintaining flow rate fairness and congestion control cannot be realized as a pure end-to-end function only; both can only be resolved efficiently by some cooperation of end-systems and the network. We have thus a trade-off in between requiring further network assistance and endangering scaling and survivability of the network (violating these principles should be avoided).

1.2.3.1 State of the Art

Congestion control challenges are known from many years - the problem being that they are becoming more and more complex to solve (heterogeneity of data link layers and TCP stacks being certainly one of the main reason but also anonymity in exactions against the Internet shared resources).

1.2.3.2 Target

The long-term objective is to lay progressively a charter for an internet citizenship - *code de conduite* - that will be shared and respected by Internet users. The problem remains open on which incentives can be put in place in order to enforce such behaviour - beside explicit congestion control scheme - reputation cost should be seen as a possible answer.

On the other hand, the key concerns will stem from the amount of control resources needed to manage a steadily increasing (about 50% per year) amount of traffic. If the ratio (between the increasing in amount of control resource and the increase in traffic) remains below 1, thus sub-linear, then we could pretend scaling.

1.2.3.3 Topics and key issues to be addressed

Congestion control includes many research challenges that are becoming important as the network grows and the heterogeneity of TCP stacks increases. In addition to the issues that have been known for many years, these challenges are generally considered to be open research topics that may require more study or application of innovative techniques before Internet-scale solutions can be confidently engineered and deployed.

- **Congestion control and network resource sharing**: the future Internet will incorporate network mechanisms to enforce sharing of resources between users and between traffic flows. It is important to understand exactly what mechanisms are necessary and how they will interact with end-to-end congestion control algorithms. Current reliance for resource sharing on end systems cooperatively implementing TCP or a TCP-friendly surrogate is clearly unsustainable.

- **Accountability:** end systems should be made accountable to the congestion they cause when using shared network resources. Indeed, the congestion they create prevent flow rate fairness with concurrent traffic flows engaging traffic sources into practices such as aggressive TCP stacks, multiple parallel TCP connections, anticipative TCP segment acknowledgement to boost transmission, etc. From a microeconomic viewpoint, the principle of accountability may be also combined with congestion charging so as to incentivize end-systems behaviour. It is of course necessary to device implementations that remain acceptable to users who expect charging and resulting pricing to be both transparent and predictable.

- **Traceback systems:** very little research efforts have been dedicated to provide a traceback systems that would allow to retrieve the source of traffic that induces serious network congestion (or endangers network infrastructure by intrusion).

- **Enhancing best effort resource control:** the best effort model of the current Internet continues to provide satisfactory service for most applications most of the time. Rather than increasing complexity by the introduction of unproven stateful QoS mechanisms (hence toward stateless resource and traffic control), there is scope for enhancing the best effort paradigm with lightweight mechanisms that arbitrate resource sharing and act to limit service degradation in overload. At best such system shall become stateless compared to the current situation where most (if not all) resource control mechanisms are stateful (meaning a state is maintained inside the network that accounts for the current resource usage).

- Investigating the role of cross layer designs of congestion control and scheduling.

1.2.4 Radio Networks

Extensive and high quality ubiquitous wireless access cannot be managed with the currently established infrastructure or with emerging ad hoc radio network technologies as the traditional radio access schemes will not scale to large collections of nodes and is destined to be plagued with unmanageable interference, and network congestion. To develop such scalable and dynamically pervasive wireless access, there is a need for fundamentally new methods to address spectrum sharing cooperative and adaptive link management, opportunistic access, information routing, and quality of service management.

Current wireless access networks have been developed in a fragmented way, cellular systems with spectrum dedicated to operators being one example. In the future a great deal of flexibility is needed in terms of how networks are constructed and operated, how spectrum is used most efficiently between several operators and technologies for managing the flexibility. The future wireless access schemes should be developed to facilitate flexibility for the allocation of throughput values per user, high aggregate average throughput per area, low latency and high cell edge capacity, as well as high speed access with somewhat modest power consumption requirements and different access range as well as relatively short range techniques having the power saving (lower power wake-up radios etc.) as some of the key driver. It can be foreseen that on top of current networks and architectures several new topologies will be applied. For example local mesh extensions to improve connectivity at e.g. cell edges, public areas, home/office environment, vehicular environment etc. would improve the coverage and capacity of existing cellular networks. In such architectures, new radio interfaces suited for multi-hop wireless transmission will need to be developed; including advanced relaying, network-oriented channel coding, and the development of a suitable protocol stack, in particular medium access schemes.

The demand for wireless communications will continue to increase at an accelerated pace, which with the current paradigm of rigid spectrum allocation and licensing will undoubtedly lead to a spectrum crisis, even with the development of highly spectral-efficient transmission techniques. Nevertheless, considerable spectrum might be available, especially for local area communications, if both the space and time dimensions are considered. Hence the problem is more a problem of inefficient access to parts of spectrum that are under-utilized rather than actual spectrum shortage.

While such an approach represents a major deviation from the current paradigm of spectrum allocation, the debate on alternative and more efficient spectrum management policies has started in the standardisation bodies and national regulation agencies, but to support the eventual step of going towards a more liberal approach of spectrum management, the decision-makers need proof of evidence of the viability of technologies that would enable the alternative approaches.

Providing novel mechanisms for enhanced and more efficient spectrum usage would support the i2010 initiative of the European Commission towards the Information Society. Opportunistic communications would facilitate the emergence of new business models. For instance, it would support the implementation of much heralded secondary spectrum market, by using or leasing some licensee frequency bands for a limited time period and under some specific constraints on interference level.

Cognitive and docitive radio as well as new business paradigms allow flexible use of spectrum resources that expand wireless markets and enable the true future wireless internet. User groups create own ad-hoc networks interchangeable with commercial infrastructure. New ways to address rapidly increasing data rates will be supported, reflecting consumer needs. To that aim, the design of agile and highly reconfigurable physical layers is a must. This implies, for instance, the need for developing transceivers capable of operating at different frequency bands (within a huge and adaptable range), and handling variable modulation formats (trans-modulation and adaptive modulation). Furthermore, these systems must target high spectral and power efficiency, and be based on Software Defined Radio (SDR) strategies in order to meet the required level of integration and interoperability. The introduction of cognitive radio technologies enables wireless access to the future internet by improving the spectrum utilization for communication purposes. But in a wider context, the "cognitive" principle should also be applied not just at the link level but at a network-wide level. This is fully justified due to the increasing dynamicity and complexity (in technical and administrative terms). Therefore, the term cognitive may also be employed as "cognitive networking", i.e., not only focusing on radio level parameters, but also on network-wide parameters as well.

1.2.4.1 State of the Art

a) Radio access

Spectral efficiency and fundamental capacity limits at the radio link is now very close to the Shannon capacity limit particularly with 3GPP LTE and HSPA+. When this capacity is viewed at a cell level, multi-cell structure and multi-users, there is massive reduction in area spectral efficiency. This is mainly due to excessive signalling exchanges on the radio access imposed due to inflexible and centralised nature of design and operation of cellular system. The inflexibility prevents dynamic allocation of capacity to locations where extra capacity is required, leading to locations where spectrum is heavily under-utilised whilst some areas starve for capacity. There is need to focus on performance of radio access networks with close consideration on achievable performance at system level for new and flexible system architectures/topologies and distributed/ cooperative protocols/schemes between cells, networks, operators and different systems.
The new flexible systems should define relationship between devices-networks, device-device, cell-cell and network-networks

b) Opportunistic communications

This is fundamental change to the way resources are allocated to an operator, network, cell and to users. Currently resources allocations are pre-defined and fixed to some extent. Opportunistic communications exploits local knowledge and uses resources without causing instability to a system operation whilst maximising resources (radio, network, processing, memory, power) efficiency, operational cost and energy efficiencies. To do this besides the definition of the above relationships, there is need to specify the type of local knowledge, how to obtain them their integrity/reliability and how they should be fused together.

c) Cognitive Radio and Cognitive Radio Networks

Cognitive radio and networking are concerned with specification of appropriate mechanisms that should be in place to enable capturing, fusing and utilisation of local and distributed information/knowledge for flexible and stable allocation of radio and network resources adaptively. This is not limited to one cell or one network, one operator and one system. It also includes all systems using licence and license-exempt bands. This specification of relationships encompasses device-device, network-device and cell-cell interactions in exchange of useful information as well as cooperation in transport of each others communications. To minimise network operation costs, cognitive radio and networking should be carried out through new self-organising network management system.

1.2.4.2 Target

a) Radio access

In the development of future Radio Access Networks (RAN) the efficiency will become even more important issue than ever. Operators publicly providing RAN solutions are in a new business model where they need to compete with other operators and access technologies for various applications. New solutions for access technologies (both user and backhaul links) and signal processing methods are needed which result in efficient use of spectrum and network resources, and higher throughputs, through appropriate cooperation and adaptation techniques. Simple and low-cost deployment of access infrastructure is of paramount importance to the overall economy of access provisioning. The target is not necessarily higher bit rates as in the past but *high and uniform* capacity in most of cell coverage such as 85% of cell area. Autonomous self organization is needed to continuously operate at the optimum point under dynamically varying conditions, as well as capabilities to easily incorporate (as yet unforeseen) future services and requirements.

Radio access network and backhaul system research are part of the overall system design. It needs to be emphasized that radio interfaces for the future should be designed jointly with the overall systems. However, achievement of major advances in, e.g., RAN capacity, power efficiency, distributed network control, new network topologies requires also independent and highly focused research at different layers. This results in an integrated and iterative design process, where the major difference with the past is that the overall system design is much more emphasized. New design criteria such as energy efficiency need to be considered together with capacity and throughput for developing sustainable technologies for the future. Also the development of future Internet from mobile wireless perspectives must be carefully monitored as the wireless component will be setting the most stringent requirements for the development of Internet. Inclusion of sensory data to be a natural part of the wireless networks will set totally new requirements for the networks security matters.

In-band mesh networking (i.e. backhaul sharing spectrum with user access) is increasingly being considered as a solution to linking WLAN access points, but suffers from capacity limitations as traffic levels grow. Out-of-band mesh topology instead promises to cope with the capacity and performance requirements if adequately designed.

One major paradigm shift driving the future RANs and backhaul systems development is related to more liberal spectrum allocation policies, leading to simplicity in regulation and efficiency in spectrum usage. Opportunistic communication technologies based on the concept of cognitive radio must be extensively researched and developed for this purpose.

b) Opportunistic communications

The development of frequency-agile terminals that can sense holes in the spectrum and adapt their transmission characteristics to use these holes may provide one tool to address and take advantage of the spectrum under-utilization. Although, some current adaptive radio systems already exhibit the feature of automatically adjusting their parameters for a given standard, the development of truly agile terminals requires to go much further, since it is not possible for the designers to foresee all the possible scenarios and then provide deterministic schemes for the selection and reconfiguration.

Opportunistic communication challenges fit in the general framework of the Cognitive Radio research, focusing specifically on techniques exploring mainly the frequency dimension to find and use the best spectrum and space opportunities in a fair manner. Research needs to be conducted on concepts, mechanisms and architectures for cognitive radio terminals and networks. Business advantages of opportunistic spectrum usage in both time and space need also to be demonstrated.

c) Cognitive Radio and Cognitive Radio Networks

Cognitive radio systems locally exploit under-used spectrum bands for radio communication enabling new future internet services and new related business opportunities.
The introduction of cognitive radio technologies might be happening in a phased approach:

- Cognitive Radio access in unlicensed bands (medium term),
- Dynamic Spectrum Access shared with a limited number of specific technologies (medium to long-term),
- General exploitation of spectrum opportunities without restrictions on specific technologies and frequency bands (long-term),
- Energy efficient radio transmission classes.
- Cognitive networking and its associated measurement needs.

The cognitive radio evolution will provide significantly increased spectrum utilization and provides access to new frequency bands currently not available for mobile end-user services. It is envisaged that the process of cognition is supported by an emerging and largely unexplored concept of docitive networks where nodes essentially teach other nodes with the prime aim to reduce cognitive complexity, speed up the learning process and draw better and more reliable decisions, in order to support next, as well as beyond-next generation applications. These dramatic improvements are required to make the wireless internet a reality.

1.2.4.3 Topics and key issues to be addressed

a) Radio access

The target is to develop future integrated systems in a unified manner. The commonalities of different access networks are used to support developing a flexible radio for the future whilst maximizing the unique capabilities of different types of networks by somewhat independent system optimization. The identified major research areas pertain to user link (radio access) as well as backhaul links between access points and concerned with deployment concepts, radio interface technologies, reconfigurability, spectrum and coexistence, trials and prototypes as well as regulation and standards.

The Radio access research topics include:

- Joint optimization of coverage, capacity and quality-of-service techniques through co-operation and adaptation techniques involving different layers in protocol stack assisted by information from physical layer and radio environment,

- Efficient mechanisms for joint exploitation and operation of available diversities in time/space/frequency/code/power domains,
- Development of radio access schemes with high peak aggregate spectral efficiency for noise-limited environments and high area average aggregate spectral efficiency values with high cell edge spectral efficiency for interference-limited environments,
- Energy efficiency in future wireless networking and radio technologies,
- Radio access schemes with high flexibility and adaptability of data rate allocation to users,
- Novel multicarrier modulation techniques (such as filter bank multicarrier modulations) for high spectral efficiency and reconfigurability.
- Investigation of alternative, low cost deployment concepts, new network topologies and system architectures beyond the classical cellular approach, such as relay-/multi-hop-based concepts, meshed networks, distributed antennas and radio over fibre for signal distribution,
- Intelligent resource (frequency, battery, power, hardware, software) discovery and management techniques,
- Evaluation of Network Information theoretical limits of cooperative and self-organising networks and advances in coding design and signal processing schemes to achieve these limits,
- Investigation of the impact of new frequency bands for future systems on the radio propagation and specification of appropriate output power levels to ensure compliance with relevant guidelines and regulations related to human exposure to radio frequency electromagnetic fields,
- Development of radio access and networking schemes for unpaired frequency bands for mobile cellular systems to take full advantage of radio channels reciprocity and MIMO techniques capacity gains,
- Autonomous networking concepts and related technologies for femto-cells in home and public areas,
- Networking concepts and information filtering for supporting dynamically changing information for e.g. vehicular networking,
- Development of methods for supporting efficient multicast transmissions in cellular systems with significantly different fading channel conditions for the links to and possibly different levels of meaningfulness of the transmitted information for various recipients,
- Development of the self-configurable user terminal by the software defined radio technology to assure mobility to the final user and an efficient interoperability among different networks,
- Development of software defined radio technologies for multi-standard base stations and reduce their cost by diminishing diversity of hardware platforms.

b) Opportunistic communication

The main areas of opportunistic communications requiring research advances include:

- Spectrum sensing techniques to acquire relevant information from the radio environment and define the feasible operating region,
- Distributed and centralized decision making processes to allow intelligent choice of spectrum access, based on spectrum access policies available or unused spectrum,
- Optimisation procedures to define the best waveform when applicable given the environment,
- Identification and dissemination of spatial opportunities in opportunistic radio networks and collaboration strategies to efficiently make use of them on a network level,
- Adaptable and flexible broadband RF front-ends for variable carrier bandwidth,
- Adaptable baseband architectures that may efficiently adapt to the radio environment,
- Scalable and reconfigurable techniques to support all digital RF flexible transceiver architectures,
- System-level studies to evaluate the effectiveness of the proposed techniques in terms of system parameters (e.g., capacity, and quality).

c) Cognitive Radio and Cognitive Radio Networks

Innovative ways to exploit the radio spectrum need to be addressed. The Cognitive Radio Architecture needs to be define, spectrum usage models are to be developed to allow the revolutionary change of wireless communication systems towards cognitive radio systems and networks.

The following key issues and technology areas need to be researched:

- Technology and Concept Enablers for Cognitive Radio:
  - Cognitive spectrum sensing and utilization,
  - Cognitive radio system design based on further improved, appropriate channel models,

  - Self-organization, optimization and healing for uncoordinated network deployments,
  - Flexible spectrum & resource use,
  - Techniques for cognitive radio transceivers – amazing RF,
  - Distributed network and communication control,
  - Cooperative communication, sensing and decision making,
  - Transport independent connectivity,
  - Co-design of communications and data fusion to minimize the transmission needs and optimize network resource usage,
  - Spectrum Etiquette and decentralized spectrum decision making,
  - Docitive radio and network designs.
- Network Topologies for Cognitive Radio Systems:
  - Multi-operator local area wireless internet access,
  - Ad-hoc and mesh networking for terminals, relay nodes and access points,
  - Distributed, autonomous user-centric network topologies.
- Energy efficient Cognitive Radio communication:
  - Energy efficient radio equipment and protocols - adapting the radio utilization to the actual traffic needs,
  - Energy efficiency considerations related to networking topology and smart routing enabled by ubiquitous/transport independent connectivity,
  - Optimal application/service oriented routing over different access schemes and network topologies with highest energy efficiency.
- Techno-Economics of Cognitive Radio:
  - Modelling of radio usage patterns,
  - Emerging business models enabled by CR – identification & assessment based on techno-economical and game-theoretic methods,
  - Determination of the Cognitive Radio cost structures.
- Cognitive Networking
  - Measurement architectures for cognitive networking
  - Techniques for inferring parameters of interest based on partial information
  - Autonomic reconfiguration and optimization of wireless networks
  - Artificial Intelligence (AI) techniques, such as Neural Networks, for cognitive networking.

1.2.5 Optical networks

Optical Communication networks underpin the whole of the Internet architecture. Without optical fiber communication networks, the Internet would be greatly limited in speed and distance between nodes. The importance of optical systems and networks and the interaction with the IP transport protocols should not be underestimated in the construction of the next generation Future Internet network.

The consideration of optical networks should be in two distinct areas:

- Firstly, the evolution of backhaul and transport networks used to provide very high bit rate connections to and between local hub sites and major ISP sites, as well as the transoceanic/ intercontinental connections which are essential to the backbone Internet architecture.

- Secondly, the provision of a high-speed fiber optic connection to the home, the street cabinet or very local access point.

- The need for increased backhaul capacity and connection speed will be driven by an increased demand in the metro and access network. This access network increase is in turn driven by the increased take-up of high speed internet services for business, residential and mobile customers.

1.2.5.1 Optical Broadband Connections

Broadband connection to each dwelling is becoming a commodity in most countries. The number of broadband subscribers in the OECD countries increased by 14% from 221 million in June 2007 to 251 million in June 2008.

Broadband penetration rates rose from 18.6 to 21.3 subscriptions per 100 inhabitants in the same period. Over the past decade these connections to the final users have shown a constant increase in performance, with 'fibre to the home' (FTTH) making even higher speeds possible. Speeds of hundreds of Mbit/s per user are reasonably achievable in the foreseeable future, backed up by standards such as Gigabit Passive Optical Network (GPON). FTTH is today widely deployed in countries like Japan and Korea, while in Europe and in the US several companies are developing detailed commercial plans for mass deployment of FTTH. It is thus possible to envisage a scenario in which a large number of users will be offered a very high-performance connection directly to their homes.

Following the empirical Nielsen Law, the annualized growth rate of broadband connection speed is 50% (this value is also verified by the FTTH Council Europe). Following this Council, high-end broadband usage is growing at 20% a year;, and FTTH broadband homes in Europe drive three times more traffic than ADSL.

Consequently, high data-rate services such as TV programmes or video on demand over xDSL are currently available and commercialized to end-users.. New mass-storage devices such as media renderers and storage servers are on the market, both high definition television (HDTV) and 3D television (3DTV) are progressively made available. All these home devices offer not only demodulation of digital broadcast programmes and access to remote services by operators' networks, but also high connectivity to end devices such as TVs, home cinema or PCs. Home networking is therefore growing, while the progress of mobile communications helps to extend the experience of multimedia services outside homes. This triggers major changes in the communication networks, from access to core, both in terrestrial and submarine networks, where photonics has played a key role and will continue to do so.

First-mile/last-mile access technologies still rely on a high quality, high speed optical network to deliver increased capacity to the access points for any of the above technologies, being wireline or wireless. Without a significant increase in the access network rates, it will not be possible to provide high speed services to densely populated areas. In rural areas, the service requirements are the same, but the delivery mechanism may be slightly different. Optical fiber will likely be the only wireline access technology capable of providing the capacity needed for future broadband Internet. The structure and architecture of this last mile access network will need to be the topic of study and will be dependent on economic and regulatory considerations as well as purely technical. There have been some trial rollouts begun in both Scandinavia and Holland which have highlighted the benefits of an improved access network in the services that can be offered and the benefits generated.

Since their introduction thirty years ago, photonics technologies have greatly contributed to the massive development of communication networks. It is highly likely that they will further sustain and enable new applications requiring high bandwidth capacity. The rapid pace of development in photonics will continue to lead to the increases in network capacity and performance that are necessary to support innovative applications. Different constraints will drive the evolution of optical networks: increasing bandwidth demand from continuously renewed applications (e.g., multimedia content exchanges and HDTV - 3DTV over the Internet, e-science computing, etc.). Future applications will require guarantees in terms of service (e.g., upper-bounded latency, minimum available bandwidth). Support of these applications will be achieved not only with equipment breakthroughs (e.g., development of higher data rate transmitters and receivers) but also through several levels of **convergence** in optical network architectures. In addition the increased data and video content of the Future Internet will have a significant impact on the internal processing requirements of the devices supporting the infrastructure, for example the routers and servers may need very short reach internal and external optical interfaces to achieve the data rates required and implement the power savings that will be demanded of the technology in the future.

1.2.5.2 State of the Art

Four major trends and one key requirement are driving photonics in telecommunications: increased speed, optical transparency, dynamic interaction with IP/MPLS based control plane and reduced power consumption. The se four trends together, with the over-riding need to reduce cost will contribute to a more efficient network to support the needs of a Future Internet.

The development of new optical technologies and the enhancement of existing components to reduce size, power and cost will be a fundamental part of a Future Internet Network.

The drivers of photonics suggests that its future expansion will be made along (1) Make networks faster, (2) Make networks more transparent, (3) Make networks more dynamic and (4) Make networks greener.

These paths correspond to four market drivers that pull simultaneously, but cannot all win simultaneously. It is therefore important that the European industry benefit from research along all four paths in order to preserve its leadership.

More transparent optical networks

Too many optical-electrical conversions are performed in today's optical networks, from transport to access networks, and the potential of photonics technologies to manipulate light itself remains largely unexploited. Increasing optical transparency (as opposed to opacity) means removing these conversions as much as much as possible. It will benefit to the transport but also to the access networks, by allowing several bit-rates, several modulation formats, or several radio standards to travel across the same generic fibre infrastructure. In particular, transparency will make possible the cost-effective convergence of some networks, e.g. radio and fixed access, or metro and access.

Today's optical transport networks are mainly opaque, i.e. they consist of electronic nodes connected by point-to-point WDM links (incorporating also optical-electrical conversions at the terminal ends). The on-going introduction of transparency through optical cross-connects based on wavelength selective switches has already removed some limitations to the development of network capacity. In the ideal scenario, an optical data stream enters the network though the input node, possibly travel across several intermediate nodes, and reaches its destination node without conversion to electronics along the route. Numerous challenges remain to be solved in order to create fully meshed optically transparent networks or sub-networks (also referred to as "islands"). For example, longer distances will need to be bridged, across a greater variety of fiber type than today's. This will require novel link designs, with appropriate dispersion maps, and to revisit all the performance estimators, that have already become obsolete. The interactions between signals at various bit-rates, travelling across a variety of fibre types will cause new propagation impairments (nonlinear effects, primarily) that have to be characterized and contained. The accurate assessment of the distortions stemming from transparent nodes in terms of cross-talk or filtering will need to be included in this picture as well. In order to contain the above spurious effects, coherent detection and massive digital signal processing will most likely be very helpful. They will deserve particular research focus. The all-optical processing techniques for signal regeneration (preferably of all the wavelength multiplexed signals at once) or for wavelength conversion are also promising techniques. They could not only help to expand transparency further, but also to bring about wavelength agility and, hence, further save on the number of terminals.

The requirement for more transparency also spreads in optical access and home networks for a simple reason: the distribution of many heterogeneous data formats and communication applications will tend to convergent optical distribution network architectures characterized by a high level of transparency, so as to cope with all types of traffic in a cost-efficient and energy-efficient way. Radio over fibre techniques will be for example a key technique towards more transparency in optical access and home networks, leading to convergence of fixed and mobile networks. Long reach optical access networks (up to 100km) will allow convergence of metro and access networks, with WDM and cheap optical amplification as a common denominator and colourless customer modules as a pre-requisite. This trend towards more transparency may largely rely on the use of wavelength and/or sub-carrier multiplexing techniques, which can be combined with transparent optical or radio-frequency processing, alleviating the need to perform digital processing in all parts of the network. Hence, the convergence of metro and access could be eased if the aggregation and distribution of signals are performed by optical means. Similarly, the convergence of home and access networks would clearly benefit from the introduction of optically transparent home gateways, which remain to be developed. Transparency has the additional advantage of contributing to more energy-efficient networking without decreasing flexibility and agility. Overall, optical transparency is a useful feature for decreasing cost (cost/bit) and energy consumption (J/bit).

More dynamic optical networks

The increasing competition on leased-lines and Virtual Private Network services strongly encourages operators to offer quicker provisioning of connections, or even customer-controlled switched connections at the transport network level. The dynamicity of the optical network is thus related to the possibility for the network to automatically and dynamically control and manage connections, either for protection or restoration purposes in case of equipment failure, or for traffic engineering purposes, or at the customer's demand. In a longer term view, a truly agile network will require self-learning and auto-discovery of the available resources, making it really zero-touch. It will thus pave the way towards truly dynamic optical circuit switching or even optical flow switching (switching very large bursts of packets). The introduction of optical cross-connects is one of the first requirements for transport network dynamicity. But dynamicity also requires a control software (or plane) of the network. In each node, it should drive the configuration of the optical cross-connects (which wavelength from an input fibre goes to which output fibre) but also force electronic regeneration of a given wavelength, that cannot be sent transparently all the way to its destination. This software has to be impairment-aware, i.e. aware of the feasibility of all optical paths before establishing connections: this is, by itself, a real challenge. In the routing process of optical channels, the control plane will also have to take into account energy consumption, thus allowing energy-aware optical networking. To be accurate, it needs to be fed with photonic components parameters, possibly from active monitoring, and should rely on dedicated fast routing algorithms.

The motivations for dynamicity can be partly addressed by remote wavelength management, thanks to cross-connects. However, other approaches deserve to be investigated as a complement or to go beyond. The most promising of them consist in automatically varying the bit-rate per wavelength, continuously or step-wise, or in varying the wavelength spacing. Dynamicity can also be obtained by adding or dropping sub-bands in/from a multicarrier signal e.g. an orthogonal frequency division multiplexed (OFDM) signal. All these approaches deserve deep investigation to assess their potential. Other strategies rely on optical switching with much finer granularity than the optical wavelength channel, whether at burst or packet level. These optical burst or packet switching techniques allow efficient aggregation of traffic coming from access networks, and will spread into metropolitan networks first, then into backbone networks. They will be in particular the cornerstone of convergent metropolitan and access networks.

As a matter of fact, the need for dynamicity will also be a key of future optical access networks, able to provide on-demand and bit-rate adjustable broadband access connections to the end users. Variable bit-rate transmitters and receivers will be one approach for this optical access network agility. Agile multiplexing and multiple access schemes will also be developed and tend towards fully wavelength-agile optical access networks. These advanced schemes will be combined with dynamic time-based, wavelength-based, or even sub-carrier-based bandwidth allocation mechanisms. In particular, agility provided by multi-carrier multiple access techniques (such as OFDMA – Orthogonal Frequency Division Multiple Access) is a promising solution towards future generations of PON (Passive Optical Networks). In a longer term view, optical burst or packet switching is considered as a solution towards convergent access and metropolitan networks, opening the way towards end-to-end all optical switching in the whole network.

Future usage of home area networks will also require a high level of dynamicity: as broadband and digital storage devices gain more success to the home every day, the trend is that it shall be possible to use all these devices everywhere at home with high flexibility, and with high data rate connectivity to transfer content either from remote servers or between end-devices sparsely distributed everywhere at home. This will require agile multi-format optical home networks based on multipoint to multipoint topologies. These advanced home network architectures will largely benefit from wavelength division multiplexing and/or sub-carrier multiplexing techniques, so as to easily manage multiple access to the network as well as various formats and services, including data, video, and wireless.

1.2.5.3 Target

For the backhaul and core transport networks: Photonic Systems - Networks for High and Ultra High Speed Optical Core Networks : to develop system, sub-system, and component technologies to deliver cost effective transport at 40Gbps, 100Gbps and beyond, to enable the next phase of core network evolution. This research priority is considered as a key input into the "networks" research area as it provides the essential linkage between the components research and applications in systems.

For the customer/consumer access networks: Photonic technologies and system architectures for next generation ultra high capacity optical networks – driving innovation and optical capacity towards the end-user : current networks running over fixed and/or mobile physical layers are readily reaching their limits in terms of transport capacity, scalability and flexibility, as well as mobility management. "Bandwidth-hungry" applications like video, grid applications, and peer-to-peer push the bandwidth demand for each subscriber. This research priority aims at the vision of "10 Gbps everywhere", which means that each subscriber or each relevant location will require an optical access bandwidth of 1-10 Gbps to connect to the global network, with business users demanding multiple 10Gbps channels. This is significantly higher than anything planned in the current FTTx rollout plans of any operator.

For Optical Interconnects and Networks : This includes 'non fibre' optical networking technologies, extending from satellite to high altitude platforms down through shorter reach FSO (Free Space Optics) technologies for ad hoc networking to 'last metre' high bandwidth links within customers premises. Moreover, integrated optical interconnects within systems (board-to-board, chip-to-chip, and on-chip) with different properties (removable, flexible, free-space, etc.) for various applications (e.g. high performance network equipment, mobile devices, etc.) are covered by this priority.

In addition, this priority includes the use of fibre, both in massive-volume low-cost consumer networks (in homes and cars), as well as in niche high-end applications such as processor interconnection networks in the world's largest supercomputers.

1.2.5.4 Topics and key issues to be addressed

Scientific and Technical topics:

- Low-cost fibres, e.g. polymer or multi-mode glass with high data rates and reasonable long ranges are required in many application areas. Optical modulation and signal processing, but also advanced Laser or LED components are key issues to be solved here,
- High-speed signal processing and electro-optical components,
- To handle ever higher rates signal with new and complex modulation schemes, new techniques for the digital signal processing electro-optical components must be developed,
- New architectures such as for instance (but not limited to) hybrid fibre radio and multi-domain involving necessary technological breakthrough.

General topics:

- The problem of **increasing capacity** has always and will continue to drive a large part of the research effort in the future. In particular, higher data rates, larger number of wavelengths in core networks, newer modulation formats, more flexible/tunable transmitter/receiver architectures, faster switching in the network core, will remain topics of interest,
- **Power consumption** of network elements, both at core and access level, can be lowered to decrease the carbon footprint of ICT,
- Several techniques currently compete within the optical layers to carry data, e.g. wavelength, burst, packet switching. A **convergence of these switching techniques** is required to achieve optimal exploitation of the network resources,
- This should be complemented by a unified, multi-granular **control and management plane**. Cross-layer design will be encouraged so that physical-layer impairments can be mitigated at the higher layers, in order to make networks more "agile". Cross-layer design should be kept within well-defined limits so as not to break the broad principle of a layered architecture, with the goal to achieve "network convergence" where network layer/IP and optical layers still co-exist, but are better adapted one to the other. The notion of IP flow switching directly at the optical layer is one way to leverage transparency and agility,
- Multi-domain architectures can be extended to encompass several levels of optical networking (e.g., core, metro, access) to achieve another level of convergence and end-to-end optical connectivity with possibility of setting traffic engineered data paths in a scalable way
- Convergence of the multiple overlay networks to deliver different services, i.e. as far as possible use the same network to deliver voice, mobile and internet services, including video,
- The cooperation between several operators to enable end-to-end service is hitting administrative/confidentiality issues.
- The proposed architectural changes need to account for the massive amount of equipment already deployed in existing optical networks, and hence incremental changes need to be possible,
- The optical layers must remain compatible (for instance, through appropriate grooming) with the packet switching paradigm imposed by the ubiquity of IP,
- A last important topic is the recognition in the optical community that much of the last mile access could eventually be through a wireless access, and hence the **synergy optical core/wireless access** should be better understood and studied.

For Backhaul and Core Transport Networks: key areas in this research priority include:

- What are the network possibilities enabled by the current and future components?

- How do we predict and control what happens when we put these components together? Examples include:
  - Operation of Concatenated Wavelength Selective Switches,
  - Management of optical power transients,
  - Handling of transparency, reconfigurability etc…
- Component design naturally links to architectural aspects e.g. control plane implications,
- How to achieve and manage core network capacity growth required to support projected IP traffic increase and bit rates at the network edges,
- Robust 100Gbps and beyond component technologies, including:
  - 100Gbps interfaces e.g. using multi-level modulation formats, management requirements, etc,
  - Development of coherent technologies including ASICs for implementation of real-time digital signal processing for mitigation of optical impairments,
  - Supporting technologies,
  - Fiber Technologies.
- Development of a 'Capacity Roadmap' beyond 100Gbps
- Network and systems concepts to transport and manage Tbps transmission capacities.

High Speed Optical Access Networks: key areas in this research include:

- Innovative network concepts, device technologies, and components for more intelligent and functional (plug & play) heterogeneous networks,
- Concepts for access and in-house networks based on optical fibres for ultra-high speed access network provision including protocols and management,
- Low cost high volume optical components for optical access networks, e.g. FTTx,
- Migration and future proofing of the core network - enabling capacity towards Tbps per channel whilst radically driving down the cost per bit through technology innovation e.g. opto-/opto-electronics integration, low cost material systems - the core bit rates per channel will be 40Gbps, 100Gbps and higher,
- Seamlessly linking access, backhaul and core network architectures, migration and strategy:
  - Covering components, switching and transmission technology,
  - This could include work on fibre types (plastic, multimode, single mode etc) and properties (such as bend sensitivity).
- Current and future technologies as enablers of future transmission, in the core and migrating to access as demands rise beyond 10Gbps:
  - Technologies such as COHERENT with the capacity to deliver robustness, resilience, reach and bit rate/ capacity (through multi-level coding….) as well as tunable/ colourless aspects.
- Digital signal processing devices and technologies:
  - Focus on algorithms needed,
  - Targeting intercepts with the Si roadmap.
- Key component technologies/ requirements/ designs will include optical hybrids for e.g. polarisation handling and phase discrimination, integrated and hybrid technologies including InP, OPLLs, VHDWDM, agile technologies for tuneable and colourless DWDM, new fibre technologies etc,
- Including the architecture convergence with the radio access network to develop wireline/wireless systems integration,
- Photonic network concepts, technologies & components enabling significant reduction in electrical power requirements i.e. address "Green" agenda.

The high speed Access Network is recognised as becoming increasingly important as demands for data and bandwidth increase. One of the key problems in Europe is how to enable ubiquitous broadband access – whilst meeting shorter term economic needs of system suppliers and users. The regulatory issues must be addressed elsewhere and any solution must favour the deployment of next generation optical systems, not only the current short reach relatively low capability Passive Optical Network (PON) systems being deployed in Japan, Korea and elsewhere in the Far East. Investment in the development of next generation access technology will enable a future proof optical access network to deployed and radically reduce access infrastructure costs through removal of local exchanges and much of the metro network. The traditional PON technologies must be enhanced to much greater bandwidth and reach, as well as radically cost reduced to enable deployment directly into subscribers' premises. PONs have exploited the space (splitting) and time

(TDM) domains for equipment sharing and hence to reduce costs. This needs to be expanded to include wavelength and other schemes. Colourless technologies must be developed for customer premises, with performance and reach equivalent to today's long haul systems to enable aggregation points to be maybe 100km away. Evolution schemes for seamless upgrade of PON infrastructure must be devised and proved, so that connection bitrate and number of served optical network units may increase gracefully and cost-effectively.

The technology focus should be on the components and architectures to achieve the next generation of access, including transceivers, amplifiers, switching / routing components and manufacturing technology to achieve the performance and yield. The technologies convergence focus should be on wireline and wireless integration technologies as these will enable wider distribution of e-services.

For High Speed optical Interconnect: key areas in this topic could include:

- Components and terminal technologies for FSO applications,
- 'Optical wireless' technologies,
- Networking supported by lighting including resilience and capacity aspects,
- 'DIY'(do-it-yourself) and ad hoc networking technologies,
- Integrated optical interconnects for high data rate robust but low cost communication within any electronic equipment,
- Technologies for inter-vehicle, in-home, in-car networks, for both entertainment and control,
- Technologies for mobile and handheld applications,
- High-end optical interconnection networks for data storage and high performance computing systems,
- Optical data storage,
- Electro-optical packaging concepts,

1.2.6 Satellite networks

Satellite Communications (SatCom) systems provide the foundations of European and worldwide digital information networks. They refer to any system providing communication services via satellite. It encompasses stand-alone SatCom systems as well as solutions integrating SatCom with terrestrial access technologies. SatCom systems deliver their broadcast, broadband and narrowband services to fixed, portable and mobile terminals. They are based on Geostationary (GEO), Medium (MEO) or Low Earth Orbiting (LEO) satellite constellations and can operate in low frequency bands (<3 GHz, such as UHF, L and S band) or in higher frequency bands (> 3 GHz, such as C, X, Ku, Ka, Q and V bands). SatCom systems cover all the earth including north and south poles.

Satellite Communications deliver telecommunication services to European institutions and citizens thanks to their inherent properties of global coverage and dependability. Satellite networks nowadays provide:

- Broadcast delivery to end users;
- Content delivery to network head end such as DSLAM;
- Data distribution to the banking, business, health, governmental sectors;
- Connectivity in the Internet backbone;
- Backhauling of other access technologies;
- Fast Internet access in emergency scenarios;
- Mobile, nomadic and fixed broadband services (audio, video and data) to citizens in rural areas, to passengers on board vessels, trains or, recently, aircrafts;
- Handheld services in areas beyond terrestrial networks reach.

In the Future Internet, the role of Satellite Communications will be enlarged to provide global connectivity coverage to support the ambition of service continuity. Indeed, Satellite Communications inherently offer three undisputable characteristics:

- **All the time**: as a dependable solution, Satellite Communications are the key element to ensure a service continuity under natural or man made disasters. Given the increasing importance of Internet in our society, great emphasis will be given on robustness of the Future Internet infrastructure requiring a smart integration of Satellite Communications.

- **Everywhere**: thanks to their global coverage, Satellite Communications are the most economical access technology in low density populated areas (typically below 50 inhabitants/km^2) which represent more than 10% of European population distributed over 50% of the territory. Satellite Communications are therefore the key technology to fulfil the right of all citizens, being either fixed, mobile or nomadic onboard vessels, trains, cars or aircrafts, to have access to the Future Internet. They are also expected to play a big role in the emerging field of machine-to-machine communications, given their great scalability for low-traffic terminals.
- **Anything**: thanks to their global coverage, Satellite Communications are the key solution to connect all kinds of objects, such as, sensors, machines, devices, handsets, terminals, gateways, etc, thus constituting a cornerstone for the future Internet of Things.

1.2.6.1 State of the Art

Currently, Satellite Networks can be categorized according to the following three main service classes:

- Broadcast services: satellite are extensively used to broadcast TV programs in Standard- and High-Definition format (SDTV, HDTV) directly to end-users or to network head end such as DSLAM all over the European territory.
- Broadband access (including backhaul): this typically refers to C or Ku band broadband SatCom with fixed terminals. SatCom are now starting also at Ka band.
- Mobile services: LEO and GEO satellite based systems, operating at frequency bands lower than 3 GHz, provide narrowband communications (voice, messaging and data rate of up to 0.5 Mbit/s) to handheld, vehicle mounted and laptop devices.

It shall be noted that, in recent years, the boundaries among these three typical SatCom categories are becoming vague given that

- Broadcast services are being combined with broadband and mobile services offered over the same satellite infrastructure,
- Broadband services are now offered on board vessel, aircraft, trains which are also mobile,
- Mobile services are now targeting service rate capability up to 1 Mbit/s while addressing smaller form factor devices similar in size to cellular devices.

1.2.6.2 Target

Regarding Satellite Communications, upcoming R&D efforts in the area of Future Internet shall be geared to achieve:

- A better usage of frequency spectrum and exploitation of higher frequency bands for optimum performance and coexistence with other services;
- A seamless interoperability with terrestrial, wired and wireless, networks at service, management and networking levels;
- A better quality of experience for the users with up to date Quality of Service (QoS) and Low cost/size, fast/easy set-up user terminals.
- An increase in service rate capability and satellite throughput performance;
- A better use of coverage allowing dynamic traffic allocation among spots.

In this regard, the next decade will face significant advances beyond current state-of-the-art. Emerging SatCom architectures will allow enhanced service capabilities, increased performance and higher flexibility, as summarised in the Table below.

Progress	**Broadband services**	**Broadcast services**	**Mobile Services**

Service capabilities	• Max service rate increase up to 100 Mbit/s for broadband services to fixed, transportable and mobile (public transportation such as aircraft, trains and even buses on a wider scale) terminals	• 3DTV program delivery • Interactivity • Local and regional broadcast	• Narrowband services to cell phones (same form factor) and battery activated modems (for asset management) • 4G service capability and interoperability
System performance	• Throughput increase by more than one order of magnitude with respect to current systems	• Increased spectral efficiency	• Increased spectral efficiency • Increased power efficiency

Table 1: Expected progress through emerging SatCom architectures during the next decade

Emerging SatCom architectures, which will drive several innovative and optimized solutions, are characterized by:

- Increased performance and availability in adverse channel conditions like atmospheric or interference impairments as well as challenging user environments;
- Increased fixed and mobile service capability, depending on the terminal profile and operational constraints ;
- High flexibility in terms of capacity distribution over the service area and routing capability including single hop communications as well as inter-satellite links;
- Integration with Global Navigation Satellite Systems (GNSS) and Earth observation (GMES) systems, with particular focus on emergency scenarios.

Thanks to increased capacity, the SatCom larger addressable market size will enable great improvements on terminal pricing, form factor, power consumption, easy set-up and operations. With the foreseen progress, emerging SatCom architectures will be even better positioned to meet key European goals in the context of current and Future Internet:

- Institutional telecommunication service
    - Security: Flexible solutions for the response phase to disasters with improvements in transportability/mobility and operational constraints. Surveillance missions of assets;
    - Transport: Global availability of Air traffic Control and Airline operational control services. Sustainable surface transport. Fleet management. Asset tracking, Ubiquitous eCall service;
    - Energy: Contribution to ease the operations associated to energy transport, distribution.
- Universal Service
    - Provisioning, with cost and energy efficient solutions, of High Speed broadband Internet access to European citizens located in low density populated areas (up to 50% of the European territory);
    - Provisioning of cost efficient HDTV, 3DTV and emerging broadcasting services;
    - Provisioning of "on-board" entertainment to trains, aircrafts, vessels, buses.

1.2.6.3 Topics and key issues to be addressed

The following key issues need to be solved:

- Smart and efficient spectrum /resource management:
    - for increased spectral efficiency;
    - for allowing coexistence with other systems or services;
    - for reducing connection costs;
    - for efficient emergency response.
- Seamless interoperability with terrestrial, both wireless and wired, networks within NGN:
    - network and management interoperability (subscription handling, authentication and authorization, and accounting/billing);
    - alleviate satellite access characteristics to the users (e.g., latency);
    - for enhanced ubiquitous coverage and availability even in critical emergency scenarios.
- Development of satellite terminals (fixed and mobile) at low price, size and installation cost:
    - for maximum market acceptance.
- Development of high capacity and flexible satellites.

The identified progresses associated to emerging SatCom architectures will be made possible thanks to innovative technologies and techniques, such as those reported in the following Table:

Progress	Broadband services	Broadcast services	Mobile Services
Enablers	• Innovative payload and flexible multi-beam geostationary satellite architectures • Exploitation of Ka and higher frequency bands • Advanced radio resource management • Next generation network (NGN) interoperability	• Convergence with broadband • Advanced flexible waveforms	• Advanced flexible waveforms • Terrestrial and satellite component spectrum coexistence • Advanced payload • Cooperative cross-layer techniques • Next generation network (NGN) interoperability

Table 2 : Enabling technologies for emerging SatCom architectures

In order to optimise the benefits associated to SatCom technology in the Future Internet, the following R&D developments need to be undertaken:

- ***Smart and efficient spectrum /resource management and cognitive radio networking techniques:***
    - Spectrum sharing techniques through cognitive radio and cross-system interference suppression: sharing with terrestrial systems as well as between satellite systems.
    - Smart and efficient radio resource management (RRM) and scheduling algorithms with cross-layer information from adaptive physical layer and QoS requirements from upper layers, to achieve optimum performance for broadband satellite services.
    - Integrated approach to spectrum and resource management to optimize satellite networks' QoS performance; in particular, a tight cooperation between scheduling algorithms and dynamic capacity allocation procedures facilitate the achievement of (i) full-IP QoS management, (ii) minimization of access latency, (iii) maximization of network resources. In this context, advanced service-aware admission control algorithms are also of interest to protect SLA provision and manage the blocking probabilities of the different services in various traffic conditions.
    - Advanced Software Defined Radio (SDR) and cognitive radio concepts and architectures for the design of reconfigurable terminals well suited to emergency scenarios.

- ***Hybrid terrestrial/satellite communication system architectures:***

The current access to Internet is limited to the areas with well developed terrestrial infrastructure, The Future Internet shall, in addition to technology enhancements of the fundamental IP protocols, focus on the development of the lower layer wireless protocols allowing wide, fast and cheap deployment of Internet in currently under served areas. These developments shall include systems development of the innovative wireless systems including satellite and long range terrestrial systems, as well as fully meshed satellite networks. Related topics are detailed in ***Section 1.2.8***

- ***Delay-tolerant and error-resilient network protocols:***

The main limitation in using GEO satellites results from the large latency of the link, which has a significant impact on performance of applications using interactive protocols. This is the case for interactive applications using TCP, a reliable window-based acknowledgment-clocked flow control transport protocol, which is the basement of many Internet applications (http, ftp, email, etc.). Optimum protocol design or improved architectures must be addressed to counteract the mentioned impairments. Two families of R&D topics may be explored: (i) breaking the end-to-end Internet paradigm with Performance Enhancing Proxy (PEP) or (ii) trying to maintain the end-to-end Internet protocols in taking into account satellite constraints following other trends such as Internet Congestion Control Research Group. Advanced routing protocols for satellite-assisted ad-hoc and cooperative networking shall also be pursued. Note also that delay–tolerant satellite networks shall be addressed in line also with the DTN topics addressed in the other related chapters, e.g., Chapter 1.4.6 "Seamless continuity between all networks" and 1.7.1 "Energy efficient systems".

- ***Reduce transmission costs and increase efficiency, flexibility and dependability:***

Ensure that sufficient spectrum is available, that existing allocations are justified and protected, and that spectrum is allocated in the right bands (e.g. to permit interworking with terrestrial services). Ensure also efficient adaptation of terrestrial radio interfaces for satellite networks for reduction of development and production costs of multi-mode terminals. Develop techniques and system designs that improve radio transmission efficiency and spectrum utilisation (e.g. narrower spot beams, multi-user detection, robust and efficient video/audio compression technologies, innovative spectrum sharing technologies) in order to maximise the exploitation of the available spectrum. Develop advanced techniques for interference mitigation and avoidance whether caused from or to satellite services.

- ***Increase spectral and power efficiency by at least an order of magnitude:***

Investigate utilization of smart diversity techniques in order to meet strict power and spectral efficiency requirements, with particular focus on satellite and polarization diversity, so that mobile terminals can rely on multiple replicas of the transmitted signals in order to overcome the induced propagation impairments and so boost the system performance. Advanced multi-user detection (MUD) for interference mitigation and cancellation shall also be addressed for both the forward and return link of multibeam broadband satellites. Interbeam interference is a limiting factor of the frequency reuse in multibeam satellites. Such techniques will allow a more efficient spectrum usage by reducing the frequency reuse pattern and allowing the use of transmission modes with higher spectral efficiency. New channel coding and modulation techniques for multi-resolution broadcasting. Such techniques allow a graceful degradation of the received signal quality when the channel conditions are adverse. Additionally, it is possible to broadcast to different types of receiving terminals (fixed terminals and mobile terminals) with different received signal quality, achieving high spectral efficiency. Advanced multiple-input multiple-output (MIMO) techniques as applied in satellite networks after careful adaptations and optimisation shall also be addressed in this regard,

- ***Align form factor and power consumption of satellite terminals to those of terrestrial systems, in particular for mobile services***

Efficient adaptation of terrestrial radio interfaces for satellite networks shall also be addressed for reduction of development and production costs of multi-mode terminals.

- ***Adaptive physical (PHY) and MAC layer techniques:***
    - Advanced satellite channel adaptive transmission techniques represent an efficient solution for communications on channels with highly varying channel characteristics, and will gain increasing importance also in future satellite communications systems. Advanced channel adaptive transmission techniques, able to cope with the different system and scenario configurations, shall be addressed. For example, Adaptive Coding and Modulation (ACM) has recently been introduced in several SatCom contexts but its applicability has not fully investigated over the whole range of satellite networks and especially, in mobile satellite channels as well as at low (< 3GHz) and very high (e.g., Q/V) frequency bands. Moreover, high efficiency mesh network air interfaces for low cost mesh satellite terminals shall be pursued. Multi-User Detection (MUD) techniques for enhanced waveform and increased protection against interference, as described above, are also of paramount importance to this end. The employment of adaptive transmission techniques relying on smart diversity concepts, such as MIMO-like satellite/polarization/antenna diversity and Space-Time Coding, is also crucial in this regard. Thus, the utilization of several advanced adaptive transmission techniques on mobile and fixed satellite channels should be investigated in detail.
    - In addition, more efficient multiple access control (MAC) schemes shall be pursued for the return link of mobile broadband satellite networks with emphasis on well field proven technologies such as OFDMA (Orthogonal Frequency Division Multiple Access) and IFDMA (Interleaved Frequency Division Multiple Access) as well as on their applicability and optimisation in the satellite context. Efficient Random Access (RA) schemes for the reverse link of sparse packet satellite networks shall also be addressed in this regard aiming at an enhanced waveform.
    - Adaptive and cooperative cross-layer techniques with information exchange between PHY-MAC layers as well as with other upper layers (e.g., link/application layer FEC) for efficient fade mitigation and channel adaptation shall also be addressed.

- ***Enable the exploitation of higher frequency bands (Ka band and above):***

Investigating and proving technologies, covering both satellite payload and ground segment, for the utilisation of Ka-band (20/30 GHz) for integrated broadcast, broadband and mobile satellite services, and the utilisation of the Q/V frequency bands for broadband satellite services, with particular emphasis on low-cost satellite access terminals. Enhanced smart diversity and satellite channel adaptive transmission techniques, such as ACM (wider SNR range), shall also be investigated in the context of higher frequency bands (e.g., Q/V).

- ***Integrated security, privacy, mobility, QoS:***

Investigate security of networks and protection of privacy in new mobile and heterogeneous environments and examine QoS requirements. Research in technologies to improve citizens' security, as communication infrastructures to support security forces missions and, at the same time, to preserve citizens' privacy. In this regard, the paradigm of 3GPP SAE (System Architecture Evolution) followed in terrestrial mobile networks could also be followed by satellite networks. Moreover, further investigation shall be pursued towards the development of new security countermeasures as well as the applicability and optimisation of well field proven security countermeasures in the context of satellite networks (see e.g., "IPSec-compatible" PEP vs. "PEP-compatible" IPSec issue for increased security in satellite networks). In this respect, Layer 2 security protocols and mechanisms, based on well-established cryptographic techniques, providing confidentiality, integrity, and/or user authentication, control and/or management data shall be addressed. It is important also to note the need for scalable key management protocol in order to address large groups of satellite terminals.

Moreover, some further necessary R&D developments to successfully meet the Future Internet objectives for satellite networks are outlined below, which mainly refer to satellite on-board processing (OBP) technologies and, as such, they are mainly intended to be carried out in the framework of Space Agencies' work programmes:

- ***More flexible satellite payloads with On-Board Processing (OBP) capabilities:***

Next generation satellite systems shall provide advanced mechanisms supporting On-board Processing (OBP), on-board routing and Inter-Satellite Link (ISL) connectivity. Expected developments in the area of efficient inter-satellite networking shall address mesh ISL connectivity, advanced on-board dynamic routing (incl. non-GEO satellite orbits) and radio resource management techniques in order to achieve a more powerful and flexible satellite overlay network. On-board Software Defined Radio (SDR) techniques and dynamic satellite radio resource management/service planning, which offer high degrees of flexibility to allow satellite mission adaptation to evolving requirements (e.g. coverage evolution, traffic distribution change, connectivity modification over the coverage), shall also be addressed towards the development of enhanced regenerative satellite payload technologies. The consideration of recently deployed satellites with intelligent payloads and configurable transponders should also be further investigated in order to understand how satellite radio resources would be managed more efficiently between the ground and space segments.

- ***More powerful satellite buses:***

Future satellite payloads will include new power consuming characteristics. Furthermore, the throughput will increase. It will be therefore necessary to refine existing technologies in order to increase the efficiency of on-board generated power (solar panels, batteries) and reduce the power consumption of the equipment used.

1.2.7 Exaflood management

1.2.7.1 State of the Art

To Be Completed in Version 1.2

1.2.7.2 Target

To Be Completed in Version 1.2

1.2.7.3 Key issues and topics to be addressed

To Be Completed in Version 1.2

1.2.8 Provide a flexible infrastructure to support networked economy

1.2.8.1 State of the Art

To Be Completed in Version 1.2

1.2.8.2 Target

To Be Completed in Version 1.2

1.2.8.3 Key issues and topics to be addressed

1.3 Security, privacy, trust and accountability

1.3.1 Security, privacy and trust

Security, privacy, and trust, together with the closely-related area of dependability, form a cross-discipline that has to be included in all aspects of the design and development not only of the Future Internet, but also in general considerations of all digital dimensions of our environment.

The current Internet emerged in a domain of mutual trust, where the initial network was based on a closed group of trusted parties protecting themselves against the outside world. From that initial situation, the Internet has already grown several orders of magnitude. Its topology has evolved; its role and functionality have changed. Trust is no more simply assumed, the users of the internet are not a close knit group but span the entire globe, many communication barriers have been broken and culture, language and distance are not as constraining as previous.

The objective is to provide an infrastructure that delivers optimal levels of security, privacy, trust and dependability that fit to the needs and dynamic context of the situation and that are subject to monitoring, measuring, automated adaptation or other type of action. Some of these mechanisms already exist, but it is also important to address how current standards and best practices will apply and adapt when services are created out of aggregated component services of potentially different origin.

Since its inception, the variety of communication paradigms in the Internet dramatically increased, passing from a few fixed communication links to a world of smart dust seamless connected, where each human being is currently equipped with PAN (personal area networks) and in the near future likely with BAN (biological (rather than body) area networks, e.g. for e-health applications). Security and privacy have not been included as fundamentals of the Internet engineering, so, to date, users have had to tolerate inadequacies and difficulties in the services as a necessary price to be paid for what they deliver. The result is either a reluctant need to trust and hope for the best, or often an unawareness of the possible risks. Not only is our use of services a source of risk, but simply being connected to the network is a risk in itself due to the vulnerability of end-systems. Unless the needs for security, privacy and trust are included in the foundations of the FI, the whole enterprise will be of limited value compared with an FI that we can trust to deliver the services we expect and to protect the privacy of information: corporate, personal, or critical to our security and safety. An essential by-product of attention to security etc. is the increase in dependability of the system, which in turn reinforces our ability to deliver the needed trust. The drivers behind the creation and implementation of services have been largely business or technology oriented. It is now time to position the "user" at the centre of the picture, protecting user data and privacy and providing usable and trusted tools usable by a large community. The pervasive nature of new, sometimes critical services and their impact on key elements of the citizen's life – work, social activity, health, government, finances, entertainment and education – increases the importance of offering trust and strong security, with flexibility, privacy and confidentiality.

Security mechanisms must be flexible and designed for change, evolution and adaptation in line with other ICT development advances and able to resist unpredictable threats. In this ambit, security mechanisms must be designed to automatically configure and self-optimize themselves with respect to several dimensions, e.g. risk, context. The increasingly distributed, autonomous, open and heterogeneous nature of the current and future challenges demands for a coherent set of methodologies, techniques and tools to identify, assess, monitor and enforce system and services behaviour as defined in SLA's. Indeed the different levels of security required by different stakeholders for different purposes add to the complexity of implementation of security and trust dimensions. In particular, for a truly pervasive computing and communications infrastructure, it is absolutely essential to provide a rigorous framework for informed decisions on trust issues. Such trust relationships and frameworks are indispensable in the Internet that is becoming a main means for new computation and communication paradigms (e.g. social networking).

1.3.1.1 State of the Art

Compared to the current situation, pre-defined trust relationships between components, applications and their system environments can no longer be taken for granted. Indeed, not only systems as a whole but also individual services running in or supported by those systems will have to adapt to dynamic changes to hardware and software, and even firmware configurations, to unpredictable appearance and disappearance of devices, software components or infrastructure resources.

Dynamic security embraces the whole set of runtime mechanism, from distributed monitoring and data collection to validation and dynamic policy management. Today's system components deliver 'intelligent' functions that can provide information critical to their state. These features could let them perform self-diagnosis, self-healing and self-managing tasks, shortening the time it takes TSD administrators to identify and resolve potential problems. Related to this are issues of runtime distributed monitoring and automated data collection features. The discovery of errors and malicious behaviour during runtime is a subject of distributed monitoring. In the future monitoring and recognition mechanisms, combined with predictability mechanisms would analyse context information and service code before execution.

Increasing security awareness is one the key issues that would enable future vision of adaptive security. Advanced, model-based system monitoring and data collection support needs information about physical and logical context and at the same time is collecting, in a dynamic fashion, information about changes of these contexts. This would include capabilities in predictive analysis, capturing semantics of context information, and making this information available across the distributed service infrastructure. Awareness, together with the flexibility offered by service orientation, is the key to provide an increased degree of self-resilience and other "adaptive security" features (see figure). By making the security and dependability characteristics of the application as well as its security status accessible, awareness components will influence dynamically taken decisions. This includes users' protection and privacy needs, organizational context, and technical parameters. Probably the most sensitive part of this component awareness is privacy, which refers to the anonymity, pseudonimity, unlinkability and untraceability of subjects. Although privacy is often investigated in relation to user preference, depending on the context, ensuring or forbidding actor privacy may also be the consequence of legal requirements (e.g. from anonymity for citizen or investigator protection to unique identity for non-repudiation).

Other aspects to be investigated in relation to awareness are management of huge amount of distributed data (mining, filtering, clustering and collection techniques might be applied), ownership, temporary nature etc.

Autonomous security is not only dealing with the developing of self-healing and self-configuration of security properties, but also with conflict resolution (e.g. local and global security policy), boundary between autonomous system defence and human intervention, multi-agent systems and multi-level security, as well as injection of autonomous features into resilience and security as a service. Additionally, one of the most important research issues is autonomous decision making and in this sense it is closely related to the global definition and acceptation of measurements and metrics (see also Section 2.4), as well as trade-off design where security cost has to be expressed in a computable form.

We often assume that users generally desire the greatest amount of security available, and that security is generally tempered by cost. The cost may take the form of money lost due to downtime, lower usability or performance degradation, for example. When the cost is very high (e.g., slow response time or time consuming authentication), users may be willing to accept security that is less than their ideal level of service. Thus, we need to design security (the same applied to trust and dependability) that would range from a minimum to an ideal. However, a flexible security of one service may be able to impose performance degradations on others in a composed service based system. What we need is (again) set of metrics and a TSD range within which each component of service based system is willing to operate (possibly as a part of service level agreement). Movement from piecemeal security measures to comprehensive framework that links individual TSD properties with integrated end-to-end TSD properties is one of the primary objectives of future R&D in service oriented systems.

A combination of transport-layer and message-layer security mechanisms, such as SSL (Secure Sockets Layer), TLS (Transport Layer Security), WS security and XML encryption, is not enough for securing web services. SSL is designed to provide point-to-point security, which is not enough for web services because end-to-end security is required. In a typical web services environment where XML-based business documents are routed through multiple intermediaries, it becomes difficult for those intermediaries to participate in security operations in an integrated fashion.

The new service oriented security architecture must adhere to the essential characteristics of SOA. SOA also enables organizations to build a set of reusable security services that can be used by business applications. For example, an authentication function can be offered as service.

An integration scheme may impose assumptions on trustworthiness: If we choose to implement the event log pattern locally attached to the invoicing service, this will only be allowed if the invoicing service is owned by the application owner (due to the fact that the application owner is responsible for reporting, and obviously trusts himself). If the invoicing service is run by a different owner (in the case of outsourcing), the integration scheme either requires a trust establishment mechanism (again represented by different patterns) or a non-repudiation mechanism (another pattern). If both is not considered appropriate by the application designer, he might enter an iteration loop in the framework, by selecting a different architecture (e.g., by choosing a "trusted third party pattern") subject to different restrictions, dependencies, and integration schemes. An application can only be considered secure if all applying integration schemes are satisfied.

1.3.1.2 Target

Any change operated on the Internet modifies the approach to existing risks, as well as introduces new risks related to scale, dynamicity etc. Target is to achieve security, privacy, trust and dependability that can be characterised as:

- Dynamic: as a reaction on on-demand computing paradigm, run-rime composition and other emerging computing trends,
- Adaptive: so that when regulations, rules, availability or trust changes, a security configuration can adapt automatically,
- Composite: to derive end-to-end security properties as the result of the overall process linked to the security of individual components,
- Measurable: to be negotiable between partners as different levels of security and dependability can be traded for costs and/or functionality,
- Predictive: to discover unplanned behaviour that may occur when service is applied in a different context,
- Scalable: to scale trust, security and dependability mechanisms to a number of clients, services, outsourcing steps, size of the business processes. Given the complexity of this problem, this has been also included as a research topic,
- Persuasive: to represent the system security status in a form suitable for end-user decisions,
- Open: openness as a foundation of system security was included as a research topic in NESSI SRA Vol 3.version 2006. TSD WG members argue that this issue, listed as the initial TSD research topic in NESSI SRA Vol 3 is actually working approach and should become part of Vol 2,
- Trustworthy: one of NESSI principles that appeared in SRA Vol 2, version 2006 was trust. NESSI TSD WG members argued that trust and trustworthiness are both guiding principle and a research topic (actually research topic is renamed into "trust analysis, management and monitoring"),
- Interoperable: where this refers to technical, semantic and organisational interoperability of policies, mechanisms etc.
- Available all-the-time: As a dependable solution, Satellite Communications ensure service continuity under natural or man made disasters. Given the increasing importance of Internet in our society, great emphasis should be given on robustness of the Future Internet infrastructure requiring a smart integration of Satellite Communications.

1.3.1.3 Topics and key issues to be addressed

Protection of user credentials and Privacy-friendly ID-management: as more and more user data is processed on distant nodes not under local user control, user data as well as his access and even personal credentials travel over the network and require appropriate protection. The network design needs to enable the control of private data in a way that implements a thorough 'need to know' principle. Other considerations include legal and regulatory items, governmental collaboration to enforce legislation has certain over-riding abilities that counteract crime and terrorism.

Protection of nodes and devices against misconfiguration and malware: as most attacks to the Internet infrastructure and services are launched from within – by collections of rogue nodes such as bot-nets – a node or terminal in the Future Internet should be able to bring itself into a trustworthy state by secured bootstrapping. The properties of a state must be verifiably by any remote party which is authorised to challenge a node to prove it.

Trust in processing and probative value of processes and communication: the Internet of the future evolves from an information browsing to an information processing facility, and bears a great deal of critical business processes. As users of, for instance service oriented, architectures heed little care about where and how their precious data are processed; they naturally assume that it is protected by the best possible security. A new requirement comes from the necessity, nowadays implemented by global treaties, EU, and national jurisdiction almost globally, to make every operation in a business process auditable and to keep detailed, and true, records. Therefore, the Future Internet must provide ubiquitous support for non-repudiation not only of communication but also of distributed data processing.

To realise these objectives, there are several research challenges have to be addressed:

- Find methods to leverage the, hitherto scattered and unconnected, hardware-based security building blocks into an overarching **trust architecture** to protect connected devices. This comprises new, high-performance, methods for application separation perhaps beyond virtualisation. Furthermore, security primitives need to be developed that enable fundamental operations on and communication with secure devices,
- A uniform **credential management architecture** leveraging hardware trust must be envisioned. Trusted means to control operations with user credentials such as enrolment and migration between devices shall ensure uses' privacy and seamless access to network services. This also calls for novel, secure, **multi-modal, seamless user authentication** methods, as well as methods to prove the trustworthiness of a device or service *to the user*,
- New and uniform methods for the provisioning of security to higher application levels must be deployed throughout the Future Internet. This shall enable applications to review the state of the host system and in turn the host systems to provide scaled security to each application. This security comprises in particular new **means to bind trust-related information to data** that is stored or communicated to other nodes. Those methods need to be independent of data formats and representations.

The first challenge of the future Internet security **is architectural**: we need to guarantee that a number of technical components with ever increasing complexity are flexible and strong-enough in order both to match user's expectations and to fulfil promise of inherent and sustainable security. The main issue here is related to understanding the future usage contexts with the future internet services being formed in a dynamic and layered fashion. It may be impossible to foresee future usage scenarios and thus provision must be made for scalability and user interaction. Another important consideration is to make sure that security requirements are embedded in the design from the beginning so that it is not considered a bolt-on option that may result in further integration issues.

The second challenge is more **related to preserving European societal values**, and assess architectural and system wide consequences, threats and risks related to these values. These might include the loss of privacy, transparency and accountability in communications and service provision chain, an open and fair operation and use of future internet that permits seamless cooperation and a competitive e-service market. Already we see the advantage to the marketing discipline in obtaining buyer behaviour data and thus we need to pre-empt these type of scenarios and protect users of the internet. The lack of accountability in today's Internet, for example, is demonstrated by the distributed denial-of-service attacks, spam, or phishing. At the IP layer all Internet traffic is almost anonymous, due to e.g. ease of source address spoofing and proliferation of network address translation. Many unwanted IP packets are sent by computers running programs unknown to their owners.

The third challenge is related to user experience, the **credibility** and the **efficiency** of the future internet. The security foundations of future internet should not impede efficiency and user acceptance and in this sense should follow, for example, the banking services and network efficiency. The problem of negotiation between security and other requirements, as well as between security mechanisms and controls, each working at a different "layer" in the future internet technology "protocol stack" and value chain, lies in the multi-dimensionality of the problem. While the most of research efforts deals with 2 dimension problem (e.g. security versus cost or security versus usability), the future internet research in security, trustworthiness, reputation etc, should advance simultaneously in multiple directions.

The fourth challenge is the alignment of value protection with future Internet models: The current Internet relies on the connectionless datagram exchange model, while the traditional telecom network uses connection-based model. However, the future internet might use different models, depending on the value (Is it in the content? Is it in data?) composition and delivery. The future principle of "value protection" should not focus only on threat but also on the nature of service and value chain (e.g. information collected or disseminated) where it should meet typical security requirements such as sensitivity, or confidentiality. This issue is related to a preservation of contextual integrity, where contexts are constituted technical environment elements, but also regulations, rules, roles, expectations, behaviours etc. In this sense, the value protection is aligned with a number of context properties, such as security measure appropriateness, control flow etc.

Integrated security, privacy, and mobility for Hybrid Terrestrial/Satellite Networks: Investigate security of networks and protection of privacy in new mobile in hybrid terrestrial/satellite systems. Research in technologies to improve citizens' security, as communication infrastructures to support security forces' missions and, at the same time, to preserve citizens' privacy. In this regard, the paradigm of 3GPP SAE (System Architecture Evolution) followed in terrestrial mobile networks could also be followed by satellite networks. Moreover, further investigation shall be pursued towards the development of new security countermeasures as well as the applicability and optimisation of well field proven security countermeasures in the context of satellite networks (see e.g., "IPSec-compatible" PEP vs. "PEP-compatible" IPSec issue for increased security in satellite networks). In this respect, Layer 2 security protocols and mechanisms, based on well-established cryptographic techniques, providing confidentiality, integrity, and/or user authentication, control and/or management data shall be addressed. It is important also to note the need for scalable key management protocol in order to address large groups of satellite terminals.

1.3.2 Accountability

1.3.2.1 Introduction

(Resource) accountability had been initially positioned a secondary design goal of the Internet – the primary being the effective multiplexed utilization of existing interconnected networks – underlying the DARPA Internet protocol. Indeed, the architectural principles, model, and components of the Internet networking aimed to solve was primarily resource sharing. Consequently, accountability has received little attention during the initial phases of the Internet and its deployment.

The shift of the Internet role toward an infrastructure with increasing commercial and business usage resulted in an increasing need to address this initial Internet design goal. Hence, over time, a number of techniques have been proposed to provide for accountability support by the Internet Infrastructure such as congestion control and IP Traceback

1.3.2.2 State of the Art

Two techniques are often considered when it comes to accountability enforcement: traceback techniques and congestion control.

- IP Traceback [Savage00] is a mechanism that allows receivers for tracking anonymous packet flooding attacks in the Internet back towards their source. IP Traceback mechanisms allow the correct identification of sources that use spoofed IP addresses or that reside behind NATs. While it has proven to be a successful tool to identify the source of anonymous packets it is however only part of the problem as attackers may use innocent hosts or zombies to propagate attacks. A framework for allowing Internet forensic analysis has been proposed to allow the identification of the attacker. The framework assumes that there is always some kind of communication between the entity that launched the attack and the entity under attack. It is the existence of such communication that can lead back to the actual identification of the attacker.

Congestion control is a (typically distributed) algorithm to share network resources among competing traffic sources[1]. Two components of distributed congestion control have been defined in the context of primal-dual modelling. Primal congestion control refers to the algorithm executed by the traffic sources for controlling their sending rates or window sizes. This is normally a closed-loop control, where this operation depends on feedback. TCP algorithms fall in this category. Dual congestion control is implemented by the routers through gathering information about the traffic traversing them. A dual congestion control algorithm updates, implicitly or explicitly, a congestion measure or congestion rate and sends it back, implicitly or explicitly, to the traffic sources that use that link. Queue management algorithms such as Random Early Detection (RED) or Random Exponential Marking (REM) fall into the "dual" category. Congestion control techniques meet accountability in two ways: a) the network expects traffic sources to adopt their rate when signalled to do so and b) the sources expect the network to allocate to them a fair share of the network resources (well behaving sources are not signalled more than necessary to reduce their rate). Next to the "fairness" supported by the congestion control mechanisms these mechanisms are also impacting the network efficiency and stability.

1.3.2.3 Target

Accountability defines a bi-directional relationship: from "host" to network but also from the network to the host. Indeed, not only the host shall be accountable for its resource-share usage but the network shall also ensure that i) it does not bias this usage (e.g. ensure that the technique used to enforce accountability is "neutral"), and ii) it does not impede/intervene by taking arbitrarily detrimental decisions (e.g. does not privilege certain hosts over others for pure commercial or political reasons) that would prevent open resource usage. This target follows the higher-level objective of the Internet capable to meet new and common people (Internet user community) expectations and needs while promoting their continuous empowerment, preserving their self-arbitration (control over their online activities) and sustaining free exchanges of ideas. This target is to be achieved on an equal and fair-share basis: recognizing dissimilarity of individual utility shall not prevent improving the total utility of the Internet.

1.3.2.4 Topics and key issues to be addressed

Taking these targets into account, the following topics shall be addressed:

- Augment the traditional forwarding and control functions, present in today's networking equipment e.g. routers by monitoring how a subscriber behaves in the network and detect if this monitored behaviour differs from the expected behaviour. This functionality shall allow to more intelligently configure queuing and scheduling mechanisms where subscribers which are out of profile can be penalized (e.g. by giving them a lower priority or dropping packets of them) whereas subscribers which are in profile can be rewarded Note that a subscriber profile is either defined in terms of "traffic rate", as determined by a metering function that measures the traffic temporal properties (rate r, burst size b) that in turn allows determining single or multi-level of conformance against traffic profile, or in terms of congestion volume as determined by a function that integrates the measured congestion rate over time or a combination of both.

- Design mechanisms to detect, identify/determine the correlation among traffic flows such as to predict occurrence (including localization) of fallacious/malicious usage of these resources that are detrimental to the Internet end-hosts. Using of this information, develop and experiment techniques to diagnose and predict deviation over time of profile-based fair allocation of the node/link resources among traffic flows.

[1] Congestion can be defined as a state or condition that occurs when network resources are overloaded resulting in impairments for network users as objectively measured by the probability of loss and/or of delay. The overload results in the reduction of utility in networks that support both spatial and temporal multiplexing, but no reservation

- Equivalent mechanisms shall be investigated and designed for systems including data/information storage and processing capacity.

1.4 Availability, ubiquity and simplicity

1.4.1 Resiliency against normal accidents and failures

An important aspect that characterizes services offered by the Internet is the availability, in particular, the IP connectivity availability. For the Internet users the important aspect is the resulting service availability, measured in terms of average service availability over a given period of time (e.g. one week or one month) and of maximum service interruption (max recovery time) before real outage time starts being counted. Availability is defined as the probability that the system is operating properly when it is requested for use, i.e., the probability that a system is not in a failure state or undergoing a repair action when it needs to be used. Availability is expressed as a function of reliability[2] and maintainability. Maintainability is defined as the probability P_m that a system or component will be retained in or restored to a specified condition within a given period of time: Mean Time To Restore (MTTR) ~ 1/P.

Improving availability implies thus to improve the maintainability capabilities of the Internet infrastructure by means of resiliency techniques. Resiliency is the ability of a system to reach (rapidly) and maintain an acceptable level of functioning and structure with one or more of its components malfunctioning due to the presence of attacks, failures, or accidents. In particular, a resilient network aims at minimizing impact on resource (soft or hard reservation) and access downtime to controlled resources. Note that resiliency does not refer to a "full" but an "acceptable" level of functioning and does not refer to the correction of these malfunctioning components.

1.4.1.1 State of the Art

To be addressed in Version 1.2.

1.4.1.2 Target

The short- mid-term target is to reach possibility for a network system that can detect and interpret events as a failure event (by eliminating false positive and negative), determine level of severity of the failure and decide but also execute corrective actions (ranging from local re-configuration to distributed notifications of specific action execution by remote nodes).

The long-term objective is to reach the possibility to predict and anticipate failures from progressive degradation conditions or periodic events (time-driven). It is to be emphasized that anticipation and prediction are highly medium/environment dependent. In any case; the fundamental objective to reach is that resiliency shall not impede distribution and or scalability of the system i.e. additional such as "centralized" monitoring and decision system are by definition non-starters to efficient address network resilience to failures.

1.4.1.3 Topics and key issues to be addressed

As the infrastructure plays an increasing role, its resiliency is an important challenge to overcome. From this perspective, the following issues shall be addressed:

- Self-healing mechanisms (including automatic detection/discovery, and correction of faults),
- Enhanced resiliency against both intermittent and permanent link/node and more generally topological failures would be obtained by augmenting current routing protocols to allow more than one path for any end to end flow. For instance, multi-path routing could be used to identify an active standby path for use in case of failure. Alternatively, several paths might be used simultaneously with dynamic load balancing depending on current path status.

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[2] Reliability is defined as the probability Pr that a system or component fails within a given period of time (MTTF ~ 1/Pr). Reliability is a function of time that expresses the probability at time t+1 that a system is still working (without failure in specified environments with a desired confidence), given that it was working at time t. t. Reliability, in itself, does not account for any repair actions that may take place.

- Resiliency against distributed attacks: access to accurate and timely network management and control information as well as application data can be denied due to node failures and variety of cyber-attacks. Use of fragmented and encoded content which is distributed across a collection of nodes, providing resilience to missing nodes and/or corrupted data in compromised nodes in a way that is analogous to network coding's use of multiple paths in concert with erasure codes. This Byzantine-resistant mechanism is an efficient means for providing intrinsically assured access to data.

1.4.2 Fast convergence/recovery of routing systems

Until recently, the Internet routing protocols were not designed to accommodate fast convergence/recovery mechanisms (time performance of routing protocols provide for failure recovery in the order of the second without taking into account any traffic properties or characteristics). Indeed, traffic disruptions resulting from network failure have lasted for periods of at least several seconds, and most applications have been constructed to tolerate such a quality of service.

1.4.2.1 State of the Art

Fast-convergence of the routing system is currently an add-on to the routing system. Recent advances in routers have reduced this interval to below a second for link state routing protocols (such as OSPF and IS-IS). Such techniques allow the failure to be repaired locally by the router(s) detecting the failure without the immediate need to inform other routers of the failure. In this case, the disruption time can be limited to the time taken to detect the adjacent failure and invoke the alternate routes.

However, new Internet services are emerging which may be sensitive to periods of traffic loss, which are orders of magnitude shorter than this. Nowadays, network resiliency techniques need to ensure time performance for sub-second recoverability. For this purpose the routing system must deliver built-in recovery mechanisms.

1.4.2.2 Target

Fast recovery mechanisms are characterized in terms of the level of protection they provide (e.g., full or partial protection against single failures) and the time required to activate them. Take into account the network dynamicity to design dynamic and distributed routing schemes is a relatively complex problem; henceforth the target would be reached in two steps:

- Recovery upon topological failures: the routing scheme is robust and resilient against node/link intermittent and permanent failures. Depending on the routing scheme itself but also the topological constraints, several recovery mechanisms will be evaluated from reactive (dynamic re-computation after failure) to proactive (pre-computation before failure occurrence).
- Adaptive routing system: the routing scheme dynamically adapts its routing decision according to the properties of the topology, and/or the policy and corresponding changes.

1.4.2.3 Topics and key issues to be addressed

In order to achieve that vision, there is a need to address the following aspects:

- **Fast re-routing (FRR)**: to cope with pure connectionless datagram forwarding technology (IP and its variants) Techniques shall be designed such as to prevent traffic flow disruption (minimizes packet losses),
- **Fast recovery techniques**: these techniques should i) overcome the currently limitations resulting from maintenance of alternative paths per destination and per failure and ii) provide for loop avoidance (re-convergence process prevents formation of micro-loops) and may be combined with a micro-loop detection technique (by means e.g. of monitoring before failure or after failure),
- For inter-domain routing, ensuring fast-convergence/re-routing depends on the routing scheme e.g. for path-vector routing protocols such as BGP. Mechanism to mitigate (and at best prevent the (uninformed) path exploration effects resulting from the intrinsic properties of BGP becomes critical in order to ensure expansion of the Internet routing system.

1.4.3 Global connectivity coverage availability

Global access to the network capacity and high availability for operational continuity are basic technological requirements for the development of a Future Internet that responds to the challenges and priorities of the modern society with services that communities use and rely upon.

Future Internet should embrace a "user-centric" vision where no gap is encountered among user requirements and network design. Currently, users are searching for Internet connections, "calling" it by operating their PC, laptops, mobile terminals, etc. Users are "constrained" to accept the service modalities and the quality of service offered by the Internet connections found in the place where they are. In the case of absence of connectivity, no service is available. The latter is a big issue of the "digital divide", affecting a large part of the world. In a future vision, the Internet "follows" the users, offering them "friendly" services, wherever they are. Thus, one of the keys for winning the challenges of Future Internet lies in the provision of technologies enabling ubiquitous services explicitly targeted to a real mobility of the users, and in the provision of global network coverage breaking the barrier of "digital divide".

Broadband access to telecommunication network capacity and services must be guaranteed "anywhere-anytime". As such, telecommunication infrastructures must be conceived to guarantee access to the Future Internet also where currently it is poor. In this view the role of Satellite Communications can be of primary importance to guarantee real universal connectivity coverage availability.

As a communication system requiring ubiquitous access, the Future Internet should be capable to provide same performance and services throughout users located anywhere around the globe, including not only on the Earth surface -which is a major challenge- but also in the sky. There must be no barrier between the information producer and consumer; regardless of ubiquity, even in rural areas, and either the access will be on the move or static.

In order to be compliant with the abovementioned requirements, the Future Internet must consider satellite networks as a part of its portfolio of bearer technologies. Satellite communications span a wide range of bearer service types, geographic coverage, data rates and type of terminals (handheld, mobile, fixed, nomadic, etc). Advances in satellite terminals and payload are likely to result in significant changes in capability, and an all-IP interface is expected to yield greater commonality, both in the interface presented to the user network, and applications that use the satellite network.

1.4.3.1 State of the Art

Nowadays, current standards inspired by a thirty-year-old "fixed networking" view severely limit the capacity in terms of available data rates, especially for mobile and, more in general, "wireless" users. One of the catchy phrases of the 6th Framework Programme: "Broadband for all" will remain only a "declaration of intent" if a clear step ahead with respect to the "state-of-the-art" Internet will not be done. In a global World, where people are moving everywhere and the mobility of people is regarded as an added-value, the Internet must not remain bounded to "fixed", "local", and "static" visions.

Satellite Communications are a key stakeholder in the mobile market segment, due to major technological innovations which are emerging to increase the attractiveness of satellite solutions in the field of mobility towards better coverage, performance and reliability. Such innovations include efficient and flexible frequency spectrum and radio resource management, interference mitigation schemes, hierarchical modulation and coding, smart diversity mechanisms, but also by elaborating on "disruptive" concepts such as collaborative phased array antenna and cooperative MIMO techniques. The associated R&D efforts for mobile satellite services above 3 GHz have already started and are supported in particular by the European Commission and the European Space Agency (ESA).

Presently the convergence of video-data-voice on IP network is increasing, and communication infrastructures adapt to new protocols (IPv6) to expand capabilities. In this scenario, previous technologies developed for space-based systems gain new field and present competitive advantages being already partially exploited.

The geographical area at stake, the entire world, and the diversity of users, make the reaching via radio impossible unless satellite is considered.

The Internet Protocol routing would enable the connection of thousands of users through networks rather than limited point-to-point connections, and additionally, it would enable high data rate connections to mobile platforms such as aircrafts, vessels and trains.

Satellite-based systems open up many capabilities complementing ground systems (permitting e.g., ubiquitous access to information for the citizens, enhancing mobility and interoperability capabilities, improving disaster protection and security management). Developing and using satellite-based technology as a component and a basic infrastructure for the communication layer of the future internet appears to be a key contribution of its innovative features and performance.

Some of the technological basic elements of the above defined satellite based infrastructure have been already achieved. What still has to be implemented is a consistent research and innovation path, which is required to build the complete satellite component by filling technological capability gaps and considering all user requirements.

Technologies left to be developed include but are not limited to: inter-satellite link (ISL), on-board processing (OBP) and on-board routing, packet switching, bulk and packet encryption/decryption, multi-beam or steerable communication antennas, dynamic bandwidth and resource allocation techniques, protected bandwidth efficient modulation. Past European developments were mainly driven by commercial goals in the fields of multimedia, which in some cases failed to become concrete on the dawn of the new century not because of technological challenges or hurdles, but due to a lack of aggregated public demand and to the emergence of the all-digital network.

1.4.3.2 Target

Very significant benefits could be drawn from new synergies between terrestrial and satellite combined operation, in particular in terms of service ubiquity, resilience and spectrum management. Mobile satellite services (MSS) spectrum is needed to implement these innovations and their associated benefits.

Satellite Communications support a range of services, from specialised application-oriented services to network-centric services. A tighter coupling between the network and future services, with future services predominantly being offered over IP (IPTV, VoIP, P2P, etc.) can be expected and the satellite should play a more integrated role in enabling development of new services and in guaranteeing service continuity over large coverage areas.

There will be increased convergence of technologies. Hybrid networks seek to balance the characteristics of different networks. Where reprogrammable and software-based components provide new opportunities to integrate new services and respond to new demands. To exploit the benefits of satellite the future Internet must embrace the range of heterogeneity of the under-lying bearer services.

New satellite systems can improve the provision of ubiquitous connectivity. Mobile and transportable terminals will effectively support a wide range of applications and services. Dual-use will become an important opportunity, especially as legacy systems transition to an all-IP infrastructure. Broadband satellite communications offer Internet access where other terrestrial based technologies cannot (e.g., maritime, airborne, etc environments). They play an important role in addressing the digital divide by providing rural access in areas such as Africa, Latin America and parts of Asia. Such deployments could take place in parallel with the new technologies developed for low-cost laptops, phones, etc. Satellite communications can also provide communications for highly distributed networks, including sensor networks, and other geographically dispersed systems and objects.

Interoperability with most terrestrial protocols and technologies would constitute an ideal basis for integrating requirements from various technological platforms, such as ICT or nanotechnologies, which constitute the basis of the EU R&D plan. The standardization of protocols and interfaces, especially the inter-satellite and satellite-to-ground protocols, as well as the seamless integration of satellite/terrestrial networks, should also be considered in order to render such global system efficient. As an example of a related initiative, the European U-2010 (Ubiquitous IP Centric Government & Enterprise Next Generation Networks, Vision 2010) Programme can be mentioned, which addresses public safety issues by analyzing new emergency and crisis management solutions based on Internet technologies.

1.4.3.3 Key issues and topics to be addressed

Under the abovementioned circumstances, the Future Internet architecture should include and be augmented by satellite networks in order to achieve a global connectivity coverage availability. To this end, the R&D developments necessary to successfully meet this objective refer to those required to be undertaken as part of satellite networks, which have been outlined in Chapter 1.2.6 "Satellite Networks". Below, the high level R&D developments needed in this respect are outlined, where further specific details can be found in Chapter 1.2.6.

- Smart and efficient spectrum /resource management and cognitive radio networking techniques for Satellite Networks
- Hybrid terrestrial/satellite communication system architectures
- Delay-tolerant and error-resilient network protocols for Satellite Networks
- Reduce transmission costs and increase efficiency, flexibility and dependability for Satellite Networks
- Increase spectral and power efficiency by at least an order of magnitude for Satellite Networks
- Align form factor and power consumption of satellite terminals to those of terrestrial systems, in particular for mobile services
- Adaptive physical (PHY) and MAC layer techniques for Satellite Networks
- Enable the exploitation of higher frequency bands (Ka band and above) for Satellite Networks
- Integrated security, privacy, mobility, QoS for Satellite Networks
- More flexible satellite payloads with On-Board Processing (OBP) capabilities (to be addressed as part of Space Agencies' Work Programmes)
- More powerful satellite buses (to be addressed as part of Space Agencies' Work Programmes)

1.4.4 Global connectivity coverage reliability

Future Internet needs to be seen as a "global interconnection network", which is available to provide access to network capacity and services "everywhere", "all-the-time" as well as a fundamental service that communities use and rely upon. As such, Future Internet should be able – among others – to support emergency management and to assist society to restore situations on emergencies, crises or natural disasters.

In the case of disasters, emergencies or crises, Future Internet should be a real "salvation anchor" for disrupted populations. Currently, it is well known that most communication connections can be completely or partially destroyed in the early disaster phase and so it is important to install and provide emergency links between rescue teams and survivors in the disaster area. These connection links must provide voice, data and, when possible, video transmission from the area of calamity. In some situations, it is even impossible to organize temporary terrain mobile station due to floods, tsunamis, hurricanes (see e.g., Hurricane Katrina in New Orleans in 2005), or strong earthquake, where police, fire and emergency organizations were cut from any connection in early phase and could not provide any help or necessary information about situation in injured area.

One of the main concerns of crisis management communication in the current situation is the strong reliance on terrestrial communications infrastructure such as land-line and cellular telephony as well as infrastructure-based land mobile radio networks. Thus, in case of a major physical or man-made disaster resulting into severe damages and outages to the ground communication services, the remaining functional parts of the terrestrial network are usually unable to provide adequate telecommunication services in the aftermath of the disaster. Furthermore, crisis management communication systems suffer from lack of support for broadband data rates. Reliable real-time access to sensitive information such as high resolution digital maps of the calamity area can be very valuable for decision-makers. The provision of live video stream from the incident site to the command post can increase the situational awareness which is one of the main objectives in the field of crisis management.

Given the abovementioned concerns of current communication technology used in the field of crisis management, emphasis in the Future Internet shall be put on hybrid terrestrial/satellite network infrastructure capable of effectively providing ubiquitous availability even in emergency scenarios. As an example of a related initiative, the European U-2010 (Ubiquitous IP Centric Government & Enterprise Next Generation Networks, Vision 2010) Programme can be mentioned, which addresses public safety issues by analyzing new emergency and crisis management solutions based on Internet technologies. Satellite-based technology and, particularly, Satellite Communications (SatCom), which can provide broadband, broadcast and mobile services in areas beyond terrestrial system reach, constitute a promising and viable solution for the exchange of information required in crisis management services among the eligible entities. Moreover, satellite-based technology can further contribute in critical emergency situations in terms of satellite navigation (GNSS) and satellite-based earth observation (GMES) systems. Particularly, the European Telecommunications Standards Institute (ETSI) has already recognized the importance of the Location and Navigation Services in the Emergency Telecommunications (EMTEL) framework, which must provide real-time information regarding the position of personnel or vehicles to a command point. Also, satellite-based Earth Observation data can provide valuable and indispensable information for decision-makers involved in all stages of crisis management, including pre- and post-crisis.

1.4.4.1 State of the Art

The design and the implementation of reliable communication systems for emergency scenarios are currently one of the main focus of the R&D activities within the international research and scientific community. Related results achieved so far refer mainly to the following topics:

- Control and management of major crisis events;
- Enhancement of the responsiveness capabilities of the security operators;
- Provision of enhanced localization services;
- Multi-sensor Data fusion;
- Integration of satellite navigation and communication functionalities in a single terminal;
- Integration of Software Defined Radio (SDR) concepts;
- Heterogeneous satellite and HAP (High Altitude Platform) networks and security issues in an emergency scenario;
- Integration of satellite communication and navigation components in the European emergency call service "eCall" for transportation sector.

1.4.4.2 Target

In the context of availability and reliability even in critical emergency situation, upcoming R&D efforts in the area of Future Internet shall be geared to achieve:

- Hybrid terrestrial/satellite communication systems towards interoperability within NGN for ubiquitous coverage, even in emergency scenarios;
- Integration of Satellite Communications (SatCom), Global Navigation Satellite Systems (GNSS) and Earth Observation (GMES) system components within the Future Internet:
    - The development of a global security system which encompasses hybrid terrestrial/satellite-based communication, localization/navigation and remote sensing capabilities is essential for Future Internet. In this regard, the ISICOM (Integrated Space Infrastructure for Global Communications - http://www.isi-initiative.eu.org/) system concept, which envisages interconnectivity with terrestrial networks as well as integration with the Future Internet, is of particular interest.
- Reconfigurable and interoperable terminal devices to adapt in the emergency scenarios:
    - A fully software controlled handset will have to reconfigure itself to cope with any communication, navigation, and remote sensing related requirements and services.
- Robust crisis management communication mechanisms with self-healing and auto-configuring capabilities;
- Robust and scalable databases (i.e. knowledge library) ensuring reliability and availability of the stored satellite-based earth observation data;
- Reliable mechanisms for independent and permanent access to satellite-based communication, localization/navigation and remote sensing information;
- Ubiquitous data relay services based on Everything over IP (EoIP) concept for provision of real time data to emergency control and management centres;
- Ubiquitous E112 and eCall emergency services all over Europe.

1.4.4.3 Key issues and topics to be addressed

In the context of availability and reliability even in critical emergency situation, the following key R&D issues and topics need to be addressed:

- Development of advanced hybrid terrestrial/satellite communication systems for ubiquitous coverage, even in emergency scenarios.

Special attention needs to be paid to:
  - Seamless network handover between the terrestrial and satellite components: the difference of transmission conditions and propagation delays for the two components will impact the hybrid system design;
  - Impacts on the latency, jitter, throughput and QoS due to satellite component constraints. Different types of traffic (with different requirements) need to be supported. E.g., VoIP support needs to be addressed on the satellite component at the same QoS level as on the terrestrial networks;
  - Network and management interoperability (subscription handling, authentication and authorization, and accounting/billing).
- Advanced satellite-assisted Software Defined Radio (SDR) and cognitive radio concepts and architectures for the design of reconfigurable terminals for emergency operations;
- Smart satellite-assisted Radio Resources Management (RRM) strategies in order to effectively manage the available resources within the emergency areas, guaranteeing the connectivity to the integrated SatCom/GNSS/GMES satellite system.
- Smart satellite-assisted node localisation techniques to be implemented either by the terminal or by the network in case of emergency scenarios.
- Innovative multicast techniques to deliver information to different groups of first responders through the integrated terrestrial/satellite network.
- Enhanced satellite-assisted ad-hoc network connectivity to provide support in emergency scenarios.
- High efficiency mesh network air interface for low cost mesh satellite terminals.
- Intelligent data formats for easy and efficient integration of space-borne data with other input sources' heterogeneous data.

In addition, the specific key R&D issues and topics to be addressed as part of the role of Satellite Networks in the Future Internet (See Section 1.2.6 "Satellite Networks") apply in this case, as well.

1.4.5 Quality Of Experience

1.4.5.1 State of the Art

To Be Completed in Version 1.2

1.4.5.2 Target

To Be Completed in Version 1.2

1.4.5.3 Topics and key issues to be addressed

To Be Completed in Version 1.2

1.4.6 Seamless continuity between all networks

In pervasive wireless applications and services, the users will use a truly substantial number of wireless terminals and devices and networks. People and all their "things" communicate: there will be a transformation from one transmitter per thousands of persons (as in the broadcast case) via one transmitter per person (as in the mobile telephony) to hundreds of tiny wireless devices per person (as in the ubiquitous networking world). The networking technology will need to undergo a transformation, from a highly visible, "hi-tech technology" to a "disappearing technology" that everyone can afford, use and deploy, and which utilizes only minimal amount of resources (like energy). A pervasive technology needs to be:
- Based on situated and autonomics paradigm,
- Reliable, secure, **trusted** and **simple** to use,
- Simple to add and develop new services also by users themselves and to select service providers,
- Extremely low cost and energy efficient.

Note: network/communication specific topics are captured in other sections.

1.4.6.1 State of the Art

Flexible growth from small-scale, to continent-wide up to global systems and services needs to be supported, enabling a wide variety of both wide area and local area solutions for all the various application offerings, including unicast and multicast services. One key element will be wireless and wireline access with optical transmission integration. Satellite access, which provides global coverage capability, ubiquitous connectivity and cost effectiveness for broadcast/multicast connectivity, is another key element in this regard. A heterogeneous networking environment as outlined in the previous section calls for means to hide the complexity from the end-user as well as applications by providing intelligent and adaptable connectivity services, thus providing an efficient application development framework. In this section we present possible impacts and technical challenges the vision presented in the previous section will have on networks and network architectures.

Architecture allowing users to be always reachable and having access to their normal personal service environment requires at first step nomadism in the wireline access network meaning the ability to reconnect to the network at new locations and being able to access e.g. the service environment at home and everywhere. The next step is to be able to do the same across different mobile access networks, for example between access networks controlled by different operators and administrators. The last step in the evolution towards a true always best-connected network is the seamless and efficient interaction between the fixed and the mobile/wireless networks. The interworking and convergence between the fixed broadband networks and mobile networks will be a key factor of the future infrastructure to support multi-service capability and mobility over multi-access networks that enable true broadband for all and everywhere, even in mobile platforms which are beyond the reach of terrestrial systems, e.g., vessels and aircrafts.

The complexity of network management will also increase between the providers of network connectivity. This is addressed through provision of substantial automation for achieving both network composition and cost efficient network operations and maintenance via various autonomic functionalities. The autonomous functions operate also on the network control layer, facilitating the negotiation of agreements between networks as well as their efficient verification and enforcement. This will include policy-based networking within a given business framework to enable maximum and stable use of the networking resources.

The emerging communication systems are oriented towards the interconnection of heterogeneous networks able to provide various types of services, including those with high transmission rates and with quality of service guarantees. The integration of optical, wireless and satellite technologies allows an efficient solution to provide multimedia services to the end user in high traffic density areas, merging flexibility and mobility characteristics of the wireless and satellite networks with the high capacity of the fibre.

Applications will have to be supported by intelligent connectivity service taking care of context information and relying on user and application preferences; for instance by increasing the semantic understanding of media flows in the network. The composed connectivity networks must provide predictable and dependable connectivity service to applications with the acceptable robustness in order to be trusted by users and service providers. At the same time, the connectivity service must be secure enough to identify, isolate and autonomously react to any malicious behaviour by, e.g., applications.

Generally speaking TCP/IP Internet solutions assume a fairly predictable and simple notion of the end-to-end communications. This implies that operational assumption for the TCP/IP depends on the need for availability of at least one permanently functional path between a source and a destination with relatively small end-to-end delay and packet loss. This major assumption does not always hold true in a dynamically varying mobile environment. The emergence of sensor networks, RFIDs, ad-hoc networks, and large mobile networks with high and varying cases of mobility, various degrees of intermittency and burstiness, heterogeneity in many different aspects of networking and diversity of services available questions the very essence that the Internet paradigm was built on. The Delay Tolerant Network Architecture (DTN) in IETF recognises this shortcoming and provides recommendation for a very specific research in the Interplanetary Internet but at the same time introduces interesting notions and solutions for Internet evolution in areas of architecture advancements concerning services, topology, routing, security, reliability and state management. This research offers useful insight in methods of adaptations and enhancements of Internet communications in the emerging communications paradigms. The case being investigated in the Delay Tolerant Network Architectures bases the argument on the specific examples of networks where the end-to-end communication delay is highly variable and large with different expectations on the transit properties and delivery constrains of the traffic. This can be interrelated with some of the abovementioned recent types of emerging communication environments in the Internet and considered as an important challenge in *evolving* Internet communications paradigms and associated solutions.

1.4.6.2 Target

The Future network architectures will need to have the following characteristics:

- More intelligence in the end-points**:** Moore's law is applicable to electronic devices - not for infrastructure since infrastructure costs are dominated by the system deployment costs (like site rentals, wiring, installation, maintenance etc). New user equipment and servers can appear on the market in a matter of months, whereas large-scale infrastructure deployment takes years. Therefore, appropriate technologies are needed that enable inherent flexibility and intelligence through reconfiguration, adaptation and self-x functionalities at the end-points (user devices, access points, PANs, and network elements like servers and gateways). In "access independent" IP networks, the end-to-end principle applies to all services. In order to provide this flexibility the transport network has to provide sufficient capabilities such as high enough throughput to be prepared for potential future developments at the edge systems and to avoid bottlenecks in the less intelligent large-scale infrastructure. However this should not preclude the introduction of advanced mechanisms in the transport network that will intelligently optimise the available resources with respect to the capacity demand. A further driver for the increased intelligence is the increased energy efficiency which this can facilitate.
- From "Single system for all needs" to navigating in the "Wireless mayhem"**:** no single wireless access solution or radio technology is capable of providing cost-effective wireless access in all scenarios and for all user needs. Large investments are already made in existing networks and technologies which already provide cost-efficient solutions for certain applications, e.g., wide-area voice and medium data rate wireless, or wireless local area networks. Instead, future wireless access will be provided by plethora of systems forming a heterogeneous wireless environment. New access technologies will appear (e.g. IMT-Advanced, evolutions of IEEE 802.11 and 802.16, gigabit-per-second short range systems, BWA) and many of these will be successful in limited scenarios, thus complementing existing technologies rather than replacing them. More advanced Radio Access Networks (RANs) e.g., for high speed mobility with quality of service (QoS) guarantees) will need to coexist with simple local access solutions (e.g., best-effort nomadic connectivity), and modern infrastructure will coexist with the legacy infrastructure. Hybrid satellite/terrestrial (both wireless and wired) systems are also a key element in this regard for truly global coverage and ubiquitous availability, even in emergency scenarios. Multi-service capability and mobility over multi-access networks (fixed and the mobile networks) enables true connectivity for all and everywhere, even in mobile platforms which are beyond the reach of terrestrial systems, e.g., vessels and aircrafts.
- Multimode access for cooperation and competition**:** multimode terminals adapt to both new services and new wireless access technologies in a much faster and flexible way than the corresponding infrastructure. Significant cost gains are derived from multimode terminals and efficient use and reuse of access resources. The fact that full coverage is not necessary for all access options is probably a key factor for new radio access technologies. Infrastructure can be deployed incrementally and cost-efficiently where needed. Effective access competition will provide additional benefits for the end-users.
- Networks that automatically "compose" and manage themselves**:** the heterogeneity between the network administrators ranging from the typical non-technical personnel (household/local wireless access) the experts managing the large networks will increase. Furthermore, the dynamics within and between these systems will increase, and the large providers can spend less money on management due to increase competition and cost pressures. Both trends imply that the management systems must be more self-managing, they need to be able to cope with most situations autonomously, and when interaction with an administrative person is required, present the problem as abstractly as possible and provide easily understandable tools to remedy the situation. These autonomous functions have to work also on the network control layer, enabling the negotiation of agreements between networks, as well as, their efficient verification and enforcement.
- New information acquisition schemes leading to new internet architectures: the current Internet addressing scheme is based on IP addresses. In the future, ubiquitous wireless environment information gets outdated

very fast and cannot be stored to servers but is shared between network nodes and users. Wireless environment sets strict requirements in terms of e.g., number of connected devices, node mobility and nomadicity, bandwidth availability and variability, utilizing of new features like position information, variability of devices processing power and energy availability, security and trust on vital information exchange etc.

- Energy consumption aware networking and services: as the CO_2 emissions must be reduced in all sectors of society, ICT field must also pay special attention on energy consumption and other environmental issues when developing new technologies or improving existing ones. Due to expected explosion of the number of wireless devices and network entities, energy consumption should be minimized in any technology developed in the future. This will create new design criteria e.g. for wireless network architectures and will foster e.g. heterogeneous networking development to the direction "All ways minimum effort and energy connected". In this regard, the "green" solution of satellite networks, where satellites are entirely powered by solar energy, shall also be addressed.

1.4.6.3 Topics and key issues to be addressed

Today's trend is that large, feature-rich systems tend to become more complex to specify, build and operate. Hence further research is needed on:

- Design novel data delivery mechanisms matching the dynamics of large scale mobile networks and particularly for ad hoc and infrastructure-less networks and network constellations. Richer notions of networked objects including new means for naming, addressing and identification. Study layered vs. non-layered stack design, statically or dynamically configured networking stacks should also be included. With the requirement that the architecture should operate efficiently over both wireline as well as wireless and satellite access networks,
    - Hybrid terrestrial/satellite communication system architectures: Standalone satellite or terrestrial – both wired and wireless - systems are not suitable to provide efficient Future Internet services due to several inherent limitations that each segment shows. Thus, each technology must be considered as an element that can complement the other implementing a concept of global system in which the cooperation among different segments is a real added value. Integration between terrestrial and satellite components must be addressed at different levels, such as coverage, radio, terminal, spectrum, network and service integration, by ensuring seamless availability, diversity gain, portability and continuity across composite networks. Special attention needs to be paid to:
        - Seamless network handover between the terrestrial and satellite components: the difference of transmission conditions and propagation delays for the two components will impact the hybrid system design.
        - Impacts on the latency, jitter, throughput and QoS due to satellite component constraints. Different types of traffic (with different requirements) need to be supported. E.g., VoIP support needs to be addressed on the satellite component at the same QoS level as on the terrestrial networks.
        - Network and management interoperability (subscription handling, authentication and authorization, and accounting/billing).
- Delay tolerant network (DTN) and disruption tolerant network service based on a communication with disruption and disconnections with high delay of heterogeneous peers: non-real time data transfers should be able to proceed even when connectivity is intermittent due for example to mobility or unreliable radio links.
- Concepts for intelligent distribution of content/information/etc. Across multiple access technologies. Delivery of information and media flows to users, adapted to their current access situation, location-dependent interests and preferences,
- Design and development of new network topologies and routing structures to cope with a composition of multitude of networks. Mesh architecture should be validated in an integrated wired/wireless network. Scalability and optimization of network and service control technology which can deal with all sizes of networks, from small ad hoc networks up to large-scale corporate and public wide-area networks, employing a common networking concept,
- Alternative deployment strategies and technologies for capillary networks,
- Multi-layered (ISO layers as well as overlaid/underlaid cell layers) mobility support, which enables ad hoc cluster mobility, as well as, user-mobility across networks,

- True multimedia support: Basic technologies for content distribution over heterogeneous networks and media conversion techniques for multi-modal presentation of content to users. Ability to cope with a wide range of application middleware to support applications with more intelligent communications services,
- Unifying solutions for personal networking (PN), interaction with body area networks (BAN), new types of home networks, vehicle networks, wireless sensor networks (WSN), RFID, deployment and operation of emergency networks, and other network types,
- Solutions enabling efficient OPEX and CAPEX for fixed very high bandwidth multi access networks with scalability for number of users and bandwidth including a variety of first mile technologies such as wireline (fibre, xDSL) and wireless (HSDPA, 4G),

The major objectives of the research are therefore to:

- Nomadism and mobility with session continuity with alignment of business models, roaming protocols, user & service management and architecture between fixed and mobile networks. In these conditions; enable Information accessibility anytime, anywhere as if it were stored locally (e.g., music database on mobile players) even in the case of intermittent or fluctuating connectivity,
- Enable the future infrastructure supporting multi-service capability and mobility over multi-access networks (fixed and mobile networks) with heterogeneous devices where privacy, security and safety are prerequisites but need to be easily managed,
- Enable interworking and convergence between the fixed broadband networks and mobile networks to reduce cost and make services available everywhere including full acknowledgement of optical transmission as well as of satellite access,
- Unbundling: network architectures that allow for collaborative business models in which complementary providers join forces, as well as for unbundling of the access network to competing service providers in order to achieve the most attractive service offer for the end-user,
- Propose network architectures capable to cope with i) the new and emerging wireless networking requirements,
- New protocol frameworks and collapse of current protocol stack and layering into minimum required protocols in face of widespread availability of fibre optics networks and ii) that supports high-bandwidth real-time services over multiple access technologies,
- Complement research effort on networking of devices with networking of information, e.g. towards semantic technologies, data fusion, to support ubiquitous availability of content and information for all application scenarios (e.g. user-centric, M2M-centric), emergency scenario with collapsed terrestrial infrastructure, etc),
- Understand the evolution towards context-awareness and support of cognitive networks and media-aware networking thus providing the intelligent connectivity services required for efficient application development. Develop support of automatic context-aware discovery, selection and composition of devices, networks, resources and services as well as personalised service selection and decision making,
- Enable harmonisation of actuations amongst sensors, monitoring and control applications working under critical requirements (e.g., security, availability, reliability, speed of action).

1.5 Adaptability and evolvability

This challenge deals with the adaptability and evolvability to heterogeneous environments, content, context/situation and application needs.

1.5.1 Semantic web

(The term WEB 3.0 is used in the following text)

The Web was originally designed for accessing contents in the Internet. What started just as an instrument for the network has become the main protagonist in our relation to the information world. The huge amount of information available and the limited processing capability (human and computing machine) is limiting its usefulness and creating big bottlenecks.

1.5.1.1 State of the art

The focus of innovation of the third generation of the Web will start shift back from front-end improvements towards back-end infrastructure level upgrades to the Web. This cycle will result in making the Web more connected, more open, and more intelligent. It will transform the Web from a network of separately isolated/decoupled applications and content repositories to a more seamless and interoperable whole. A more precise timeline and definition might go as follows.

Web 1.0 was the first generation of the Web. During this phase, the focus was primarily on building the Web, making it accessible, and commercializing it for the first time. Key areas of interest centred on protocols such as HTTP, open standard markup languages such as HTML and XML, Internet access through ISPs, the first Web browsers, Web development platforms and tools, Web-centric software languages such as Java and Javascript, the creation of Web sites, the commercialization of the Web and Web business models, and the growth of key portals on the Web.

The term Web 2.0 was invented by a book publisher as a term to build a series of conferences around, and conceptualises the idea of Web sites that gain value by their users adding data to them. According to the Wikipedia, "Web 2.0, a phrase coined by O'Reilly Media in 2004, refers to a supposed second generation of Internet-based services—such as social networking sites, wikis, communication tools, and folksonomies—that emphasize online collaboration and sharing among users." Moreover, it also deals with the emergence of the mobile Internet and mobile devices (including camera phones) as a major new platform driving the adoption and growth of the Web, particularly outside of the United States.

Finally, Web 3.0 could be defined as: "Web 3.0 refers to a supposed third generation of Internet-based services that collectively comprise what might be called 'the intelligent Web'—such as those using semantic web, microformats, natural language search, data-mining, machine learning, recommendation agents, and artificial intelligence technologies—which emphasize machine-facilitated understanding of information in order to provide a more productive and intuitive user experience.

There are actually several major technology trends that are about to reach a new level of maturity at the same time. The simultaneous maturity of these trends is mutually reinforcing, and collectively they will drive the third-generation Web. From this broader perspective, Web 3.0 might be defined as a third-generation of the Web enabled by the convergence of several key emerging technology trends such as ubiquitous connectivity, network computing, open technologies and the Intelligent Web.

1.5.1.2 Target

- Creation and implementation of new tools that will allow breaking the barriers/boundaries between information producer and information consumer, allowing the creation of any type of business regardless size, domain and technology, etc.
- Full Semantic Web. Both structured data and even what is traditionally thought of as unstructured or semi-structured content (such as Web pages, documents, etc.) will be widely available in RDF and OWL semantic formats.
- Intelligent applications (natural language processing, machine learning, machine reasoning, autonomous agents) that support the concept of Intelligent Web.
- New standards for data-exchange, linking and synchronizing between machines, so that users are capable of using the power of all different data resources on the web.
- Developing hierarchical statistical graphical models for the study and optimization of the interactions of the semantic layer, the content layer and lower layers.

1.5.1.3 Topics and key issues to be addressed

Semantics is widely thought to be the "unifying glue" that will put together all the bits and create the overall intelligent interconnected network. This concept leads to the vision of the Semantic Web. However the development and application of semantics is facing challenges of its own, among the most relevant are:

- The "'scalability challenge'": semantic processing has already proved its value in focused, domain-constrained applications. But the web is essentially an unconstrained environment, dealing moreover with incredible huge amounts of information. Hence semantics must adapt to extend its scope and deal with data that is of increasing complexity, both in the physical side (huge volume) and in the semantic side (wildly heterogeneous),

- The "'generation challenge"': in order to perform semantic processing, it is obvious that semantics have to be generated first. This is the major bottleneck. Neither automatic generation (e.g. by media analysis or by carrying-on data from production), nor human generation (by annotation or by collaborative crowd sourcing) will be able to solve the problem alone, but the intelligent combination of both is already producing promising advances.

In the end, the solution provided by ontologies and formal reasoning will only be able to fulfil its interoperability mission by achieving semantic uniformity across all information processed, and this will also need to solve the dilemma between modular (local) semantics and all-encompassing (anchored in upper-level) representations.

If the Web 1.0 was content-centric (it consisted mostly on accessing content), and the Web 2.0 is roughly people-centred (it puts users at the centre by empowering them with tools to become active producers), the Web 3.0 will be process-centric, and consist mostly in ways in which information will flow between nodes, therefore achieving (aided by semantics) an interrelated triangle of:

- "people", turned into active elements of the Web, and for which tools coming from Social Network Analysis, psychology and cognitive science will provide the necessary integration elements,
- "content", fully understandable and therefore processable (including multimedia content and the "sensor web"), and,
- "devices and nodes", interacting both with users and with systems with all vertices talking to each other, and between them. It will be less on 'nouns' and more on 'verbs'.

Applications should allow sharing knowledge within a given community, structuring information taking into account the existing profiles and points of view ("anyone can say anything about any topic"). Ontologies expressed in standardized languages such as OWL, will help in the reasoning of Web applications.

The current web is facing three major problems:

a) The attention problem

"How we can extract the relevant information to our personal limited attention?"

The total amount of information generated in 2006 was 161 Exabytes, this is expected to increase by 2010 to about one thousand Exabytes per year. This information will be mostly unstructured, no metadata and no organization whatsoever, and the majority of it will be generated by end users. Quoting H. Simon, "this wealth of information creates a poverty of attention" and it is necessary to allocate it efficiently. More significantly, much of this new information is of multimedia nature, which is occupying an increasing share of our attention. This will require significant adjustments, both in management and retrieval systems (which are currently more or less tuned to textual data, and fail frequently when dealing with multimedia content) and in visualization systems (since this information must be presented to users in a way in which it can be digested efficiently). For instance, video is already taking a very significant space but new techniques have to be devised to adapt what is inherently a linear media to nonlinear uses, including video skimming, browsing and adapting run time to users availability.

We need intelligent browsing applications that would extract the relevant semantic information and present it to the user. It is also crucial to be able to estimate and measure user attention and react accordingly.

b) The interface problem

"How can we use best that information when our conditions change, when we are moving…?"'

The user experience is the most important thing that we have to consider in the future of internet. We have lots of contents and we need to show them in a very limited space. This issue takes to think that content itself will be the interface of the future.

Only 14% of mobile users use the Mobile Internet regularly, even if the number of Internet capable phones is increasing very rapidly and will soon reach 100%. Information has to be adapted to the terminal and to the person using it, for it to be relevant and useful.

This requires pushing the technology in 4 areas:

- Enhancing the mobile network capabilities, including reduced battery consumption,
- Improve the user terminals experience. This requires new research in new multimodal user interfaces, including location positioning, accelerometers etc. that will enrich the user experience. Also social networks have to use the new context awareness to be more useful and interesting to users,
- Search requires a radically different approach in the mobile environment. Users need to find answer in the time that they are available, but these must be provided within a highly constrained interface,
- Develop new and specific applications. New browsers and search engines, which take into account the limitations and contexts will be needed. But also new content and compression methods to enhance and ease transcoding will have to be developed.

Terminals have to be more intelligent to incorporate semantic behaviour and transmit to servers their characteristics. The server has then to choose the most adequate way of conveying the information to the terminals.

c) The applications problem

"How can the web be used to make best use of our devices and applications?"

The original design of the web was to access Internet content; however, it soon was imported in the applications space to solve problems difficult to tackle:

- new software releases and patches distribution,
- document-application integration,
- upload-download of files in applications.

This initial Web had thus to evolve as to incorporate technologies enabling functionalities required for applications (e.g., JavaScript), which ultimately lead to Web 1.0. Then it evolved to the Web 2.0 including new features such as tagging , mash ups, etc.

This tendency of incorporating new functionalities as required by the applications will lead to the new SOA/Web 3.0 that will include new features that have to be fully developed and used:

- SOA for things,
- Indexing of internal applications,
- Semantic services,
- Automatic behaviour.

The above mentioned vast amount of information, coupled with the incorporation of data coming from the huge amount of sensors being deployed (the ""sensor web"") will preclude human processing; therefore at the application space it is increasingly becoming a game of machine-to-machine communication. A great share of the future Web will consist of systems talking to systems, not to humans.

1.5.2 Seamless Localization

Localization is gaining importance for many use cases. While applications like e.g. Google Earth and the GPS capability of mobile devices are increasingly bringing location-aware systems to the user, also industrial applications (e.g. logistics, safety applications, factory automation, maintenance tasks) benefit from localization capabilities. While, however, typical GPS availability and accuracy can fulfil the requirements of most end-user applications, industrial applications also require indoor-coverage and sometimes also an accuracy of only a few centimetres.

The growing need for ubiquitous positioning and navigation to service the anywhere, anytime needs of the consumer location-based services (LBS) and intelligent transport systems (ITS) markets will strongly influence future navigation receiver architectures. In particular, there is a need to operate with a multiplicity of GNSS (Global Navigation Satellite System) systems, but also with other positioning techniques based on wireless communication systems and inertial measurement units. Anywhere, anytime navigation requirements will favour architectures that can deal with a large variety of signal types. Rather than rely on just one signal type for navigation, future receivers will need to scan through the universe of potentially available navigation signal sources and dynamically choose those that are available at its current location and time.

1.5.2.1 State of the Art

Information about the position of a user's mobile handheld device is a potential trigger for a myriad of emerging applications. From fireman operations to interactive, personalized touristic guides, position constitutes a valuable data to be exploited by systems which only imagination can bound. Unfortunately, the problem of user's position remains unsolved, at least with the degree of coverage, reliability and accuracy that applications (and imagination) demand. The outstanding approach to mass-market positioning is usually referred to as Global Navigation Satellite Systems (GNSS), a concept that includes the well-known GPS, GLONASS or the forthcoming Galileo system. These satellite-based systems, often assisted by some kind of aiding system providing local information (WAAS, EGNOS, RTK), are able to determine the user's position with a high degree of accuracy under proper conditions. However, the performance of those systems severely degrades in common scenarios such as the urban canyon or indoor navigation, where there is no line-of-sight between the mobile device and the satellites. In these cases, the weak receiving power, the multipath effect and interferences make a standalone GNSS receiver almost useless. The rapid deployment and pervasiveness of wireless communication systems (GSM, UMTS, WiFi, WiMAX, Bluetooth, UWB, DVB, DAB) and sensor networks, in combination with the availability of flexible, low-cost commercial off-the-shelf components, offers a bundle of electromagnetic waveforms that can be exploited in order to compute user's position in harsh scenarios. Although these systems are primary designed for other applications, they can provide worthy information for urban/indoor positioning.

Systems which fulfil different localization requirements have been around for some time now and can be classified into the following segments:

- **Satellite-based Localisation:** In outdoor and light-indoor propagation environments, most current Global Navigation Satellite systems (GNSS) receivers (including GPS and Galileo) are able to deliver reliable navigation with accuracy within a few meters.

- Base-Station / Access Point ID: The position of base stations and/or access points is known, the location of a (mobile) terminal is estimated based on which base stations and/or access points are available. This trivial method is possible with almost any technology but only provides low accuracy.

- Received Signal-Strength Evaluations: This technology has gained popularity especially for WiFi localization. Based on extensive measurements of received signal-strength values of different base stations in the surrounding, an estimation is done about the terminals location. This method typically shows better accuracy than the trivial base-station ID evaluation, it needs lengthy calibration and is very sensitive to changes in the environment.

- Signal propagation measurements: This technology is known to provide the highest accuracy. If the radios fulfil certain requirements regarding timer resolution and stability, channel bandwidth, etc., the signal propagation time can be used to derive the distances between radio stations. If enough radio stations are available, a coordinate system can be built out of the distances and thus the location of the single nodes can be determined.
  One challenge here is the design of a cost efficient yet accurate system which requires research in applying general-purpose wireless systems (i.e. WLAN) for localization. While first systems are already available, accuracy, reliability, scalability and mobility support are still considered topics for future research.

1.5.2.2 Target

The localization of networking devices must become a standard functionality of the Future Internet. It must be provided to the applications as a service. Furthermore it will allow for other advanced network functions (e.g. localization based routing).

Localisation is also of paramount importance for emergency scenarios, e.g., in natural disasters where the rescue team needs to know the exact position of survivors. In this regard, integration of Satellite Communications, Global Navigation Satellite Systems (GNSS) and Earth Observation (GMES) system components within the Future Internet shall be addressed.

1.5.2.3 Topics and key issues to be addressed

While dedicated localization systems are available especially in the "signal propagation measurement" segment, those systems are typically used for localization only. As research challenges in this area, we see especially the following two points:

- Utilization of standard wireless communication systems for "industrial-grade", high-precision localization,
- Global availability of localization information, independent of the current access network and the current localization method (e.g. GPS, time-of-arrival measurements).
- Smart satellite-assisted node localisation techniques to be implemented either by the terminal or by the network in case of emergency scenarios.
- Smart hybrid satellite/terrestrial based localisation techniques to improve positioning accuracy in indoor and outdoor environments.
- Standards for interoperability between indoor and outdoor systems to give a seamless experience
- Emphasis on indoor location systems combining GNSS and short-range transmission techniques.

The future of GNSS tends to scenarios where a receiver will have a large number of possible useful sources for positioning. Currently, GPS is the main - if not the sole - player in satellite navigation. However, the reborn of GLONASS, the advent of Galileo, the increasing regional systems alternatives (QZSS or IRNSS) or the worldwide maturity of augmentation systems (WAAS, EGNOS, MSAS, GAGAN) makes the design of future GNSS receivers more complex, since the number of visible satellites is expected to increase from the current 10-13 values to 30-40. In summary, multi-constellation/multi-frequency GNSS receiver promises improved positioning solutions and enhanced integrity, at the expenses of posing a challenge to the scientific community. For instance, there is a need to define a satellite selection criteria (e.g. power level, lowest Time-To-First-Fix,…) or propose efficient implementations of such receivers (defining the integration level achieved: baseband, observables or position solution). The design of software-defined receivers appears as a timely, essential task to achieve the goals of efficiency, modularity, interoperability, and flexibility demanded by different user domains (aeronautical, land mobile, maritime, earth observers, geodesy, etc).

1.5.3 Industrial mobile networks

Mobile data communication plays a more and more important role in many industrial scenarios. Due to the progress of the wireless technologies in the communication, office and home areas (mobile phone, WLAN, Bluetooth, …) these technologies are also deployable for industrial applications. This includes, among others, logistics applications, fleet-management, airfield communication and railway scenarios. Besides other advantages especially the feature "Mobility" allows for a lot of new application fields.

1.5.3.1 State of the Art

There are already solutions for industrial mobile networking today (e.g. Industrial-WLAN). The advanced requirements of theses networks are mainly achieved by specialized systems. Reuse or cooperation with "common" wireless technology is hardly possible. New standards like Wireless HART, ZigBee and others try to cope with enrgy and computing limited embedded devices.

Depending on the scenario, the demands for mobility support varies. Logistics and fleet-management systems for example are mainly relying on sporadic communication with uncritical time-constraints but are very cost-sensitive.

Today wireless connections are often used in a "non-mobile" way, to reduce installation costs. So the mobility aspect is often not addressed in today's systems.

1.5.3.2 Target

The architecture of the Future Internet (especially the mobile aspects) must be designed in a way, that it can also be used for the industrial application fields. These applications often have very demanding requirements which are not seen with other Internet applications. Examples are: strict real-time communication, reliability, difficult environments (factory floor).

1.5.3.3 Topics and key issues to be addressed

- Seamless handover: The demanding requirements of industrial applications (e.g. real time) doesn't allow for "longer" connection interrupts. Furthermore these mechanisms must work also in heterogeneous network systems. Efficient handover of networks, i.e. (large) groups of moving devices along roughly the same path. A typical scenario for that is a fast moving train where many of the passengers are connected to a wireless network. In case a handoff needs to happen into a different wireless cell or even into another wireless cell based on another wireless technology, either the handover is realized for each and every passenger separately or one is trying to perform a somewhat intelligent, optimized handover of all passengers at the same time. Seamless network handover between the terrestrial and satellite components of hybrid terrestrial/satellite systems shall also be addressed, particularly, for critical applications, such as railway and aeronautical scenarios.

- Handover prediction: Moreover due to the fact that the train only can move along the tracks, based on the current velocity of the train, the movement of the train and thus the movement of the passengers could be predicted quite well. That knowledge could also be used to optimize handoff mechanisms.

- Self-organisation: In areas without a fix installed network infrastructure, a group of mobile devices must be able to build an ad-hoc network. (e.g. containers at a harbour which belong to the same company).

For industrial mobile networking the topics include system architectures, communication over heterogeneous networks, optimal network selection real-time support (seamless handovers) and energy efficiency of the protocols and - as an especially important issue - reliability. As many industrial scenarios are mainly based on Ethernet mechanisms without much IP routing, it important to create solutions integrating layer 2 and layer 3 in an optimal manner. Apart from mobility support as such, typical sensor/actuator networks face two additional challenges. One is the fact that many devices are very energy limited (i.e. battery less sensors), so protocols must support power save modes and should support energy efficient computations. The second fact is that many networks are very low rate and operating Web Services and IPv6 with a reasonable performance requires new efficient algorithms (i.e. for header compression).

- SCADA (Supervisory Control And Data Acquisition) industrial applications are also relevant in this regard. In the case of large networks of widely distributed terminals with sparse packet communication requirements, satellite network solutions are of significant importance and specific advanced techniques, such as efficient random access schemes which allow a more efficient exploitation of the return-link spectrum and a reduction of latency for small data packets, shall be addressed in this regard.

- Increasingly, surveillance applications are becoming common also for mobile systems like trains. Together with the requirement to have real-time access to this data or, at least to be able to upload the recorded data during stops in the railway station, we see high demands on wireless data rates for static as well as highly mobile situations. Thus a quick identification and usage of heterogeneous connection opportunities is essential for the static case. For the mobile case, broadband connectivity over heterogeneous networks (e.g. 802.11, 802.16, FLASH-OFDM, DVB-S2/RCS) with low handoff latency is required. As also applications like "Internet on Trains" are in focus, mobility has to be supported on all layers (e.g. client-initiated VPNs have to be supported in a stable manner across multiple heterogeneous networks).

1.5.4 Adaptive interaction

1.5.4.1 State of the Art

To Be Completed in Version 1.2

1.5.4.2 Target

To Be Completed in Version 1.2

1.5.4.3 Topics and key issues to be addressed

To Be Completed in Version 1.2

1.6 Operating system, application, and host mobility / nomadicity

1.6.1 Cloud OS

We envision a paradigm shift on how in the future Internet services will be created, deployed, executed and maintained. The new paradigm is characterised by Layer Fusion and promotes a new kind of Network embedded Operating System approach beyond today's cloud and grid computing, for the first time implementing the consequent separation of information and its processing logic from execution and networking resources.

1.6.1.1 State of the Art

Today cloud computing starts to expose a subset of computational resources (e.g. Amazon EC2) or storage resources (e.g. Amazon S3) to a global community.

However the burden for service developers and service providers to make use of those offered resources is still high as each solution demands a specific adaptation of the service to the resource (no portability of services between e.g. cloud providers) and end-users can not take advantage of the cloud directly. Also cloud computing architectures are still very much focussed on the provisioning of IT resources.

In order to go a significant step ahead it is required to address both issues. Explore means to manage a multitude of resources ranging from "traditional" cloud resources like computational or storage resources but also communication network resources, sensor resources, display resources, mobile devices, etc. Here it needs to be distinguished between highly-available resources (e.g. data centres) and volatile resource (coming and going with a very dynamic behaviour) like e.g. mobile devices.

1.6.1.2 Target

The developer of a service should not be required to consider details on the infrastructure environment his service will be executed in. In order to achieve this, an abstract description of the actual service requirements according to the involved execution and networking resources is need. Service components should be assigned to appropriate execution resources in the network at the latest possible point in time. This late binding of resources allows accounting for the current status of relevant resources in the network. Even more, the late binding can consider other parameters relevant for the execution of the service, which are only known at service instantiation time. Thus, the concept of late binding ensures an optimal assignment of service's components onto available resources in the network also taking into account required transport resources. Besides supporting optimum placement of service components at service instantiation time, the architecture concepts worked out should also provide simple means to support a reassignment of service components to different resources in the network. By this, for the first time it is feasible to react on changing utilization patterns of individual services or changing resource utilization in the network. In such cases, components can be seamlessly moved at service runtime onto better suited resources in the network.

1.6.1.3 Topics and key issues to be addressed

- Cloud OS service offer: High and low level services which are the ones which should be offered by an OS for the Cloud.
- As service components are executed on shared resources, a strict separation between components must be ensured. This should avoid unwanted interaction between different services respectively service components. State of the art concepts for an execution container are rather course grained respectively show performance limitations. In contrast, a lightweight solution is needed coming with very limited overhead and at the same time showing almost native execution performance on the occupied resource.
- The envisioned new service architecture fundamentally differs from available architectures due to the new paradigm that service components are assigned to resources at the latest possible point in time namely at service instantiation time. Key characteristics of the new architecture are the possibility to initially

instantiate service components on best fitting resources concurrently taking into account component-specific requirements and the intrinsic capability to seamlessly migrate service components at service runtime.

- Therefore the Cloud OS should not only allow for an optimum placing of service components at instantiation time but also for an adaptation of the resources assigned to a service at run-time. Here, on the one hand it should be possible to react on the dynamic changes of the resource utilization patterns in the network. On the other hand, the adaptation of allocated resources based on service utilization changes should be carried out. An example for this case is the active relocation or duplication of a service component to optimally serve new users of a service,.
- The new paradigm implies that service components are dynamically interlinked with each other at run-time. This must be done in such a way that the communication necessary for the contribution of the service is always guaranteed, based on the characteristics specified in the abstract description of the service. Efficient and at the same time secure communication mechanisms have to be found, which enable the instantiation of the respective scenarios in an optimal way.
- The goal of an optimal placement of service components within the network makes it necessary to supervise the load and the utilization of the relevant resources (like processors and memories, but also links). In addition, the quality of the services in progress has to be supervised. Measurement assistance must be provided within the architectural concept to facilitate this supervision.
- A major question is how far the Cloud OS is able to autonomously scale a service according to the number of its users. For this investigation it should be supposed that - notwithstanding today's status quo of technology - the developer of a service can build its service components such that these do not need any special and in practice quite complex logic for the support of the service scaling.

The developer of a service should not be required to consider details on the infrastructure environment his service will be executed in. In order to achieve this, an abstract description of the actual service requirements according to the involved execution and networking resources is need. Service components should be assigned to appropriate execution resources in the network at the latest possible point in time. This late binding of resources allows accounting for the current status of relevant resources in the network. Even more, the late binding can consider other parameters relevant for the execution of the service, which are only known at service instantiation time. Thus, the concept of late binding ensures an optimal assignment of service's components onto available resources in the network also taking into account required transport resources. Besides supporting optimum placement of service components at service instantiation time, the architecture concepts worked out should also provide simple means to support a reassignment of service components to different resources in the network. By this, for the first time it is feasible to react on changing utilization patterns of individual services or changing resource utilization in the network. In such cases, components can be seamlessly moved at service runtime onto better suited resources in the network.

1.6.2 Embedded OS

1.6.2.1 State of the Art

To Be Completed in Version 1.2

1.6.2.2 Target

To Be Completed in Version 1.2

1.6.2.3 Topics and key issues to be addressed

To Be Completed in Version 1.2

1.6.3 Cloud computing

1.6.3.1 State of the Art

To Be Completed in Version 1.2

1.6.3.2 Target

To Be Completed in Version 1.2

1.6.3.3 Topics and key issues to be addressed

To Be Completed in Version 1.2

1.7 Energetic sustainability

This challenge deals with the energy efficiency (EE) of communication systems addressing several relevant aspects. A special attention is given to EE of radio transceivers and protocols corresponding to their significant influence on energy consumption.

1.7.1 Energy efficient systems

The long-term sustainability of human activities is experiencing growing attention and will be one of the paramount technological challenges of the 21st century. Since the data traffic in communication networks is exponentially increasing, energy-efficient communication techniques are needed for assuring that communication-related energy consumption is not exploding and that the pertinent carbon footprint is caped or even reduced. Thus, an exponential reduction of consumed energy per transmitted bit is required, and the same holds true for the cradle-to-grave carbon footprint of network technology.

Another level of argumentation for energy efficiency is the increasing number and percentage of mobile devices that, in part or total, are driven by batteries. Decreasing the energy consumption of these devices will relax requirements on the battery charge. While energy consumption might be of secondary importance in interference-limited networks (e.g. data networks), it becomes a critical factor in energy-constrained networks, such as wireless sensor networks. In this context, where network lifetime critically depends on the sensor batteries, the minimization of the energy consumption in the network nodes, consisting of tiny, disposable nodes operating for very long periods of time, becomes of utmost importance. These envisioned sensor networks require a brand new set of transmission techniques rather than merely adapting those that were designed with interference-limited networks in mind. In general, good technological solutions for sensor networks will typically be based upon efficient transmission techniques along with scalable network protocol.

Currently, data volume transmitted through networks increases approximately by a factor of ten every five years, which corresponds to an increase of associated energy consumption by approximately 16 % – 20 % per year. Gartner estimates that the use phase of ICT equipment is responsible for 2 % of the annual carbon emissions. Other studies indicate that the share of the use phase of ICT in the worldwide energy consumption is closer to 3 %. This is comparable to the energy consumption of the aviation industry. When incorporating the entire life cycle, the share of ICTs is closer to 4 %. The exponential growth of ICTs, which will be required for reducing the energy intensity of the entire economy, is currently not sustainable.

1.7.1.1 State of the Art

In the past, the technological development of ICT focused mainly on increasing the capacity of data transportation. These efforts did not include energy efficiency considerations specifically and were thus not necessarily resulting in optimal performance from an energy consumption point of view.

While it has been a common trend that the energy consumption has not noticeably increased or even decreased with an increase in data rate, the overall volume of the data traffic, and thus the related energy consumption, has increased exponentially. Therefore, it is a challenge for any sustainable communication technology to provide holistic approaches for levelling or even decreasing the energy consumption for an exponentially increasing traffic volume.

When tackling the problem of the increasing energy consumption, instead of looking just at different isolated aspects of the overall problem, a global optimization approach is required in order not to compromise the quality of the networks. A holistic approach should be considered. This energy efficiency view is relevant not only for networks in developed countries, where it contributes to decrease in electricity bill of operators, but also in developing ones, where the access to power networks is difficult in remote areas, implying alternative source of energy solutions. Improving energy efficiency can thus foster the deployment of wireless networks in these regions and help to close a potential "digital divide".

A first step requires increasing individual energy efficiency of equipments. Evidently, by migrating from 2G to 3G, power consumption has multiplied by a factor of 5. Moreover, the radiated power of a BTS or Node B is maximally 50 Watts maximum. This demonstrates that drastic reductions in power consumptions are required and should be feasible.

Furthermore, it is a fundamental goal to extend the equipment's lifetime. This will lead to a lower impact of the production phase in the overall footprint.

Although the network itself needs energy efficiency optimization, it never received sufficient attention from the energy efficiency viewpoint, as it was easy and relatively cheap to get power supplies to the equipments. This view is changing quite fast, and the inclusion of environmental approaches, namely energy efficiency, into the design of networks, is becoming a factor for increasing competitiveness. Many ideas can already be found, some of them implementable with current technologies, like switching off a base station during the night when traffic is low or non-existent. More generally, flexible networks that adapt their capacity to the requested requirements can lead to significant energy savings. Also new network paradigms that assure all components are used at their fullest capacity will need to be introduced.

1.7.1.2 Target

In order to meet global and national goals for carbon-footprint reduction and in order to compensate for noticeably increasing energy expenditures, technological energy-saving measures are a mandatory ingredient of any emergent ICT, be it in the short term or the long term, be it for evolutional or revolutionary technology. In a short term (next decade) carbon footprint and energy consumption for Internet-related purposes need to be slowed down, and, in the long run (2050 and beyond), both have to decrease in order to meet the long-term goal of a tenfold global carbon-footprint reduction. Research has to investigate the potentials and develop detailed concepts for energy reducing mechanisms in communication systems in order to enable the definition of EE systems.

1.7.1.3 Topics and key issues to be addressed

In order to achieve that vision, there is a need to address the following aspects:

Energy optimisation of each communication layer (PHY, MAC, routing, etc.). Power amplifiers (PA) turn out to be the subsystem with the highest consumption as well as the main source of nonlinear distortion in a radio transmitter (not only in mobile terminals but also in base stations, satellite transponders, etc.). There is a clear need of research on novel linearization and joint optimization techniques of the power transference to the antenna, minimizing the radiated power interference in adjacent channel and increasing efficiency.

- Carbon-footprint optimisation and further energy optimisation of entire networks by use of cross-layer optimisation
- Consideration of energy-saving and distributed computation schemes for wireless networks:
  - Radio Access architectures, operation and new implementation concepts,
  - Innovative radio solutions (analog front-ends and digital platforms, antennas and antenna interface), to exploit the possibilities enabled by new technologies. With this regard, in future terminals the integration of RF MEMS (Micro-Electro Mechanical Systems) in RF front-ends and the co-design of some RF components (e.g, antennas and amplifiers) is promising. Reconfigurability and scalability are crucial to realize a cognitive radio so that it can reconfigure itself according to spectral opportunities. These reconfigurable capabilities should be available from the transceiver level up to the resource management strategies. Important impact on energy saving wireless devices is also expected from new antenna design techniques such as:
    - RF MEMS base reconfigurable directive antenna,
    - Combining with indoor localization Positioning ID devices/tags or DOA estimators),
    - Using cooperative beam-forming,
    - Better understanding of indoor propagation,
    - Antenna LNA co-design approach.

- Radio functionality: Energy efficient modulation and coding schemes, including network coding and cooperative networks, can bring significant savings. Indeed, wasting energy due to high interference levels, need for packet retransmissions, or very long contention periods, can be avoided if the communication system and the air interface are designed with the goal of reducing energy consumption. Furthermore, new. sampling or sensing techniques such as "Compressed Sensing" that allows the faithful recovery of signals from what appear to be highly incomplete sets of data, typically using fewer data bits than traditional methods used to request, appear to be very promising. Indeed, following this approach would bypass the current wasteful acquisition process in which massive amounts of data are collected only to be in large part discarded at the compression stage and hence results in a significant saving of the transceiver processing power.
- Radio operation: Progress on the radio design alone will not be sufficient to cope with the green challenges. A need for holistic strategies exists, to enable energy aware and spectral efficient operation. Green intelligence can be brought in the radios through the cognitive cycle in which the analysis step considers the reconfiguration opportunities also in terms of global energy consumption (terminal & network) through an interaction between the terminal and network infrastructures (Figure 3-2). As such, future terminals should be context aware and their ultra low power communication aspect will be enabled by an appropriate joint combination of sensing, localization and identification.

Green Operation:
A number of different techniques can contribute to green networking in the highly-dynamic emerging networks. Besides some classical approaches like routing, cross-layer optimization, etc., new networking paradigms offer opportunities to save energy.

- **Cooperative networking** depicts a strategy where network elements belonging to the same owner or across domains cooperate and assist each other, instead of competing in using resources in order to globally optimize spectrum usage and reduce power consumption. Cooperation is a logical way forward when network elements belong to the same owner, as for instance in home networks and personal networks. Considerable gains can be obtained through cooperation.
- **Cognitive networking** refers to the use of artificial intelligence-like techniques to make better choices in operating a network or a set of networks. An example could be that a mobile network could predict time and access points to dock with another network or with the Internet. It could be possible to save energy by predicting when to transfer non-time critical data at the best possible moment via the best choice of access point.
- **Opportunistic networking** is a technique applicable to networks where the connectivity is intermittent and, by extension, where the characteristics of the connectivity vary considerably in time. This is in particular applicable to moving networks, that intermittently dock with an infrastructure or other moving networks (e.g., vehicular networks). Opportunistic networking, in particular in combination with cognitive networking can be used to choose the best opportunity to transfer data.
- **Delay tolerant networking** is applicable to the support of services where delay is not a key requirement. Instead of activating resources that consume energy but cannot be necessary because of the delay-tolerant nature of the service, the goal of this approach is to optimize consumption using minimum resources.
- **Satellite networking**: Satellites are per se green because they are entirely powered by solar energy. Thus, Future Internet shall take into account such key environmental friendly network elements, which augment its global architecture and further contribute to its Green Operation.

Green networking requires multi-criteria routing involving “green variables” weighted according to criteria agreed by the stakeholders. Opportunistic interface selection by users can improve the connectivity of users in flexible spectrum environments and, thus, help alleviate the problem of excessive energy consumption. This approach is applicable in scenarios where a user can connect to several networks using a multiple interface terminal or in a personal network where the user can select one of the many interfaces of different personal devices. Energy efficient security and trust is crucial since most security protocols are energy hungry and resource consuming, and require many interactions between wireless devices as well as between wireless devices and fixed network elements. Solutions need to be investigated for providing the necessary security with less resources and energy.

The holistic approach to green communications demands joint consideration of all the involved subsystems namely; radio access, network architectures, network protocols, new way of networking as well as network protocols interactions. It should also consider new energy aware network planning/deployment and operation that lead to minimisation of OPEX and CAPEX. These subsystems are individually addressed in the next section.

However, the development of energy-efficient communication techniques is not only related to long-term sustainability, but it is also a mandatory requirement whenever battery-equipped devices/sensors are involved. In this case, communication must be organized in a way that the power source's charge time is long enough to fulfil the application's mission without regularly changing or recharging batteries. Suitable power-down and wake-up concepts are to be developed.

Moreover, in Internet-of-things scenarios, distributed (pre-)processing of sensor data is required in order to handle a massive amount of measurement data. Therefore, the communication network needs to support an intelligent distribution of (pre-)processing power, considering the status of the power supply of the involved (mostly embedded) devices, the energetic transport cost, as well as the processing power available at each device.

Also, the data exchange itself can be optimized by using and developing energy-efficient protocols that require a smaller number of bits to exchange for given information and that require less processing power for the data evaluation on a device level; an example for such a protocol is Binary XML.

More specifically holistic approach involves the following sub-systems:

- Radio Access and new implementation concepts,
- Green operation,
- Energy aware Networking,
- Green Deployment,
- Tight-integration of network deployment (from macro down to femto-cell) resulting in novel deployment architectures and system topologies,
- Resource sharing and resource management techniques.

1.7.2 Energy Efficient Radio Transceivers

Depending on range of coverage, utilization ratio (e.g. depending on time of day) of a base station and also on the addressed communication standard, different peak output power levels are required, as this is for instance the case for UMTS and GSM operation. Additionally, efficiency is a main problem of power amplifier (PA) modules for modern base stations, due to increased linearity requirements, associated with new complex modulation schemes, necessary to meet the increased demand for high data rates. For the transmit PA itself, the described situation leads to the fact, that different peak output power levels are required in a highly efficient manner for the different power scenarios. State of the art power amplifiers do not fulfil these requirements.

There is significant potential for improvement of the power efficiency of base station components, considering the low efficiency of PAs, and yet a PA is the component of a base station with the highest energy consumption. Most of the current activities on improvement of power efficiency are focusing on isolated solutions which consider only the functionality of the power amplifier, leading to a very limited enhancement. By considering in addition power management based on system metrics, further reductions in energy consumption can be achieved by joint optimization of traffic management and energy efficient PAs.

New approaches are desired to open the way to traffic load adaptive base station components, with harmonized solutions for energy efficiency control on system level and energy efficient base station components unlocking solutions for energy efficiency operation of cellular networks.

1.7.2.1 State of the Art

The consumed energy of the equipment, considering future services and increase in user traffic is conventionally addressed by improving the energy efficiency of radio transceivers (TRX) through innovative implementation techniques at technology, circuit and architecture level. On the TRX side, the power amplifier is the main energy consumer by showing a low efficiency (current state of the art is an efficiency level of approximately 35%).

As currently available solutions are optimized regarding the power efficiency in maximum load scenarios, in low load situations the efficiency is even lower. The maximum load scenario is a rather rare case in typical network deployments of operators. That means that most of the time, the network infrastructure is operated with sub-optimal energy efficiency thus leading to a significant waste of energy resources. As an example, at night the traffic in mobile communication networks is by far lower than at certain daytimes. Due to the low flexibility of the existing architectures to react on this situation, the adaptation possibilities of power amplifiers concerning their output power level are very limited. Therefore the possibilities of efficiency enhancement techniques along the lines of state-of-the-art approaches are very restricted, and the power efficiency of base stations components has significant further improvement potential.

1.7.2.2 Target

The aim must be to step beyond the state of the art by considering energy efficiency as a key factor in the design of communication networks. The power efficiency of the equipment has to be increased in conjunction with the holistic optimization on system level considering e.g. components, transceiver, base station, radio link and network architecture.

An EE transceiver of mobile base stations, designated for energy efficient communication systems, must show minimized power consumption by itself and has to support the appropriate features for power reduction on system level defined by the system management.

Important innovation steps are required to bring the EE investigations to the system level, to all traffic load conditions and to utilize the potentials of integrated and holistic energy efficiency optimizations.

1.7.2.3 Topics and key issues to be addressed

The expected development of energy efficient mobile radio communication systems will be based on appropriate power efficient base station transceiver.

Radical new approaches are needed to realize the required fundamental efficiency improvement:

- **Adaptable power amplifier:** In the power amplifier area new configurations have to be addressed in order to get the PA adaptable to different operation conditions with capabilities of adaptable output power in real time.
- **Power scalability of transceiver:** Transceivers should support the scaling of the consumed energy in order to enable the adaptation of energy consumption to actual performance requirements. Such energy scalability can be present in all components (analogue RF front-end, baseband) and in all devices. As indicated with the PA example above, this has the potential for major improvement in comparison to the state-of-the-art.
- **Power management enabling transceiver:** Transceivers should enable dynamic power management (dynamically reconfiguring an electronic system to provide the requested performance levels with a minimum number of active components and the minimum loads on those components). As an example, new techniques for implementing sleep modes in radio transceivers can keep only the necessary parts/modules of the transceiver active.

The interaction of all these issues will enable a power management on system level. That means, the developed transceivers will be a key enabler for improvements on the whole system.

The definition of an EE transceiver for mobile base stations, which shows minimized power consumption and supports the appropriate features for power reduction on system level defined by the system management, has to comply with several requirements:

- It is based on components and modules with reduced power consumption.
- Components and modules have to support power control management (e.g. reconfiguration for different operation conditions).
- Power management on transceiver level adapts the power dissipation of components and modules to the level of signal power using appropriate control features.

- Increasing further the power efficiency of the power amplification unit, which shows the major part of power dissipated in the mobile system, considering appropriate semiconductor technologies and amplifier concepts and suitable signal conditioning techniques.
- Implementation of required adaptability to variable signal load for power amplifier by addressing amplifier concepts and appropriate power control mechanisms. This allows to adapt the power dissipation to the signal power level and lead to significant efficiency improvement in low traffic situations.
- Depending on deployment scenario, different types of TRX modules with different power classes might be required to enable optimum energy efficient wireless communication networks, based on arrangements with various cell sizes.
- The TRX modules should support Cognitive Radio, a mobile radio system solution, which allows a flexible and economical usage of radio resources. Cognitive Radio is expected to play an important role in energy savings in mobile communications. It is expected to deliver additional measures, which help energy saving on the system level. The flexible choice of frequency bands and mobile radio standards is avoiding interference situations and allows the operation in the most efficient frequency band.
- The TRX modules must support multiband and multi-standard operation.
- The TRX modules might have to assure higher layer control mechanism in order to enable power management on system level, supporting energy efficient network architectures. For this purpose, appropriate transceiver architectures must be defined, allowing implementation of the features requested by the system.

1.7.3 Energy efficient protocols

1.7.3.1 State of the Art

To Be Completed in Version 1.2

1.7.3.2 Target

To Be Completed in Version 1.2

1.7.3.3 Topics and key issues to be addressed

To Be Completed in Version 1.2

1.8 Conflicting interests and dissimilar utility

To be complete in Version 1.2

1.8.1 Stakeholders positioning

1.8.1.1 State of the Art

To Be Completed in Version 1.2

1.8.1.2 Target

To Be Completed in Version 1.2

1.8.1.3 Topics and key issues to be addressed

To Be Completed in Version 1.2

1.9 Searchability/localisation

(Searchability/localisation, selection, composition and adaptation)

1.9.1 Search engines

Lowered publication thresholds and the growing number of network services continuously create a vast amount of potentially useful and valuable information, accessible over the Future Internet. To match the information to its potential users, search technology represents the information items or streams appropriately for users to query and retrieve information and for systems to suggest and provide it. With new forms of content, new use cases, new tasks, platforms, and categories of users, search technology stands to meet several daunting challenges in the near future.

1.9.1.1 State of the art

a) Text search is becoming a commodity

The simple provision of a set of text items based on an index matched to a specified information need -- is becoming a commodity for information refinement defined and provided by other levels of computation. It is only a technical challenge by virtue of scale issues and by service definition issues, not by its intrinsic technical characteristics.

b) Moving beyond single-language text

Information is available in several modalities, not only text. Images, audio, video, graphical models - all discussed elsewhere in this document - pose new challenges with respect to content representation. Where text wears its content on its sleeve, as it were, other modalities may require both non-trivial processing and computation to extract content bearing items, such as in the case of turning spoken language into text or depictive images into a semantic representation scheme; and non-trivial interpretation and hermeneutics to understand what the topically salient or informational content of the information item is, if any.

Current text-based retrieval schemes presuppose an unchanging content description such as text provides by virtue of the words it contains. Extending this to several languages can be done, at a certain cost in terms of retrieval quality, but without changing the underlying mechanisms. Most retrieval schemes for multimedia presuppose that information items are annotated somehow with captions or other textual information.

Content-based schemes for multimedia retrieval are being developed, but are hampered by interoperability issues: the scheme for one set of items may not be easily translatable to that of another set or another system. Content-based multimedia retrieval must address an interpretation challenge: there are multiple layers of meaning all potentially active at the same time. There are primary features that can be extracted from e.g. an image: unambiguous information that is structurally (or syntactically) objective such as colour histograms, textures, lines, etc. There are also higher-level features that can be extracted from an information item, especially in specialized domains such as medical image analysis, found through application of content analysis and deduction (e.g., face recognition in images). This sort of analysis is uncommon in the field of text retrieval, but is likely to be of more use in the future.

c) The user as part of the retrieval system

Since text retrieval systems first have been deployed and put to use, document and text retrieval has improved by leaps and bounds. One of the clear factors in this evolution is the recognition that the user should be treated as an integral part of the information retrieval process, i.e., that finding the right information is about much more than just the search system provided by a library or by a vendor or on a website.

Having the user in the loop provides many advantages to a search system. One of the biggest problems in search is ambiguity i.e., which meaning of a word, or which aspect of an image, is the one that is appropriate in a given search situation. Different aspects of an object, or a picture, or a document can be appropriate in different circumstances. These circumstances could depend on the user's needs, the context, or any one or more of a myriad other conditions. The indexing side hasn't changed; the query process is a little more complicated. The user has an initial query for which the system returns a set of results, just as in the naive system. However, here the evaluation of the usefulness of the results is done by the user taking into account his or her own circumstances, etc. If necessary, the query can be modified and the search done again.

A typical search engine returns a list of results. These are often ranked, i.e., the topmost result is what the engine predicts to be the most relevant to the given query. The change in paradigm that comes with making the user a part of the information retrieval system is that relevance is now defined with respect to the user and the task.

d) New types of information providers

The lowered publication threshold and convenient publication tools available to the general public has increased the amount of available information sources. The information people use and access is not only provided by traditional publishing processes where the investment of effort in the process itself provides a measure of trust and reputation to the items, as a guide to the user. Through user-contributed and cooperative services such as blogs, wikis, trading sites, photo and music sharing networks, video clip repositories an enormous amount of content is contributed together with an attendant vast and growing amount of annotation and other additional information. Assessing value of information items is a challenge that searchers will need support for; commercial publishers need support for delivering and authenticating their output in a setting where they want to establish themselves with more authority.

e) Changing character of interaction situations: beyond the typewriter and the office desktop

New technology with new input devices, new data provision mechanisms, and new access situations enables users to access and thus search or information in entirely new contexts: using mobile interfaces, in home settings, in ambient computing environments, in public or private situations, moving away from a topic- and task-oriented office-like interaction paradigm.

f) Changing character of information needs: beyond the task-based search

Information is not only used for topical retrieval. Previous systems have been able to work from the assumption that information is accessed by users for some topical need, more or less well-defined and that one of the problems of users is the clear-cut definition of their informational need. With the advent of multi-medial (and thus inherently non-topical) information, user-contributed (and thus to a large extent expressive rather than informational) content, new user bases of non-professional, elderly, or young users, new access technology not bound to an office-like desktop milieu, we face completely new usage scenarios and use cases for information access. Searchers will want to be entertained, rather than informed, they will want suggestions rather than provide search, they will not be engaged in finding a topical well-defined target based on relevance, they will want the system to be aware of and utilise the context the information need is being addressed in.

g) Smaller devices and larger access space: beyond access to static information containers

In a slightly longer time frame, with the advent of a realistic internet of things, the sheer scale and heterogeneity of the data being indexed and sought for, together with an ambient non-centralised computing architecture is likely to change the character of search, retrieval, and access.

1.9.1.2 Target and goals

As stated in "The Cross-ETP Vision Document", the Internet of Content and Knowledge should allow the "access by advanced search means and interact with multimedia content (e.g. 3D and virtual reality) that can be created, and manipulated by professionals and non-professionals and be distributed and shared everywhere on any terminal per needs".

1.9.1.3 Topics and key issues to be addressed

a) Handling new types of content and bridging the gap between them

As stated in the Vision Document, 'Content' refers to the 'understandable information made available to a user at any stage of the value chain', including both the 'essence' – the data representing text, audiovisual services, games programs etc. that is the object of the value chain – as well as the metadata that describes the essence and allows it to be searched, routed, processed, selected, and consumed. Therefore, 'Content' thus goes well beyond the products of the traditional media industries such as broadcasting and computer games. New searching engines should be able to retrieve advanced multimedia contents, including 3D media and other new formats. To further this goal, the CHORUS coordination action has defined a common functional architecture, which can be used to compare efforts and standardise components over collaborating projects.

b) Interoperable and semi-standardised representation schemes

Representation schemes are a technical issue, but to achieve take-up, must be couched in useful, task-relevant and salient terms. To enable and encourage third-party annotation and usage, indexing schemes must be designed with the outside world in mind. Their definition must support the introduction of externally defined standards and knowledge schemes as well as the flexibility necessary for handling dynamic and changing data.
Standardisation efforts hitherto have worked against several major challenges:

- Reuse of annotation and extracted information or metadata from system to system and collection to collection,
- Interoperability of queries and representation schemes from system to system and collection to collection,
- Contextually sensitive representations are less portable than pared down schemes, but necessary for more informed information provision.

Standardisation efforts currently in place in Europe include

- JPSearch, which aims to provide a standard for interoperability for still image search and retrieval systems via an abstract framework search architecture that decouples the components of image search and provides a standard interface between these components,
- MPEG-7 Query Format (MP7QF) which makes use of the MPEG-21 digital ítem declaration language (DIDL) for exchanging items along various frameworks and client applications. An MP7QF item acts as a container for the input query format and output query format of a user query request.

c) Integrity, privacy, and other socio-economic issues

Integrity issues come to the forefront as soon as systems are designed to take contextual and personal factors into account. The traces someone accessing information leaves are to the point and quite useful for whomever is interested in understanding more about some individual or some group of people. Moreover, the technology to support aggregation of each in itself meaningless information quanta and relating them to a background of other users is beyond the capability of individual users but available to corporate or government actors. This *information imbalance* risks forming and fomenting mistrust between users and the information infrastructure. *Trust and authority* in the provided information is a crucial issue, both to ensure take-up of technology and the informed use of the information in question by its users. How to model trust in face of a dramatically lowered publication threshold is a research issue.

d) Definition of use cases and ensuring validity of approaches

Human-machine interaction is a huge research field in its own right and *interaction design* is a trade with competence, craftmanship and established success criteria. Hitherto, multi-media information access projects relatively seldom have identified interaction as a pressing issue -- technology and system factors, or scalability issues regarding the content at hand, have overridden those concerns. This lack of overlap needs to be addressed, or the next generation of information systems risk designing themselves into a cul-de-sac. Generalisation of results and guidelines on interaction in multi-media information access need appropriate methodology and craft from the interaction field.

Search must be allowed to proceed using any modality that is perceived natural to the task at hand, including language but also gestures or other mechanisms available in the situation. All of this requires linguistic technologies as well as ontology's to be integrated in the process, including multilingual and multimodal integrated capabilities.

Evaluation of future information systems needs to be sensitive to all the specific challenges in play: content representation, use case and session design, and further lowered publication thresholds. Evaluation schemes have been the backbone of text retrieval research for the past decades: the field of future non-text, non-topical retrieval should take care not to diverge from that tradition for reasons of convenience only -- the target concept of relevance may not need to be replaced, but will need either extension or deconstruction to carry over to new use cases, new scenarios, and new types of media. Crucially, system evaluation should distinguish between benchmarking, based on system-intrinsic qualities, and validation, based on usage and implementation effectiveness for a stated use case. Development of technology should ideally be based on known general and shared use cases, where the CHORUS coordination action can provide a framework for such definitions.

In order to achieve that vision there is a need to address the following aspects:

- Efficient, scalable, tractable and interoperable *content representation schemes* for dynamic and changing multilingual multimedia content,
- *Indexing schemes* which are able to extract automatically or semi-automatically features from multimedia,

including such rich media types that can be envisioned in the near future, as specified elsewhere in this document and across various different types of networks and transport protocols, regardless of the underlying indexing, context, and network infrastructures,

- *Retrieval systems* in the most technical sense of the term, that are able to efficiently parse and process a formal query to a retrieval via the index to the content collections , streams, or sources at hand,
- Selection engines and front ends of various types which are able to support users of varying degrees of professionalism, domain competence, or usage situation to either *formulate their information needs* or to *recognise information needs* based on user actions and various contextual features, including search engines, recommendation systems, and filtering systems of various types,
- Information provision services which allow users and other higher-layer services to *retrieve and access information* as indexed by the system and as specified by some formal query,
- Mechanisms aware of the *social context of information use*, including aspects of collaboration, of information sharing, of annotation schemes to leverage usage into knowledge, as well as mechanisms aware of the *usage context*, including environmental factors, platform capability, temporal constraints and urgency of task at hand,
- Mechanisms to gracefully handle the quotidian *multilingual and multicultural environment* in Europe, leveraging it to an information asset rather than a noise source,
- Technologies for *information refinement,* for the analysis of information beyond the delivery of items matching a formal query, including:
    - Object and face recognition,
    - Information extraction and question answering,
    - Data mining and data aggregation,
    - Summarisation, entailment analysis, and abstraction,
    - Translation, tailoring, and personalisation,
    - Trust and authority modelling,
    - Topic or item tracking, detection, and monitoring,
    - Personal information management, and brand and identity management.
- An extensible scheme for *use cases*, to model usage scenarios and to validate technical approaches taken to meet them.
- *Evaluation schemes*, to handle the systematic comparison and the sustainability of research and development efforts; *resource sharing networks* to allow both industrial and academic research efforts to collaborate with a minimum of formalia.

1.10 Beyond digital communication

1.10.1 3D communications

Due to the fact that the available bandwidth in Internet is increasing, there is no doubt that beyond basic picture transmission the trend is now to improve strongly the viewers' (and listeners') immersive experience. The adoption of future networking technologies will establish the basis for future communications where virtual reality, immersive experiences and more natural user interaction paradigms will be the common way of accessing Internet Content and Services. One of the most important services of the Future Internet will then be 3D communication.

The current Internet is not able to exploit the possibilities that this increasing bandwidth offers to 3D communications. Many technological and non-technological issues are still missing to become the Future Internet 3D communications into a reality. They concern the generation, transmission, rendering and management of 3D multimedia content. Several industrial sectors (conspicuously the entertainment and media industry) are pushing strongly with new concepts and applications, such as 3D Cinema, 3D interactive TV, fully 3D virtual environments and metaverses, mixed reality experiences, etc.. The convergence of ICT and professional audiovisual technologies (HDTV, Film Industry, new production technologies, etc.) leads to achieve these goals. Moreover, not only professionals can produce contents. Non-professional users take part actively creating, reusing and consuming contents. More and more people are turning from consumers to prosumers and demand standards and tools for seamless integration and interaction among 3D models and environments.

New technologies are constantly emerging in the 3D world, but they concern mainly animation material (scenes created by a computer) together with the well established modelling tools and languages. However, some other features related to 3D elements like physical properties, intelligence, the way of how they should behave or interact with other elements, the environment itself and users, etc, still remain without solving. In addition the capture and use of natural content to produce 3D programmes (or simply 3D interpersonal communications) is still at a a starting level. Many efforts in the way of technology design and development have to be done together with standard languages and protocols that allow interoperability and universal access for professionals and end users in the Future Internet 3D communications.

Applications in 3D will be various aspects of future entertainment and business, but also tele-presence and metaverses will help contributing to reduce the need for physical transportation.

To summarize, the Future Internet should allow the convergence, in a networked media scenario, between all types of multimedia assets and environments. In the Future Internet vision, the value chain of 3D content should flow naturally overcoming the current fragmentation and barriers in different stages. To achieve this goal the following aspects must be considered.

1.10.1.1 State of the Art

Typically professional and non-professional content producers locate their activity in completely different environments. While professionals distribute the required tasks according with the skills needed to perform the designed content, non-professionals tend to cover the complete workflow. In the same way, professionals can use very expensive equipment to generate and manipulate assets. Prosumers use much less resources and therefore the quality criteria differ between these two groups. There are much more differences related to professional and non-professional producers like the target to which they are oriented and many style issues, but from the technological point of view there is no advantage keeping this to worlds separated. However proprietary systems and business models lead to this gap.

The current 3D communications workflow starts in a mostly manual generation task. Designers develop 3D elements by hand editing and combining primitives or using some other techniques that in most of the cases have to be supervised. These 3D models have typically geometrical and colour/texture information that can be stored and transmitted by using 3D vector graphics specifications like X3D, VRML, DWF, IGES, STEP, COLLADA, etc. Some of these specifications like COLLADA (http://www.khronos.org/collada/) can also define some physical attributes. However, for more complex definitions that could imply '"interaction, reaction"' or some '"intelligence"' characteristics, there are not open standards that cover all these needs. Only some proprietary solutions that mainly belong to the videogame market include some of these features.

Transmission of 3D pictures depends strongly on the way the scene to be transmitted is described. Present solutions consider the addition of a depth map to 2D scenes, but multi view coding is also under study, assuming that there is much commonality between the views to be encoded. Obviously bit-rate reduction of 3D scenes is in its infancy since the main objective of the scientific community has been 2D pictures up to now. A lot of work has to be carried out until the description and the coding of 3D scenes can reach a reasonable level, compatible with the transmission to a variety of terminals.

During the last years new markets are appearing where some 3D environments show some promising results. "Second Life" (Linden Labs) provides a good idea on the value and potential of 3D content for the Web and Internet Communities. It allows users to create 3D content, add it to a 3D world, share it and sell it. Today more than 15 million users are participating (more than one million users logged-in during August-September 2008) and also large companies (e.g. Adidas, IBM, Dell, Reuters) are involved, using this mostly for advertisement purposes. Virtual worlds like "Second Life" or "There" do not have a clear goal about activity. They provide the 3D and social experience by itself without any other concrete goal. Some other 3D environments like the "World of Warcraft" offer games and there are also some attempts to offer services using 3D interfaces for web browsing (http://www.3denter.com/fram-eng.htm) that still do not have a great market success. The lack of common standards does not allow any flow among these environments. This vertical and centralised being of current virtual worlds is hiding some other technological risks that will appear when interoperability among platform becomes a fact. Modularity, scalability and distributed computing are now solved for proprietary frameworks but will turn into big issues when these frameworks will be open and interoperable.

Mobile devices, Video games, TV broadcast and professional audiovisual world and ICT are the 4 main technologies and markets that have to converge, but the aforementioned lack of standards and market and business model issues difficult this process. Mobile devices and TV set-top boxes do not offer 3D rendering capabilities (set-top boxes are even less powerful than mobile phones) and ICT technologies videogame platform are not compatible with any other device. While ICT and mobile technologies are having some approaching process, there is not a clear idea about how TV broadcasters should play this game. Moreover, IPTV platforms are changing the way of understand the future TV business. On the other hand, Videogame developers are keeping their market as vertical as possible using Internet technologies just to connect their platforms. The film industry is looking for new experiences where 3D experience is one of the most mentioned features. Nevertheless, film industry is much more focused in 3D production and rendering than in 3D communications.

Several solutions to reproduce 3D pictures are currently demonstrated or marketed. Some solutions request the viewer to wear spectacles, some other do not. To each technology is attached a display size, viewing quality and comfort, specific viewing conditions (at home, working place or cinema) and of course a cost. Conversely to 2D displays, much of the viewing quality may be the result of picture processing before display, so that latter function may become of paramount importance for the reproduction of 3D scenes.

The quality of 3D transmission will depend on many technologies located at the transmission, or the reception side. But those technologies are strongly dependent. For instance, a reproduction device will probably be easier to design if many views are transmitted for a single scene, but that will increase significantly the complexity and the cost of transmission. Since, for instance, the same program, one can expect that several terminal technologies (with various qualities and costs) from different suppliers will be used, the standardisation of the interfaces at every interface of the systems must be considered. This approach is essential to enable the development of services, but is a real challenge since there is much to do in this respect, with severe impact on each part of the 3D chain.

1.10.1.2 Targets

This section describes the main goals of future 3D communications inside the Future Internet context.

Following the NEM initiative's Vision 2020 document the Future Internet looks forward to:

- An infrastructure of effective, ubiquitous, and seamless social networks that is people-centric, giving interesting and motivating immersive and sensory experiences,
- A service oriented society in which ambient and context-sensitive services are created and provided, personalised and customised to people's individual and social needs, available to communities of users and including ALL citizens,
- Open very flexible business models and revenue generating models derived from radically changed value chains, a loose network of niche markets and fast operating small enterprises governed by 'soft' regulation.

Concepts like people centric, immersive and sensory experiences are strongly related to 3D environments and other topics like ubiquitous, ambient and context-sensitive services, personalized and customized, specify the characteristics that these 3D frameworks should have.

The strategic research agenda of the NEM initiative refers to "Multi-modal models to describe our environments" as future representation paradigm where 3D presentations of media allow the user to "dive" into the contents.

a) New features in 3D models, environments and communications

In order to achieve the presented goals, there are many existing limitations in the current state of the art of 3D communications that have to be overcome. New features have to be introduced inside the models' properties and interaction capabilities. The goal is therefore to develop "distributed" environments where contents will be "interactive, reactive and intelligent". It means that they will have their own way of behaving with the environment, with other elements and even with end users. Physical properties of 3D assets add another way of reacting and improve the reality feeling of 3D environments.

b) Natural Content

Although 3D computer graphics generated scenes are now becoming more and more realistic, many services would also take benefit of the application of 3D approach to natural scene content. Entertainment is one application (capture and rendering of the nature to create fully immersive films), and telepresence is also concerned, reducing the need for physical transportation. For most of those services capture of the 3D content is in its infancy, which limits the use of 3D to specific scenes shot in a highly technical environment, as was television in the 50's. The target is then to develop 3D technology so that 3D becomes the basic way of scene capture and rendering (like stereo is now for sound).

c) Standards and tools

All these features need tools and open standards that allow the "plug and play" philosophy and the interoperability between different SW and HW suppliers. Any 3D world, scene or metaverse will integrate 3D elements or groups of elements developed according to these open standards. These elements will not only have geometrical and texture or illumination related features. Each element will have its own physical properties (elasticity, hardness, etc.), intelligence and behaviour. The development of these standards and compatible tools that accomplish them will be one of the main goals of the forthcoming years.

Regarding to communications, the quality of 3D transmission will depend on many technologies located at the transmission, or the reception side. But those technologies are strongly dependent. For instance, a reproduction device will probably be easier to design if many views are transmitted for a single scene, but that will increase significantly the complexity and the cost of transmission. Since, for instance, the same programme, one can expect that several terminal technologies (with various qualities and costs) from different suppliers will be used, the standardisation of the interfaces at every interface of the systems must be considered. This approach is essential to enable the development of services, but is a real challenge since there is much to do in this respect, with severe impact on each part of the 3D chain.

d) New Frameworks

Features like '''intelligence''' and '''reactiveness''' require new architectural solutions that differ completely from existing solutions. '''Distributed computing''' becomes a must when each element can require high computing resources related to their intelligence and behaviour in addition to the classical control, 3D rendering and geometrical/physical calculations.

The design of a framework that will be able to handle all kind of 3D models in a dynamic and scalable way will be another key target of the Future Internet. This framework will have some other requirements to become into fully multimedia environment (including the mentioned 3D elements, audiovisual contents, text, still images, and 3D sound) that will extend the scope to all kind of assets.

e) 3D Rendering and Interacting Hardware

Classical hardware input/output peripherals (2D screen, keyboard and mouse) can provide a very limited immersive and natural interaction experience. Complete 3D display systems including optical device and picture processing are key elements of the 3D communications. For instance, new hardware solutions like auto-stereoscopic screens or head mounted displays are needed to improve this experience where speech and body gesture recognition systems make the interaction between the end user and the system much more natural. However haptic and tactile based input devices which have been largely improved since last months must be also considered as intermediate technologies towards more natural interactions.

Light and ergonomic devices for rendering Augmented Reality applications must also be improved (glasses). New ways of interactions with mixed 2D/3D content, have also to be addressed, in particular for mobility use case

1.10.1.3 Topics and key Issues to be addressed

a) Human factors

3D is a new concept which, in some aspects, is quite different from traditional 2D TV or cinema. Already the picture resolution increase brought by HDTV has led to reconsider the way content was produced to take into account how picture was perceived by the viewers. The introduction of 3D is a deeper revolution since the content is no longer restituted as a "picture", but rather as a "scene" in which the consumer is invited to take part. The way that scene is presented is also an important factor of the user experience; it is well known that some 3D technologies imposing the viewer to focus some parts of the scene produces some kind of headache. A better understanding of the 3D perception and its acceptance of the various 3D display technologies is a pre-requisite to the deployment of 3D. Another aspect to consider is the way 3D content has to be produced , in particular, whether traditional shooting approach have to be revisited to elaborate content that will meet the users' expectations.

b) Regulatory issues, standards

Regulatory issues can be many times key issues to ensure the success of technologies and business models that support them. Radio and TV broadcasts or mobile phone technologies are good examples of former cases where governments have driven technologies establishing open standards as framework for all players. The global character of Internet seems to be not affordable for single country's regulatory framework, but common and coordinated decisions —where the EU commission plays a key role— can lead this process creating new business models and addressing standardized technologies that avoid vertical markets and monopolistic trends.

c) Economical and socio-political issues

Our vision of 3D communications in the Future Internet brings the idea of a Future Information Society in which all citizens access the contents or services they are looking for wherever they are in a very natural and technology transparent way. These ease to access any needed service will help dramatically to bridge the digital divide and will boost economical relationships like any historical communication improvement did (cart, ship, plane, car, train, telegraph, radio, phone, the first Internet, etc.).

d) Convergence among different markets

Future Internet 3D communications will change the entertainment world, the audiovisual market, the way of offering any kind of e-services, the way of making business, etc. This revolution will not only change these markets, will also create new opportunities and niches where the cornerstone will be the convergence of mobile technologies, Internet services, videogame technologies and audiovisual contents in a 3D environment.

Emerging countries will change the current map of current Internet service providers, technology providers and consumers. Asian market will become the biggest in Internet and therefore all convergence efforts have to consider these emerging countries like China or India. Technological and regulatory convergence are the main issues in that sense.

d) Educational & e-Inclusion issues

3D communications will clearly help in all issues related to e-inclusion. More natural interfaces, immersive experience and platforms able to integrate any kind of multimedia content in a seamless form improve directly any e-inclusion aim.

Future Internet will also help to ensure the universal right to education. 3D communications will set the technological infrastructure and framework to create effective e-learning environments capable to bridge physical barriers and offer similar education opportunities, especially for those who are in worse conditions.

The targets and goals described require to address a set of technical challenges in order to realize Future Internet 3D communications:

a) Capture, Generation, Production

At present the capture of natural content is implemented by cameras which reproduce the way the human eye works. To introduce some idea of depth in the scene, various solutions can be used, starting by a second camera for a stereoscopic effect. But beyond this approach, this is the concept of scene that must be analysed, not only as a 2D picture, but taking into account the collection of objects it is made of. A first and important research topic concerns all technologies that enable the capture and the identification (as well as the description) of natural scenes, considered as a collection of 3D (natural) objects.

Current synthetic content (and mixed reality) production workflows have to be much more automated in order to reduce the costs and offer high quality elements and environments in a reasonable cost. Systems to model the reality in a accurate way have to be addressed. It means a great improvement in all fields related like image processing, mathematical modelling of physics and other natural phenomena, etc. Even if they would work at different levels of quality and flexibility, these tools should not be only available for professionals. All prosumers should have access to standardized elements and tools that could be used to build their own creations. This technological democracy would be reflected in the other layers of 3D communications.

b) Transmission and Delivery

Adapted methods to describe and encode 3D pictures (or scenes) have to be designed, or adapted from the current state of the art in 2D picture coding. Those methods will have to interface easily to a variety of terminals, each of them being offering different qualities in terms of scene rendering, according to the application (and the cost of the terminal) concerned. 3D picture coding has consequently to be strongly clinked to the standardisation process and must take into account the technologies of 3D immersive viewing that will be available in the terminals.

Complex 3D environments, virtual worlds or metaverses will rely strongly on distributed processing and even in distributed storing. This architecture will require high performance networks and transmission protocols where the system will be adjusted to the network conditions at every time. A trade off between process distribution and data transmission costs will be carried out to set up the configuration of the system. The presentation layer of each user will be the goal of the delivery layer which will adapt this delivery process to the device features, network conditions and user's profile. Ubiquity and distribute computing will be the key factors that have to be addressed using Future Networks that overcome the limitations present in the current state of the art.

c) Immersive Viewing and Interaction

Several solutions to reproduce 3D pictures are currently demonstrated or marketed. Some solutions request the viewer to wear spectacles, some other do not. To each technology is attached a display size, viewing quality and comfort, specific viewing conditions (at home, working place or cinema) and of course a cost. Conversely to 2D displays, much of the viewing quality may be the result of picture processing before display, so that latter function may become of paramount importance for the reproduction of 3D scenes. Complete 3D display systems including optical device and picture processing are key elements of the 3D communications.

Sound plays an important role in the immersive experience of the consumer. New technologies to improve sound transmission and reproduction have to be designed to reproduce sound waves according to the location of the listener in the scene. Such technologies are now emerging but must be developed to reach maturity so that at the end a complete 3D system be proposed.

Semantic treatment of all existing assets (3D, 2D, A/V, text, ...) will be the next step in content interaction. Taking in account the huge amount of data that users will have to handle, current annotations and management technologies will collapse dealing with contents that mainly are based in non-text information. On the other hand, the introduction of semantics, involves context data that improves the personalization of the services according to the environment and user's profile, mood, etc. In that sense, not only the elements could have intelligence but the system itself could manage some intelligent behaviour.

d) Technological Convergence

Seamless usage of technologies and services is one of the main visions of Future Internet and 3D communications frameworks aim to follow this philosophy allowing technological convergence of communications protocols, networks and devices will allow this vision. This convergence will boost the use of 3D technologies and will create new market niches for consumer electronics, ICT services, entertainment, professionals, etc. Moreover, 3D standards (COLLADA, VRML, X3D) and multimedia standards that include 3D definitions or interactivity (MPEG-4, MHP, etc.) have to be extended to include external features. An alternative way to avoid the extension of those standards could be their adaptation for further wrapping in other future standards that would integrate all these different sources.

e) Media Communities

The creation of Media Communities is referred in the NEM Strategic Agenda (Version 7) as a new way to offer collective experiences like currently TV broadcasts or real events like football matches do. Networked media will also allow the creation of groups of interests or collaborating environments where people will share experiences avoiding physical distance problems and keeping the proximity feeling. Virtual reality technologies and social networks.

1.10.2 Behaviour communication

1.10.2.1 State of the Art

To Be Completed in Version 1.2

1.10.2.2 Target

To Be Completed in Version 1.2

1.10.2.3 Topics and key issues to be addressed

To Be Completed in Version 1.2

1.11 Internet by and for people

1.11.1 Contribution to the Grands Societal Challenges

1.11.1.1 Introduction

During the Swedish Presidency, several actions have been set up with the objective to tackle the problems that the Europeans will face in the future. The objective is to identify them and to build an cross disciplinary agenda able to find solutions.

Lund declaration

European research must focus on the Grand Challenges of our time moving beyond current rigid thematic approaches. This calls for a new deal among European institutions and Member States, in which European and national instruments are well aligned and cooperation builds on transparency and trust. • Identifying and responding to Grand Challenges should involve stakeholders from both public and private sectors in transparent processes taking into account the global dimension. • The Lund conference has started a new phase in a process on how to respond to the Grand Challenges. It calls upon the Council and the European Parliament to take this process forward in partnership with the Commission.

The global community is facing Grand Challenges. The European Knowledge Society must tackle these through the best analysis, powerful actions and increased resources. Challenges must turn into sustainable solutions in areas such as global warming, tightening supplies of energy, water and food, ageing societies, public health, pandemics and security. It must tackle the overarching challenge of turning Europe into an eco-efficient economy

Obviously ICT and the Future Internet are one of the corner stone of that strategy as far as they now permeates virtually aspects of our live. ICT is inextricably linked with our desire for a prosperous and competitive economy, a sustainable environment, and a more democratic, open, healthy society. ICT should be seen as a key positive element, empowering EU citizens, growing businesses, and helping us build and open, innovative, secure and sustainable knowledge economy.

1.11.1.2 State of the Art

The report of the European Research Area Expert Group (EG) on "***The Role of Community Research Policy in the Knowledge-Based Economy***" was prepared for the European Commission (EC) Research DG over the first nine months of 2009. The group was asked to review, assess and interpret the existing evidence on the state of the knowledge-based economy in Europe as well as on the effectiveness, in terms of roles, objectives and rationales, of the main existing research policy instruments and to come up with recommendations on how to frame and articulate the Community research policy in the post-2010 period. The Terms of Reference (ToR) of the EG explicitly referred to the need for an economic assessment that would bring forth new ideas, analyses and so-called "evidence-based recommendations for actions", hence, the dominance in this EG of experts from the academic, business and policy making community with a strong economic background; The EG started its reflective work with an internal discussion brainstorming on the major challenges the European Union would be likely to face over the next ten to fifteen years. These major challenges, grouped under the notion of "drivers" were pulled together under five headings which formed the main sections of the EG report and led, in a final section, to a number of conclusions and policy recommendations

The **first driver** the EG believed had affected European research over the last decade, and was likely to affect it even more over the next ten years, is the trend towards globalization and concentration of research in Europe and the rest of the world.

The **second driver** the EG considered in more detail was the notion of **Societal Challenges** (often referred to as "*Grand*" Challenges). The notion of **Societal Challenges**, which the EG preferred to use, applies to major social problems that cannot be solved in a reasonable time and/or with acceptable social conditions, without a strong and, in the European case, coordinated input requiring both technological and non-technological innovation, and at times, though not necessarily always, advances in scientific understanding.

A Societal Challenge dimension would, in other words add a new objective to public policy, whereby research and innovation are seen not as ends in themselves, but as a means to a wider goal, defined as a societal benefit. The aim is to foster those activities that have greatest impact on achieving the societal challenge, and not necessarily to increase research and improve innovation across the board. The relevant actors include of course private companies in various sectors, but also institutions involved in innovation in the public sector as well as public services, and in setting demand side and regulatory and market frameworks that support innovation.

The second set of recommendations of the EG deals therefore with the question on how to achieve compatibility between such "grand" societal top-down initiatives and a more market-driven resource allocation logic that would allow for "multiple decentralized experiments". In practice the EG follows the line here as set out in the Lund declaration. Meeting the Societal Challenges will require amongst others: strengthening *frontier* research initiated by the research community itself and taking a lead in the development of enabling technologies in particular along the lines of the so-called *lead-market initiative* such as in the case of "green technologies". Attention should be given here to measures that can enhance the effectiveness of both public and private research and development investment in the wide and diverse array of "green" technologies facilitating knowledge sharing, adaptation and diffusion of innovations.

The **third driver** considered by the EG, is the need for Community research policies more based on so-called *merit-based competition* than collaboration across the EU.

A series of recommendations are also made with respect to the trend towards open innovation, considered by the EG as a **fourth key driver**.

The final **fifth driver** considered by the EG is the one of regional specialisation and cohesion policies.

1.11.1.3 Target

Today, the ERA EG has not provided the identification of the Grand Societal Challenges, we can we can make a short definition of the ones identified in the Lund Declaration :

- **Global warming** : due to air pollution (industry, cars, home heating, …) CO² is beating the earth protection layer against sun. This implies an increase of the overall temperature which will have big impact in our future life (storms, under sea area extension, dry area extension, …) which have
- **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** : due to medical advances, people are living older and older 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 virus arising, that need great effort in research but also in public infrastructure which cost more an more expensive and difficult to fund.
- **Security** : Due to unemployment, burglars and bad boys are getting more numerous which imply crime development.

1.11.1.4 Topics and key issues to be addressed

From these Grand Challenges the Information Society & media clusters have identified 5 main areas where ICT could contribute :

- **Smart energy grid** : Energy grids will increasingly face risks of congestion and blackout. Internet connectivity, computing power, digital sensors and remote control of the transmission and distribution system will help to make grids smarter, greener and more efficient,
- **Smart environmental information system** : the use of sensor networks for collecting real or near real time environmental data is a growing field of application. It requires Internet connectivity for data management, dissemination and integration in complex information systems
- **Smart systems for transport and mobility** : Putting 'intelligence' into the roads and cars with Intelligent Transport Systems (ITS)– with e.g. sensor networks, radio frequency tags, and positioning systems offer a promising alternative. The internet provides a solution to interconnect these diverse technologies and bring more efficiency to mobility through real time management of public and private transport resources, traveller information and decision-making tools, way beyond the capability of current solutions
- **Smart healthcare systems** : Current research experiments aim to develop technologies for 'ambient' environments capable of assisting patients and satisfying their information and communication needs. These technologies combine devices (sensors, actuators, special hardware and equipment), networks and service platforms to harness information about medical conditions, patient records, allergies and illnesses
- **Smart culture and knowledge** : European culture is very rich and European people are so creative that we will be soon overflowed by information and archives. Even search engines become more and more powerfull, there will be a need to help people into content management including helping people to "clean" their information wherever they are stored

From these main key elements, some of them which are shorter terms are addressed in the FI PPP, some of the others which are longer term should be addressed in the future workprogram.

1.11.2 The enabling e-applications

The FI should be able to support the future people expectations which should be mainly based two major aspects that need to be taken into account at a very high level:

- Technology level: A dissipation of the digital universe has to be envisaged. In other words, finding ways for timing and throwing away information, instead of storing all that is created and handling the crashing Internet,
- Human level: A stable people factor with regard to basic social and emotional needs for communication and being connected, for privacy, for mobility, for liberation of spatial inhibitors, for satisfying physical and cognitive needs. Fast emerging global nomads and social networks are exemplary.

The onset of producing and maintaining mobile spaces of sociality, that are enabled by a complex intersection of face-to-face interaction and mediated communication, co-presence and virtual proximity, physical travel and virtual mobility, provide challenges that are beyond imagination. Personal communities become a mobile phenomenon, re-localized in a plurality of online and offline social spaces. These network relationships are reshaped and mobilized through reconfigurations of co-presence, proximity and distance in relation to the use of new media.

Societal changes with regard to evolving demographics – ageing population in the developed world and growing population in the developing world - cause huge gaps in literacy, accessibility, affordability and ability for ICT technologies. FI technologies will play a crucial role in bridging these digital gaps. Achieve e-Inclusion for all, including the ageing population as well as any groups of people that are at risk of exclusion, is an indispensable and essential condition for the NEM Vision2020.

1.11.2.1 State of the Art

Nowadays, the basic user needs are more or less covered in the area of communication (synchronous and asynchronous communication). Now people need more in order to become immerged in the ICT world (i.e. most of their daily needs helped by ICT services).

1.11.2.2 Target

By breaking the digital divide, the future Internet should be able to interconnect growing population over time. The FI shall be capable to meet people (individuals newly or already part of the Internet community) expectations and needs while promoting their continuous empowerment, preserving their self-arbitration (control over their online activities) and sustaining free exchanges of ideas.

The FI shall be capable to meet new and common people (Internet users) expectations and needs while promoting their continuous empowerment, preserving their self-arbitration (control over their online activities) and sustaining free exchanges of ideas. The FI shall also provide the means to i) facilitate everyday life of people, communities and organizations, ii) allow the creation of any type of business regardless of their size, domain and technology, and iii) break the barriers/boundaries between information producer and information consumer. The latter will foster the emergence of prosumers: people/communities will be part of the creative flow of content and process, and not just consumers. Indeed, content creation no longer requires professional expertise and content submission has been tremendously facilitated by a broad variety of tools which enable users to create high-quality content within minutes and at almost no expense. Distributed knowledge can thus be shared easily and opinions can be made public in almost real-time. Complemented with Social Networks, which allows establishing and maintaining personal networks beyond any frontier, humankind is offered an unprecedented level of interactivity. This trend combined with the evolution of the Web has induced a new phenomenon: formation of virtual communities and access to their wisdom that allows users to become part of the application development life cycle. In Web 3.0, semantic technologies, knowledge exchange, processing and generation by machines are substantial for the Future Internet. Such intelligent methods for knowledge collection processing and presentation are mandatory for being able to handle and benefit from the huge amount of information being available now or in future. This immediately leads to the second pillar, the Internet of Contents and Knowledge.

1.11.2.3 Topics and key issues to be addressed

In order to meet people expectations in ICT world, the latter should be able to sustain:

- Conversational, interpersonal & community services,
- Home and converged services,
- Ambient and converged services,
- New way of connecting people,
- New communication means & interfaces,
- Social networks,
- Collaborative tools,
- End-user devices,
- Services for workers – collaborative tools,
- Community at work,
- Workers on move,
- Real life and digital life interactions / communications,
- Service Sciences (usage, design and conception),
- Tools for usage analysis,
- Tools for co-design and co-conception,

- People-, social-, and user- centric approach.
- Easy applications/services authoring (semantic and logic composition, as well as user-friendly interface).

For enterprise:

- Enterprise collaboration and interoperability systems,
- Research on semantic interoperability and modelling of business processes,
- Enablers for easy dynamic & versatile B2B transactions,
- Inter-domain, interoperability over different networks,
- Real-time enterprise (including event orientation),
- Corporate agility & reconfiguration,
- New traceability networks,
- Networked- collaborative enterprises,
- Software, computing, storage, application as utility-services ,
- Services for Workers – collaborative tools,
- Community at work,
- Workers on move.

1.11.3 Ensure social, economical, legal and cultural viability

1.11.3.1 State of the Art

To Be Completed in Version 1.2

1.11.3.2 Target

To Be Completed in Version 1.2

1.11.3.3 Topics and key issues to be addressed

To Be Completed in Version 1.2

1.12 Internet of contents and knowledge

1.12.1 Virtual environment or Virtual and augmented reality

Virtual reality uses immersive 3-D 'displays' (including transducers for audio, and for other senses as they become available) to create the illusion of presence in a virtual or distant world as an immersive and integrated experiences for users. Telepresence services provide a virtual environment for humans to control devices, robots, etc., in a hostile or remote real environment through body-operated remote actuators.

This topic has also the objective to cover continuity between real world and virtual world including the merge of the two worlds when a real people interact with virtual world and vice-versa.

In terms of applications, many of them might be envisaged:

- Business applications in deep waters, hazardous situations, remote surgery, virtual healthcare, experiencing virtual products prior to production,
- Entertainment applications, including interactive applications such as games, walkthrough environments, virtual travelling,
- Enriched learning with collaborative tools such as pipeline video inspection for maintenance and repair, distance learning, subsea work mplex combination of contents,
- Enriched shopping experience.

It is envisaged future internet will create a plethora of virtual worlds where individuals can develop multiple facets of human activity; with mechanisms to guarantee interoperability among them.

1.12.1.1 State of the Art

Today's Virtual worlds are still in an incipient status of development. Graphical facilities still have a long pace towards a real presentation of the common world; the application of artificial intelligence is limited yet, and options put at the user disposal in terms of reproducing accurately the human behaviour must be clearly enhanced. At the moment, none of the existing most famous virtual world does include any feature of context awareness either.

Furthermore, the applications of virtual worlds have been mainly focused to the use as gaming environments, where people interact with avatars with human-like behaviour. Efforts in applying the augmented reality to other field such as manufacturing, eHealth, maintenance, virtual travelling or shopping have not been fruitful yet.

1.12.1.2 Target

Those virtual environments will be both immersive and adaptive in such a way that they will encompass the ability to become highly adaptive to user preferences, expectations, and manners to act. Furthermore, they will be able to seize our preference and adapt to them and learn from past experiences.

These immersive environments will allow new ways of entertainment more realistic and interactive, new ways of travelling or shopping, or carry out multiple facets of human dairy life. Augmented reality will be a fundamental component of this immersive world where the reception of more enhanced information will bring an enriched experience for the consumers: indications in travel, additional information while observing reality, assistance while driving, enriched information when carrying out a surgery operation etc.

Experiencing virtual reality and telepresence does not depend so much on the faithfulness of the reproduction of the physical aspects of external reality as on the capacity of simulation to produce a context in which users may communicate, interact, and cooperate.

1.12.1.3 Topics and key issues to be addressed

Multimodal interactivity with remote environments is a great challenge in respect to the growing needs in efficient remote collaboration within multi-site companies. For an efficient remote interactivity, among numerous topics to be addressed are:

- 3D capture and manipulation of multimodal stimuli,
- Network latency: Multimodal interactivity needs to have an immediate and secure feedback,
- Mutual awareness: new devices and software (audio, video, tactile) reproducing for the users a natural peripheral awareness of a remote or imaginary site,
- Displays: few haptic and tactile devices are available.

In order to achieve that vision there is a need to address two main targets:

- Business applications such as pipeline video inspection for maintenance and repair, distance learning, subsea work in deep waters, hazardous situations, remote surgery, virtual healthcare, experiencing virtual products prior to production,
- Entertainment applications, including interactive applications such as games, walkthrough environments.

These virtual worlds will not be unique, in the sense that many actors might create their own world (enterprises, entertainment entities, professionals or even amateur people for gaming/entertainment purposes). Then, the interaction and interoperability among those worlds will be quite important.

This feature is one of the most important challenges due to the advantages it provides to the final user in terms of the freedom to choose different environments where they could act with no changes in terminals or ways to operate. Moreover, the virtual world creators must not be bound to any particular transmission channel and for the device manufacturers it gives them a more ample spectrum of service capable to be settled on their terminals and equipments.

Many challenges must be:

- Adaptability and context awareness,
- Provision of inmersiveness (recreation of virtual worlds that combined interact with all human senses),
- Interoperability of distinct worlds created by different actors,

- Manageability to manipulate and live in these environment without prior training,
- Easiness of use.

1.13 Internet of things

1.13.1 Intelligence/Smart

The Internet of Things (IoT) will bring an even more pervasive revolution than the Internet and mobile technologies and today's acclaimed Information Era. The future ubiquitous IoT will make it possible for virtually any object around us to exchange information and work in synergy to increase dramatically the quality of our lives. Ubiquity will be driven by the integration of smart devices into almost everything. Such high-levels of integration will allow application developers to add significant value during the entire lifecycle. In addition to the value created during use, there will be opportunities to create value during manufacture/construction, transport and warehousing, retail and finally, at the time of disposal, smart devices can assist with environmentally friendly disposal. The Future Internet that is demanded by such a large scale, heterogeneous, ubiquitous and resource constrained device population will be very different to the Internet we use today.

1.13.1.1 State of the Art

Today, the development of a sensor/actuator network involves an ad hoc process of manual design, deployment and maintenance. Application development is also bespoke and manual; it is therefore done on a small scale trying to reuse a patchwork of technology platforms to produce, what is, as a result, a far from a globally optimal system. Debugging an application is very challenging and time consuming with what is often a resource constrained, dynamic network.

At the network level, there is no global architecture for the Internet of Things, and there is still a debate on the how much intelligence shall be distributed at the edge of the networks instead of a more centralised approach, where dumb entities simply transmit information.

The radio access network often has problems such as requiring too much electrical power or radio coverage issues. The sensor/actuator devices are power hungry, typically battery powered and are not miniaturised to the level required for many applications.

These devices will need to operate in a variety of harsh environmental and product contexts. Today, System-in-Package (SiP) technology allows flexible and 3D integration of different elements such as antennas, sensors, active and passive components into the packaging, improving performance and reducing the tag cost. Further RFID inlays with a strap coupling structure are used to connect the integrated circuit chip and antenna in order to produce a variety of shapes and sizes of labels, instead of direct mounting. However, the critical advances are in the area of the integration of chips and antennas into non-standard substrates like textiles and paper, and the development of new substrates, conducting paths and bonding materials adequate for harsh environments and for ecologically sound disposal. Work has already commenced here, but much more needs to be achieved

1.13.1.2 Target

Creation of a ubiquitous architecture that supports multiple applications. Key characteristics of such an architecture would include:

- Easy integration of new data sources into existing or new applications,
- Accommodation of machine and sensor nodes with different communication requirements and energy resources,
- Distributed intelligence and processing,
- Ubiquitous coverage via wireless and wireline access networks,
- Self-organising and configuring, minimising human intervention.

1.13.1.3 Topics and key issues to be addressed

A clear research priority focuses on system intelligence. Context-awareness and inter-machine information exchange will be central to the IoT. In the coming period, there is therefore the need to study a global architecture for the IoT, where peer-to-peer communication models, the shift of already existing bio-inspired approaches from a centric view to a distributed one, in which intelligence is pushed towards the edge of the system, and the development of autonomous devices able to generate automatic code and behaviours, will play a central role.

In order to achieve that vision, there is a need to address the following aspects: The research priorities will focus on increasing and adapting the intelligence at the device level by the integration of sensors and actuators, new power efficient hardware/software security architectures, highly efficient, multi- standard and adaptive communication sub-systems, adaptable antennas (smart beam steerable phased array antennas, multi frequency band antennas, on chip antennas (OCA), coil on chip, printed antennas, embedded antennas and multiple antennas using different substrates and 3D structures), and miniaturized smart RFID readers supporting multi standards to be used with mobile devices for different applications. Enable services built upon objects, allowing objects to become available, searchable, accessible and usable online for service creation

To make the Internet of Things vision become a reality, several key technologies must be developed. Highly energy efficient, low cost and miniaturised motes consisting of a power source, actuators/sensors, radio and computing resources must be developed. Further, the scale of their deployment combined with their resource constraints demands innovation across all aspects of network design. Intelligent choices must be made on when and where in the emergent network to perform processing, data fusion, storage and transport. Autonomous approaches must be invented for all aspects of design from tuning physical layer and MAC protocols through to application development. Finally, data will be produced on a scale that was once unimaginable and the network must efficiently transform it into knowledge.

Hereafter we categorise the enabling technology areas for the Internet of Things and list a few key challenges for each:

Knowledge planes and ontologies

- *Exposure and synthesis of application knowledge requirements to enable optimised network organisation and operation.*
- *Context-aware data abstraction into information and ultimately knowledge.*
- *Dynamic service discovery, addressing and binding.*

Self-organising networks

- *Autonomous approaches to protocol design, network coverage/capacity tradeoffs, network capital-expenditure decisions through to knowledge delivery.*
- *React to dynamic changes, such as link failures and interference.*
- *Frequency spectrum coexistence with other users.*
- *Data fusion, filtering, storage and forwarding functionality distributed and embedded in the network.*

Radio and RF technologies

- *Low power, low cost. Explore possible trade off against spectrum efficiency.*
- *Flexible front end technologies: power amplifiers, filters, antennas.*

System level integration and packaging technologies

- *3D integration and miniaturisation beyond System in Package.*
- Integration into non-standard substrates like textiles, paper and biological organisms.

Sensor and actuator technologies

- Highly efficient, multi- standard and adaptive communication sub-systems, adaptable antennas (smart beam steerable phased array antennas, multi frequency band antennas, on chip antennas (OCA), coil on chip, printed antennas, embedded antennas and multiple antennas using different substrates and 3D structures), and miniaturized smart RFID readers supporting multi standards to be used with mobile devices for different applications.

- *Energy management and energy sources:* Radio circuits and architectures with low-power standby solutions and with minimum energy per transmitted bit as a key design metric.

- Scavenging technology to exploit point-of-use renewable power sources for the transceiver section.
- Advanced models, simulation and prediction of energy use for improved energy efficiency and automatic configuration algorithms.

Integration into non-standard substrates for a wide variety of environments

- Current trends show that the research process from application-specific antenna designs to smart antennas, suitable for different applications and materials, will finally lead to the integration of devices into non standard substrates. These substrates, and their operational fields, might have very specific requirements, and the resilience of these smart electronic components must therefore be extremely high.
- Research will focus on RFID devices with sensing capabilities that are embedded in composite parts, by using antennas, integrated electronics, micro sensors, materials and special assembly techniques for operation in harsh environments (large temperature, pressure variations, etc.) or, if implanted, requiring biocompatible functionality.

1.13.2 Harsh environment and integration into material

Integration of smart devices into packaging, or better, into the products themselves will allow a significant cost saving and increase the eco-friendliness of products.

1.13.2.1 State of the Art

The use of integration of chips and antennas into non-standard substrates like textiles and paper, and the development of new substrates, conducting paths and bonding materials adequate for harsh environments and for ecologically sound disposal will continue. System-in-Package (SiP) technology allows flexible and 3D integration of different elements such as antennas, sensors, active and passive components into the packaging, improving performance and reducing the tag cost. RFID inlays with a strap coupling structure are used to connect the integrated circuit chip and antenna in order to produce a variety of shapes and sizes of labels, instead of direct mounting.

1.13.2.2 Target

To Be Completed in Version 1.2

1.13.2.3 Topics and key issues to be addressed

Current trends show that the research process from application-specific antenna designs to smart antennas, suitable for different applications and materials, will finally lead to the integration of devices into non standard substrates. These substrates, and their operational fields, might have very specific requirements, and the resilience of these smart electronic components must therefore be extremely high.

Research topics to be addressed will focus on RFID devices with sensing capabilities that are embedded in composite parts, by using antennas, integrated electronics, micro sensors, materials and special assembly techniques for operation in harsh environments (large temperature, pressure variations, etc.) or, if implanted, requiring biocompatible functionality.

1.14 Internet of Services

1.14.1 Open Service Platform

From the evolution observed over past in the past years some major trends can be identified that influenced the ICT industry motivated some changes in research, development and business operations, which are:

- The increasing modularisation of software through a service oriented architecture with loosely coupled interaction patterns in a distributed execution environment,
- The building of autonomous software components decoupled from their physical bindings in the execution container that can be easily deployed in an Internet cloud through virtualisation technologies,

- The increased transparency of layers in the networking protocols and technologies addressed by the Future Internet initiative,
- The convergence of communication, information technology and media content services and changing from an operator driven model to over the top provisioning of services.

This has lead to a high pressure on the European ICT industry, which needs to maintain and extend their infrastructure to meet future demands, while not participating adequately in the revenue streams between the over-the-top-providers and end-users. Even worse extrapolating above trends requires new investments into the infrastructure itself, which mandates changes of the business models of the market participants.

1.14.1.1 State of the Art

Service orientation and virtualisation have become the latest computational paradigm shifts. The loose coupling paradigm coming with the Service Oriented Architecture (SOA) approach broke up the application stove-pipes and eased the development of independent modules, that allows to dynamically connecting to 3rd party modules creating a new software industry eco-system, offering new business concepts like software-as-a-service or service mash-ups.

Virtualisation has adopted the distributed computation approach addressed by the grid community from a scientific to a business oriented problem space (e.g. AWS) which enables more and more the deployment of monolithic services (e.g. legacy services) but the more important also composed services following e.g. the SOA design principles across the Internet. There are major obstacles to solve like the complexity introduced by the WebService stack, security threats when crossing domains boundaries both from a service and an infrastructure perspective, missing on-demand network support, and still limited adaptability of the services to new domains.

1.14.1.2 Target

It needs to be explored how existing service platform approaches can be generalized and enriched by incorporating all types of information and communication resources to reach the goal of finally expose "everything" as a service. In this highly dynamical environment adequate resource descriptions and resource mapping functions are key challenges together with management tools that act as a kind of network operating system. As indicated above, besides traditional infrastructure services like storage and computing we envision also the exposure of network infrastructures and (sensor) information infrastructure-as-a-service etc., supporting completely new business perspective for owners and operators of such elements. These will act as application enablement functions in a fully converged world. Here new service and infrastructure federation functions are mandatory, as well as new principles for accounting, security and trust.

The Open Service Platform will incubate the creation of a new open marketplace of services, infrastructure and content by providing a self-organising and adaptive distributed service environment enabling the federation of networked resources while securing individual asset of the key players.

1.14.1.3 Topics and key issues to be addressed

Provide the technological foundation to fill the gaps of existing service platforms targeting a holistic approach:

- Providing new means to service templates that allow an autonomous "self-adaption" of the services according to a given context information or socio economics. Service and context semantics definitions, matching and learning will be key research challenges in this domain,
- A second important step for efficient service virtualisation is to decouple the service interface from the service implementation in a way that allows to map them dynamically on the resources. This will enable efficient clustering mechanisms for adjacent services in an orchestration using resource-specific interfaces. Especially real-time aware media services will highly benefit and provide optimisation synergies for telecom operators and media providers,
- Leverage existing infrastructures as we will support different granularities of the execution containers from a coarse grained virtual machine image down to a data-flow engine. This will support seamless scalability inherently. One positive side-effect is that we can decide if we move "data-to-the-program" or "program to the data", whatever is more suitable in a given context,

- Provide a new top-down approach to some potential cross-layer interactions which will attach the Internet of Services to the new networking paradigm: the transport of data shall be abstracted in a way to allow services to request communication relations with adequate quality of service independent from the knowledge of the underlying transport technology. The architecture concepts to be worked out shall allow the optimum definition and provision of the resources needed to make a service available in the network,
- Find an abstract way of resource modelling and exposure allowing the usage of those exposed resources in an easy manner being able to deploy portable services across different infrastructure providers. Extend the resource requirements description beyond what is known today. In today's approaches of SOI platform or cloud computing offers the resource description is bound to several parameters, e.g. CPU type, CPU size, OS, RAM size, Storage size,....
- Investigate how TIME (when the resource is needed) and LOCATION (where the resource is needed) will influence technologies. Both parameters will play a key role in resource usage optimization; here the topic of green technologies is quite important nowadays, but also in the context of the development of new service technologies,
- A key challenge that has to be addressed in future is how to make information more relevant in a given context as information is globally dispersed and coming from unknown potentially unreliable sources. This will apply on the future service world, where we rely on contextual information to apply the appropriate set of services adapted to the current need of the users. Two important parameters for the relevance are time and location, which can be used to cluster other information sources, like sensor networks or information to de derived from fixed and mobile devices. Particular focus has to be given to provide user's privacy and trust aspects,
- Finally, as services will become much more decoupled from physical resources and modularised, they can be directly exposed to end-users, which can dynamically compose their individual services on demand, getting rid of unnecessary features and simplifying the interaction with the systems anytime, anywhere and on any device. New service front-ends and tools for service composition have to be designed.
- Support standardised service expression in cloud computing services for QoS (service availability, bandwidth-related access quality, etc) and data confidentiality (for different requirements by each piece of data),
- Support portability of a deployed service between different cloud computing service providers.

In times when enterprises standardize their business to best common practices it becomes more and more difficult to identify differentiators that keep the business ahead of competition. Enterprises will increasingly demand flexible operation structures not only on production and IT level, which are already in place. Virtual organization for development of complex products will appear that will exist just for a limited time and will reshape the landscape of enterprises especially in the SME sector. Highly dynamic marketplaces will evolve, bargaining the eBay model to any kind of resource and service, putting high demand on the enterprises actual business models. Currently e.g. telecom operators are facing high pressure from over the top providers on their traditional business maintaining them as a dumb bit pipe, OTTs will need a continuous expansion of existing networks to enhance their service offer, while borders between equipment providers and software industry will disappear. By exposing everything-as-a-service we can allow e.g. a model that an ISP is paid by a movie rental company for delivering an on-demand HD video stream to a customer that hasn't subscribed to the appropriate bandwidth (bandwidth-as-a-service). The exposure of such on-demand services will provide new revenue models and leverage business dynamic in a cross-European context.