Future Internet X-ETP Group

Research Agenda

Version 1.0

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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
3. Security, privacy, trust, and accountability	
3.1 Security, privacy and trust	NEM, NESSi
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
4.4 Availability and reliability even in critical emergency situations	eMobility
4.5 Quality Of Experience	NESSi
4.6 Seamless continuity between all networks	eMobility
5. Adaptability and evolvability to heterogeneous environments, content, context/situation, and application needs	
5.1 Semantic web	NEM, NESSi
5.2 Seamless Localization	eMobility
5.3 Industrial mobile networks	eMobility, NEM
5.4 Adaptive interactions	NESSi
6. Operating system, application and host mobility / nomadicity	
6.1 Cloud OS and Computing	NESSi
6.2 Embedded OS	NESSi, EPOSS
7. Energetic sustainability	
7.1 Energy harvesting	eMobility
7.2 Energy Efficient Protocols , Communication & computing	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 The enabling e-Applications	NEM, NESSi
11.2 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

Figure 1: ETP Inputs for each research topic

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CONTENT

Executive Summary

This document constitutes the version 1.0 of the Strategic Research Agenda (SRA) of the Future Internet (FI) Cross-European Technology Platforms (X-ETPs) Group. To address the Future Internet 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 following 10 years. The 6 ETPs comprise altogether a large set of European and European-based organizations (more than 1000 members: Manufacturers, Operators, SMEs, Academics) and bring competencies on networks, devices, content and services which embrace most of the aspects of the Future Internet.

This SRA aims at identifying short, medium and long terms research challenges of the Future Internet. The associated topics could be used to set up specific research projects and targeted cross-domain and multi-disciplinary projects. 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 Future Internet Vision. The document takes as starting point the X-ETPs FI Vision Document (VD). This Vision Document explained the overall objectives and ambitions of the Future Internet (trends and limitation of the current Internet, high-level objectives and key technological challenges of the Future Internet). It also identified the key opportunities for Europe, and the impacts on ethical, societal, legal, regulatory, standardization, operational, industrial, economical and environmental domains. Then it introduced the ambitions that the Cross-ETPs working group pursues and the proposed recommendations to be taken into account for a successful definition of the Future Internet. Among others, the X-ETPs FI working group engaged to act to (i) Identify achievable business models based on the current ecosystem and based on disruptions brought by the Future Internet developments, (ii) Develop a dynamic roadmap for the key research challenges to be tackled, and establish a road map ensuring the take-up of the research results, (iii) Explore different R&D evolutionary and disruptive approaches, covering classical, clean-slate, and experimentally-driven and (iv) Further develop the cross-domain research fertilization covered by the set of projects working together in the Future Internet Assembly. The version 1.0 of the SRA is the instantiation of the action (ii); providing a well structured and consistent publication which reflects and covers the broad set of Future Internet aspects. The document is up-to-date with regards to new developments and evolutions of research topics addressed by the Future Internet world. The aim is to define short, medium and long terms 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 leadership position.

This SRA does not intend to cover the full space of Future Internet neither superseding the existing SRAs of the different ETPs neither this first version claims to be exhaustive in terms of FI cross-domain thematics. This document covers the main technological challenges that are perceived as crucial to initiate more systematic research cycle, being 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 break the different research silos. The defined research topics required competencies from eMobility, NEM, NESSi, EPoSS, ISI and Photonics21. One additional and significant outcome of this work is the enrichment of the individual ETPs SRAs, following this working group achievement

1 Introduction

The document takes as starting point the X-ETPs FI Vision Document (VD – version 1.0 released in January 09) and in particular the section 2.4 "Key Technological Challenges" and the appendix "Working Document- Technological Challenges".

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.

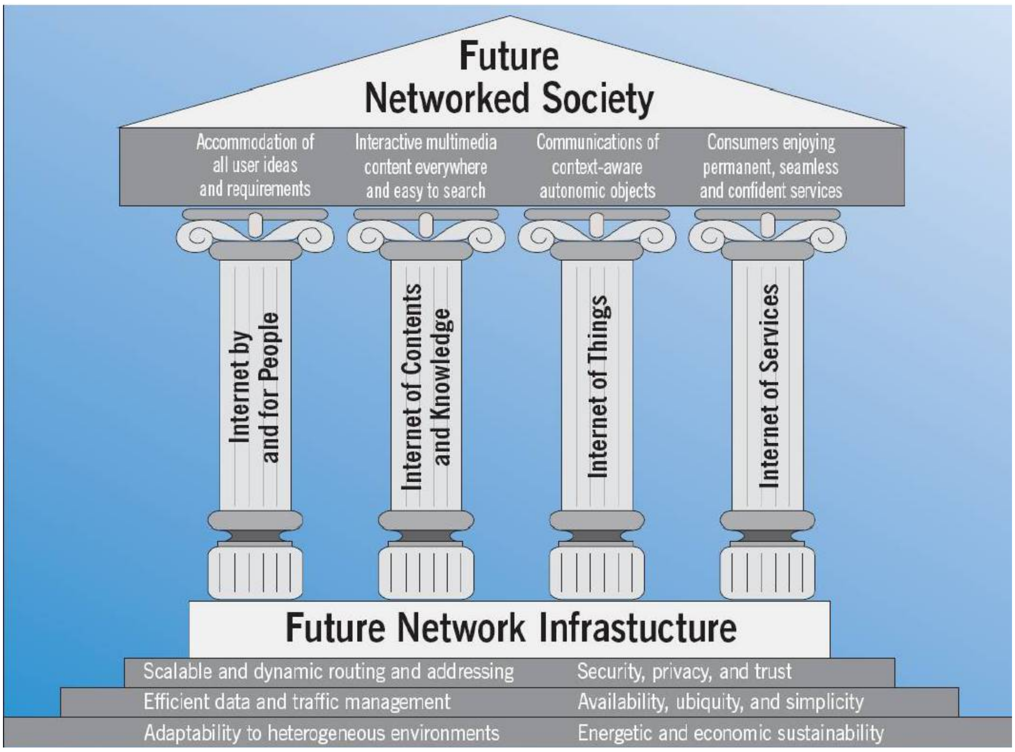

Figure 2: X-ETPs Future Internet Pillars and Foundation – X-ETPs FI Vision Document

The following 14 challenges cover cross-pillar (and referred to as cross-cutting) and network foundation challenges as well as generic challenges for the Future Internet identified so far (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.

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 brought by the Future Internet into the everyday life of citizens and businesses of organisations. Non-electronic services that operate in the real world and that citizens and communities exploit in their lives and businesses. Permanent, transparent, seamless and trustworthy interactivity.

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 terms 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 1.0 of this SRA instantiates the following thematics:

1) **Routing and addressing scalability and dynamics**: (a) Scalability of routing system, (b) Information-driven routing, (c) Addressing and routing information management and (d) Routing system security.
2) **Resource and data/traffic manageability and diagnosability**: (a) Configuration and upgrade management, (b) Problem detection and root cause analysis, (c) Network resource sharing and control, (d) Radio Networks, (e) Optical networks, (f) Satellite networks, (g) Exaflood management and (h) Flexible infrastructure to support networked economy.
3) **Security, privacy, trust and accountability**: (a) Security, privacy and trust and (b) Accountability..
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 and (f) Seamless continuity between all networks.
5) **Adaptability and evolvability**: (a) Semantic Web, (b) Seamless localization, (c) Industry mobile networks and (d) Adaptive interaction.
6) **Operating system, application and host mobility / nomadicity**: (a) Cloud OS and computing, and (b) Embedded OS.
7) **Energetic sustainability**: (a) Energy Harvesting, and (b) Energy efficient protocols.
8) **Conflicting interests and dissimilar utility**: Stakeholders positioning.
9) **Searchability/localisation**: Search engines.
10) **Beyond digital communication**: (a) 3D communications and (b) Behaviour communication
11) **Internet by and for people**: (a) The enabling e-applications and (b) Ensure 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 1.1". The editorial team has identified the related technologies as important and relevant to this SRA, for further completion in the Version 1.1. The Version 1.1,to be released in November 09, before the Stockholm FIA will also be up-dated and completed in order to include new topics that are addressing the future Internet.

For the 14 research topics identified below, there is an undisputable need for experimental research activity not only to effectively experiment the proposed paradigms, concepts, and mechanisms but also to ensure that research outcomes have a real impact. By means of this powerful methodology it has founded, the **Future Internet Research and Experimentation (FIRE)** initiative has successfully put together visionary and exploratory research and experimentation of new paradigms, concepts, and mechanisms in large scale environments. The same approach will be followed (when applicable) to address the challenges identified in Section 2; the corresponding input will be integrated in the next release of this document.

2 Research Topics part

2.1 Routing and addressing scalability and dynamics

2.1.1 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 Jan.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 Jan.2011, the RT size of a core router would reach about 400 to 500k active entries. Worst-case projection predict that routing engines could have to deal with O(1M) 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 IP capable devices.

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 Jan.2006 and Jan.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 (topology vs aggregation) but also system designers (Border Gateway Protocol).

2.1.1.1 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.

2.1.1.2 Target

New inter-domain routing paradigms compared to the current policy-based shortest AS-path routing shall be investigated that allows for i) better scaling than proportionally to n log(n) , where n is the number of nodes, i.e., sub-linearly and at best logarithmically (essential property of an indefinitely scalable routing architecture), ii) assigning node addresses independently of the topology (topology-/name-independent addressing), iii) fast convergence upon topological changes/failures while minimizing communication costs when maintaining coherent non-local knowledge about the network topology, and iv) taking benefit of the topological properties of the Internet (scale-free graph).

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,
- Phase 2 (long-term): by that time hope that research on new routing paradigms will provide for a suitable answer.

2.1.1.3 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.

2.1.2 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.

2.1.2.1 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, 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.

2.1.2.2 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.

2.1.2.3 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 increase of the number of prefixes into routing tables as nodes identifier 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).

- **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.

- **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.

2.1.3 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.

2.1.3.1 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.

2.1.3.2 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.

2.1.3.3 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.

2.1.4 Routing System Security

2.1.4.1 Introduction

To Be Completed in Version 1.1

2.1.4.2 State of the Art

To Be Completed in Version 1.1

2.1.4.3 Target

To Be Completed in Version 1.1

2.1.4.4 Key issues and topics to be addressed

To Be Completed in Version 1.1

2.2 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).

2.2.1 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, and 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 mis-configurations are frequent. Human factors, is the biggest contributor to mis-configuration 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 mis-configuration. Such mis-configurations 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.

2.2.1.1 State of the Art

Two techniques are currently used to mitigate these effects:

- **Static analysis:** uses pattern matching on configurations to detect mis-configurations 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 show the same difficulties then 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.

2.2.1.2 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.

2.2.1.3 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).

2.2.2 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.

2.2.2.1 State of the Art

Not Applicable

2.2.2.2 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).

2.2.2.3 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/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.

2.2.3 Network resource sharing and control

The end-to-end and fate 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).

2.2.3.1 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).

2.2.3.2 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.

2.2.3.3 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 user 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).

2.2.4 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.

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 radio and 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. The introduction of cognitive radio technologies enables wireless access to the future internet by improving the spectrum utilization for communication purposes.

2.2.4.1 State of the Art

a) Radio access

To Be Completed in Version 1.1

b) Opportunistic communications

To Be Completed in Version 1.1

c) Cognitive Radio and Cognitive Radio Networks

Current commercially available radio technologies enable wireless internet connectivity by using either licensed bands for cellular, operator based wireless networks or license exempt bands for technologies like Bluetooth and wireless LAN (WLAN).

2.2.4.2 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.

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. These dramatic improvements are required to make the wireless internet a reality.

2.2.4.3 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,

- 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 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, QoS).

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.

- 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.

2.2.5 Optical networks

The consideration of optical networks should be in two distinct areas: Firstly, the evolution of backhaul and transport networks used to support the interconnection of 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 majority of people in Europe will use a home broadband connection as a means of accessing the Internet. This broadband connection will be able to deliver a fairly low capacity in the order of a few Mbps to maybe some 10's of Mbps, but no more. This is clearly a big step from a few years ago when the only real private Internet access was on dial-up connections of some 56kbit/s. In some parts of Europe there are network operators offering higher connection rates – maybe by cable, maybe by fibre optic cable, but this is not generally available. Compared to Europe, the Far East, Japan and Taiwan have made heavy investments in a fibre infrastructure and can offer much higher access rates than anywhere in Europe. Herein lies a major challenge for the European Internet Vision: recognising the need to increase the home access rate, and also the access network within the ISPs to make sure that any developments in Internet of Services, Things, Knowledge etc can be delivered with a known quality of service and from the user perspective an adequate quality of experience.

Clearly there are other first-mile/last-mile access technologies but all of these will still rely on a high quality, high speed optical network to deliver increased capacity to the access points for any of the above technologies. 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.

Different constraints will drive the evolution of optical networks: multimedia content transport will introduce requirements in terms of bandwidth to optical networks; energy saving requirements will add new constraints detailed below. Optical fiber is the only medium capable in the foreseeable future to satisfy the ever-increasing bandwidth demand spurred by continuously renewed applications (e.g., high definition TV over the Internet, e-science computing, Web 2.0 and further). Future application will require guarantees in terms of service (e.g., upper-bounded latency, minimum available bandwidth). Support of these applications will be supported and 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 networks 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.

2.2.5.1 State of the Art

There is a need to consider the state of the art separately for wired and wireless networks due to the different development they have.

For backhaul and core networks:

There have been many lab and field demonstrations of 100Gbps and faster technology, but none of these have come close to delivering the radical cost reduction needed. The increased data rate drives complexity, dispersion problems, power consumption, packing density, reach reduction and many other factors which *increase* bit transport costs compared to multiple 10Gbps channels. The focus of the research activity must be to reverse this situation, allowing European system providers, component manufacturers and operators to take the lead in manufacture and deployment of these next generation systems.

The key technologies to be developed include sources, receivers, optical coding schemes and electronic methods to mitigate against dispersion, packaging and manufacturing technology to cost reduce the transmit/ receive costs and increase functionality and packing density, including multiple channel assembly. To enable low cost switching and regeneration, other all optical components may be essential, including switches, gates, non-linear devices etc. The target must be to enable 40G transport at or near the costs of 10G transport today – i.e. at least fourfold cost per bit reduction.

As a follow on from the ultra high speed access network research priority there is an assumption that if the access network evolves to 10Gbps rates and beyond then there will be an upward pressure on the metro and core networks to continue to evolve to bit rates of 100Gbps and above.

For wireline access networks:

There is only a relatively small percentage of optical FTTX access today. Some trials and initial rollout has been started with a variety of architectures including point to point and PON.

2.2.5.2 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 fiber' 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 fiber, 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.

2.2.5.3 Topics and key issues to be addressed

To address the aforementioned targets:

- Scientific and Technical topics :
  - Technological breakthroughs must happen in terms of device development,
  - 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,
  - 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,
  - Low cost high volume optical components for optical access networks, e.g. FTTx,
  - The optical layers must remain compatible (for instance, through appropriate grooming) with the packet switching paradigm imposed by the ubiquity of IP,
  - 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 like hybrid fibre radio, multidomain involving necessary technological breakthrough.
- Business, regulation topics:
  - The cooperation between several operators to enable end-to-end service is hitting administrative/confidentiality issues.

to achieve that goal, research topics include technology, systems, network architectures, for energy efficient and convergent transport.

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 datarates, 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. Such convergence must be done in a distributed and scalable way,
- 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 explosion in the IP traffic 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 fibers for ultra-high speed access network provision including protocols and management,
- 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 fiber 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 fiber 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 PON (Passive Optical Network) 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 ONUs 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,

2.2.6 Satellite networks

Satellite Communications provide the foundations of European and worldwide digital information networks. They already play various roles in the current Internet:

- Providing broadband services to citizens in rural areas, to passengers on board vessels, trains or now aircrafts,
- Delivering content to network head end such as DSLAM,
- Distributing data to the banking, business, health, governmental sectors,
- Providing connectivity in the Internet backbone,
- Backhauling of other access technology,
- Providing quick Internet access in emergency scenarios.

In the Future Internet, the role Satellite Communications will be even further enlarged to achieve the ambition of facilitating content and service always on, everywhere, all the time. Indeed Satellite Communications inherently offer:

- **All the time**: As a dependable solution, Satellite Communications are a 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 ubiquitous coverage, Satellite Communications are the most economical access technology in low density populated areas (typically below 50 inhabitants/km2) which represents more than 10% of European population distributed over 50% of the territory. Satellite Communications are therefore a key technology to fulfil the right of all citizens to have access to the Future Internet.

The European Satellite Communications Industry, representing a turn over of nearly €4 Billion (2007), is spending important R&D effort to maintain its world leading position in the domain. However still some R&D efforts need to be carried out in coordination with other telecommunication sectors to integrate Satellite Communications in the Future Internet so that it meets the ambitions set forth regarding the Future Internet of 2020[1].

[1] Future Internet 2020, Visions of an Industry Expert Group, May 2009, ISBN 978-92-79-11320-8, DOI: 10.2759/4425.

2.2.6.1 State of the Art

In recent years, the Satellite Communications sector is experiencing a consolidation of mature services and the emergence of new opportunities, brought by the appearance of new operators and new service concepts.

In 2007, the total turnover of European Space activities was above 6 Billion € out of which nearly 2 Billion € corresponded directly to Telecommunications satellites. The importance of telecommunications for European Space Industry is also made stronger because of other sectors that heavily depend on it, such as the Launcher Industry whose revenues mostly depend on telecommunications demand. In fact, it is estimated that 90% of all commercial launches are dedicated to telecommunications satellites. As an illustration, 20 of 21 satellites placed in orbit by Ariane V and Soyuz in 2007 are telecommunications satellites. We can then conclude that telecommunications and related space activities, i.e. satellites and launches, correspond to nearly 60% of the total turnover of the European Space activities.

Regarding broadband satellite services, the long-due inception of Broadband systems based on multi-beam Ka-band satellite systems is finally happening with both Europe and US based organizations currently deploying their satellite networks achieving a capacity of up to 100 Gbps. The mobile market segment is another area where Satellite Communications are intended to be a key stakeholder, in particular in the provision of mobile TV and long range vehicles such as airplanes, ships, trains and trucks, in which Satellite Communications can offer better capabilities and performance with respect to other technologies. In Europe, Mobile Satellite Services (MSS) have been widely available for several years. They are provided from both geostationary (GEO) and low Earth orbit (LEO) satellites offering several different services, such as: IP, Voice and Data, Data Messaging, Personal Communications Services (PCS), Store and Forward Messaging, Paging, and Search and Rescue services. The major outstanding development foreseen on the MSS sector today in Europe is the novel S-band mobile hybrid satellite/terrestrial systems who will cover a service area of at least 60% of the aggregate land area of the Member States, will address the provision of public interest services contributing to the protection of health or safety and security of citizens and whose start of service is expected for early 2010. Satellite networks play also a crucial role in application areas of emergency response and recovery as well as emergency situations management even under severe conditions where terrestrial infrastructures usually collapse and thus fail to offer the required telecom emergency services, Moreover, during the last years, there has been an exponential growth of Internet connections through all over the World. In particular, by the examination of the 2008 Report and Accounts of the several satellite oriented organizations, it comes out that 2008 revenues related to Internet traffic is in the order of 18% for many of them.

2.2.6.2 Target

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

- A better usage of spectrum for optimum performance, coexistence with other services and exploitation of higher frequency bands,
- 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 and Low cost/size, fast/easy set-up user terminals.

Indeed, continuous innovation will be necessary to ensure that the limited spectrum allocated to Satellite Communications is used effectively and efficiently. Coexistence of satellite services with other services as well as exploitation of higher frequency bands (e.g., Q/V band) shall also be geared. Increased flexibility is also required, so that satellite systems can support evolution of traffic types, and of satellite users' behaviour and geographical distribution. Future satellite platforms will need to be flexible enough to support an evolving range and mix of traffic types, targeting a wide range of applications and allowing reconfigurations to follow service demand and user behaviour, both in nature and in coverage.

Furthermore, there should be emphasis on developing solutions that ease the integration between satellite communications systems and terrestrial systems, thus making it far more appealing and ubiquitous for the user. This will necessitate the design and validation of fully open network architectures. Hybrid networks, in which satellite complements terrestrial technologies rather than competing with them, must be developed. Satellite can then be seamlessly integrated into hybrid systems, and its contribution will evolve in line with the progress of technology during the lifetime of the satellite. Ultimately, satellite should have the capability to serve as a universal overlay of any terrestrial network, fixed or mobile, as well as being able to deliver service where satellite has clear advantages (e.g. in remote and rural areas). This seamless interoperability of satellite networks with terrestrial, both wired and wireless, networks is required at all levels, i.e., service, management and networking levels.

In addition, satellite services need continuous development to provide more power and bandwidth in space, in order to enable cheaper, smaller user terminals, as well as lower utilisation costs, and enhanced, higher data rate services. Unlike terrestrial networks - where extra capacity can be installed incrementally, following market demand - satellites have to be ordered far in advance of the market if they are to be deployed on time for new services. Moreover, new technology components have to be tested in real conditions before being adopted in operational satellite systems. Thus up-front R&D (including protoflights) must be included in any R&D plan if Europe wants to keep its leading position in an increasingly competitive international environment.

Moreover, satellite networks need to follow various convergence trends in order to further develop their proper position in telecommunications. Among them are:

- Convergence allows multiple services transported over IP to be offered on the same networks: triple play (TV, Internet, voice) on fixed networks and quadruple play which in addition allows switching between fixed and mobile telecom networks depending on the user location: outside versus at home or in office. In hybrid networks satellites must offer the same types of convergence in order to be seamlessly integrated with terrestrial infrastructures,
- Broadcast and multicast services are evolving with the introduction of new formats and new ways of service consumption: HDTV, UHDV, 3DTV, Local programming, PVR (Personal Video Recorder), Pay per View, interactive TV, etc. Satellite telecom systems must evolve to support these new types of services,
- Telecom networks are becoming heterogeneous. Connections to the same services are available from a variety of networks, wired and/or wireless. Satellite networks must position themselves as a piece of these heterogeneous global networks,
- Telecom networks are connected to networks in the home, facilitating access to the full range of services.

…

2.2.6.3 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.
- Seamless interoperability with terrestrial, both wireless and wired, networks:
  - Network and management interoperability but also alleviate satellite access characteristics to the users (e.g. latency).
- Development of satellite terminals (fixed and mobile) at low price, size and installation cost:
  - for maximum market acceptance.
- Exploitation of higher frequency bands (e.g. Q/V band),
- Global availability of broadband Future Internet services and even in critical emergency scenarios.

Future Internet shall include a fully integrated satellite component. To this end, the necessary R&D developments to successfully meet the abovementioned objectives for satellite networks are outlined below:

- *Smart and efficient spectrum /resource management:*
  - Investigate 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,
  - *Cognitive radio and networking*: Satellite networks' QoS performance can be optimized by pursuing an integrated approach to spectrum and resource management; 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 networks offering QoS guarantees, Admission Control algorithms are crucial to effectively distribute capacity between the various services provided by a network. Advanced service-aware Admission Control algorithms are required to manage the blocking probabilities of the different services in various traffic conditions. Cost-effective satellite system solutions require a consensus to be reached to standardize the resource management procedures. In particular, the

spectrum efficiency in the air interface should be optimized by means of efficient radio resource management algorithms. The use of cognitive radio and smart antenna techniques suited to satellite communications needs to be strongly envisaged as well.

- *Design and deploy hybrid terrestrial/satellite communication system:*
  Stand alone satellite or terrestrial 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, portability and continuity across composite networks.
- *Delay-tolerant and error-resilient protocols and application:*
  The main limitation in using geostationary satellites is a result of the large latency of the link, which has a significant impact on performance of applications that use 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.
- *Reduce transmission costs and increase efficiency, flexibility and dependability:*
  Ensuring 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). Developing 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), to maximise the exploitation of the available spectrum. Avoiding interference, whether caused by or to satellite services.
- *Increase spectral and power efficiency by at least an order of magnitude:*
  Investigate utilization of spatial diversity in order to meet strict power and spectral efficiency requirements, with particular focus on satellite diversity, so that mobile terminals can rely on multiple replicas of the transmitted signals, originating from different satellites inside the user field of view. Solutions that provide diversity gain utilising both macro-diversity and micro diversity should be considered. New interference cancellation and precoding schemes for 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 are also envisaged important in this regard,
- *Align form factor and power consumption of satellite terminals to those of terrestrial systems, in particular for mobile service,*
- *Adaptive PHY-layer design:*
  Evolving satellite Channel Adaptive Transmission Techniques represents a solution for communications on channels with highly varying channel characteristics, and will gain increasing importance also in future satellite communications systems. Adaptive Coding and Modulation (ACM) have recently been introduced in several contexts. ACM assumes shortage on power resources, rather than frequency spectrum, and is most adequate for satellite systems operating at frequency bands like Ku-band and Ka-band where frequency spectrum is a less critical resource and where rain losses are more significant. For mobile satellite services in L-band, both power and frequency spectrum are restricted and very critical resources, and it is questionable whether ACM will be an adequate solution. Furthermore, mobile satellite channel characteristics change rapidly, especially in maritime environments at low elevation angles, but also on land-mobile environments where the communications signals are subject to blockage, shadowing and multi-path transmissions. ACM has been introduced associated with fixed satellite services and broadcast satellite services, where the user equipment is given by fixed installations and the channel characteristics are relatively slowly varying. As a consequence, the utilization of ACM on satellite mobile channels should be analyzed, along with a significant emphasis on investigating alternative channel adaptive transmission techniques.
- *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.

- *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.
- *Coverage:*
  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.

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 technologies and, as such, they are mainly intended to be carried out in the framework of Space Agencies' work programmes:

- *Development and deployment of more powerful satellite payload:s*
  Inter-Satellite Networking develops mesh inter-satellite connectivity with advanced radio resource management algorithms and networking / routing to achieve a flexible satellite overlay network. Dynamic satellite radio resource management/service planning to use daily measured traffic profiles. The consideration of recently deployed satellites with intelligent payloads and configurable transponders should also be studied to understand how satellite radio resources would be efficiently managed between ground and space.
- *Introduce Software Defined Radio and cognitive radio concepts and architectures:*
  Developing satellite payload technologies and spacecraft platforms, including on-board processing and software radio techniques, 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). Investigate radio resource management and scheduling algorithms with cross layer information coming from adaptive physical layer and QoS requirements from upper layers, to achieve optimum performance of mobile broadband multimedia satellite services. Elaborate a reconfigurable physical layer and radio platforms capable for multi-band and multi-user operation, by using for example mobile agents and/or mobile codes. Investigate mesh inter-satellite connectivity with advanced RRM algorithms to achieve a flexible satellite overlay network. Investigate advanced, flexible physical layer as well as regenerative satellite technologies.

2.2.7 Exaflood management

The "exaflood", or "data deluge", is the explosion of the amount of data collected and exchanged. Just to give some numbers, business forecasts indicate that in the year 2011 more than 1800 Exabyte's of data will be stored. As current network are ill-suited for this exponential traffic growth, there is a need by all the actors to re-think current networking and storage architectures. It will be imperative to find novel ways and mechanisms to find, fetch, and transmit data.

One relevant reason for this data deluge is the explosion in the number of devices collecting and exchanging information as envisioned as the Internet of Things becomes a reality. When the zillions of interconnected devices will exchange huge amount of information, future networks will need to manage this quantity.

2.2.7.1 State of the Art

To Be Completed in Version 1.1

2.2.7.2 Target

To Be Completed in Version 1.1

2.2.7.3 Key issues and topics to be addressed

To Be Completed in Version 1.1

2.2.8 Provide a flexible infrastructure to support networked economy

2.2.8.1 Introduction

To Be Completed in Version 1.1

2.2.8.2 State of the Art

To Be Completed in Version 1.1

2.2.8.3 Target

To Be Completed in Version 1.1

2.2.8.4 Key issues and topics to be addressed

to achieve that goal (mainly technological)
- Hardware (flexible allocation, virtualisation, advanced storage, energy efficiency)
- Middleware (new composite system designs, harmonised virtualisation)

2.3 Security, privacy, trust and accountability

2.3.1 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 evolve; 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).

2.3.1.1 State of the Art

In the new FI scenarios, 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. Pre-defined trust relationships between components, applications and their system environments can no longer be taken for granted.

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.

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 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.

2.3.1.2 Target

Any change in future internet is also bringing change in approach to existing risks, as well as introducing 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…

2.3.1.3 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 a 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.

2.3.2 Accountability

2.3.2.1 Introduction

To Be Completed in Version 1.1

2.3.2.2 State of the Art

To Be Completed in Version 1.1

2.3.2.3 Target

To Be Completed in Version 1.1

2.3.2.4 Topics and key issues to be addressed

To Be Completed in Version 1.1

2.4 Availability, ubiquity and simplicity

2.4.1 Resiliency against normal accidents and failures

Improving availability implies 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. 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.

2.4.1.1 State of the Art

To Be Completed in Version 1.1

2.4.1.2 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 emphasize 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.

2.4.1.3 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 (automatic discovery, and correction of faults),
- Enhanced resiliency against link/node failure 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,
- 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.

2.4.2 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.

2.4.2.1 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.

2.4.2.2 Target

To Be Completed in Version 1.1

2.4.2.3 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.

2.4.3 Global connectivity coverage availability

To Be Completed in Version 1.1

2.4.4 Availability and reliability even in critical emergency situation

To Be Completed in Version 1.1

2.4.5 Quality Of Experience

2.4.5.1 Introduction

To Be Completed in Version 1.1

2.4.5.2 State of the Art

To Be Completed in Version 1.1

2.4.5.3 Target

To Be Completed in Version 1.1

2.4.5.4 Topics and key issues to be addressed

Mapping quality of experience of the services to non-functional properties of the components based on advanced service lifecycle approaches including engineering, deployment, composition, provisioning, management and decommissioning that support transparent knowledge tracking, feedback loops, prediction and simulation, allow for a clear separation of concerns between different stakeholders (business vs. IT, developers, providers, customers, …) and support the full variety of scenarios.

Research on non-functional properties for services including:

- How to define, design, develop, and evaluate these non-functionals, including privacy issues,
- Enforcement, monitoring and management of non-functional properties,

- Mapping of quality of experience to non-functional properties, taking into account how to define and describe these properties according to different usages and contexts (including social and cultural aspects) and the need for negotiation in Service Level Agreement (including trust-related notions),
- Defining a system by tuning QoE through end-user control pane.

2.4.6 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.

2.4.6.1 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. 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.

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 and wireless 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 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.

2.4.6.2 Target

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

- More intelligence in the end-points – not in the transport infrastructure**:** 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-based transport network 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 wirelss 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, future 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. Multi-service capability and mobility over multi-access networks (fixed and the mobile networks) enables true connectivity for all and everywhere.

- 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 will increase, ranging from the typical non-technical personnel, providing local wireless access, who expects the systems to work flawlessly and will spend only minimal time on managing the systems, to the experts managing the large networks of today. 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. This implies 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: Current internet is based on IP addressing. 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. Information search must be content based. This calls for new architecture for future internet. Hence, it is justified to say that future mobile wireless networks will be the key driver for the development for the future internet. In fact, the ubiquitous wireless environment sets strict requirements for future internet in terms of e.g., number of connected devices, node mobility, 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".

2.4.6.3 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 fixed/wireline as well as mobile/wireless access networks,
- New protocols optimised for packet-only in a public access environment. Especially capacity and latency-effective alternatives to IP and TCP,
- Full delay tolerant networking,
- 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),
- Delay/disruption tolerant networking (DTN): Non-real time data transfers should be able to proceed even when connectivity is intermittent due for example to mobility or unreliable radio links. The network should implement cache storage and rendez-vous systems allowing completion of transfers in optimal conditions as connectivity is re-established.

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,
- 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),
- 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).

2.5 Adaptability and evolvability

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

2.5.1 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 (both ours and of computers) is limiting its usefulness and creating big bottlenecks.

2.5.1.1 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.

2.5.1.2 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.

2.5.1.3 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, hence 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-centred (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-centred, 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 are in need of 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.

2.5.2 Seamless Localization

Localization is gaining importance for many use cases. While applications like e.g. Google Earth and the GPS capability of mobile handhelds 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.

2.5.2.1 State of the Art

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

• **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.

2.5.2.2 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).

2.5.2.3 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).

2.5.3 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 rail scenarios. Besides other advantages especially the feature "Mobility" allows for a lot of new application fields.

2.5.3.1 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.

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.

2.5.3.2 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).

2.5.3.3 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.

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 system architectures, communication over heterogeneous networks and network selection are the main issues.

Other application areas like airfield communication and rail scenarios have more demanding communication requirements especially when safety-critical functionalities have to be maintained over the (wireless) communication links. One example for such scenarios is automated train control (ATC) where the driver-less train is fully controlled over a wireless infrastructure. The main research topics here are highly reliable communication channels at high relative speeds between the communicating devices, robustness against interference and redundancy/self-healing in case of single failures. Also low handoff latency is critical for some applications within this area.

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) 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).

2.5.4 Adaptive interaction

2.5.4.1 Introduction

To Be Completed in Version 1.1

2.5.4.2 State of the Art

To Be Completed in Version 1.1

2.5.4.3 Target

To Be Completed in Version 1.1

2.5.4.4 Topics and key issues to be addressed

- Social and business intelligence service provision
- Knowledge- and situational-driven personalization of interfaces and services
- Embodiment of intelligent access to services
- Embodiment of educating principles in services

To Be Completed in Version 1.1

2.6 Operating system, application, and host mobility / nomadicity

2.6.1 Cloud OS and Computing

Cloud Computing: "computing" model based on abstraction and shared pooling of configurable computing resources enabling service over the Internet. Similarly to object-oriented programming, abstracting actions (associated to the control/processing) and data structures (associated to the information exchanges) to allow offering desired processing and messaging capability without incurring complexity to entities external to the system (abstraction exposition), users need not have knowledge of, expertise in, or control over the resource technology in the "cloud" that supports them. Cloud computing services often provide common business applications online that are accessed from a web browser, while the software and data are stored on the servers. Note that i) the term cloud is used as a metaphor for the Internet, based on how the Internet is depicted in computer network diagrams and is an abstraction for the complex infrastructure it conceals, and ii) a cloud can be private or public.

Cloud OS: "Distributed Operating System whose informational/data model, procedures/computational model, and transactional model is optimized for controlling the execution of computer programs, allocation and usage of hardware resources such as memory, CPU time, disk space, I/Os for delivery of e.g. Cloud computing service.

2.6.1.1 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 centers) and volatile resource (coming and going with a very dynamic behaviour) like e.g. mobile devices.

2.6.1.2 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.

2.6.1.3 Topics and key issues to be addressed

- **Cloud OS** : offer high and low level services by means of service components that 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. 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.
- **Cloud computing**: virtualization of services through more flexible and granular optimization of processing and storage resources, providing applications the necessary runtime support to be provided "as a service" without no limitations of scale in number of users accessing or the amount of resources consumed, all this while complying with the terms of subscribed Service Level Agreements (SLA). This "on the cloud" support will be used by enterprises in a cost-effective manner, using on-demand provisioning and offering flexible and innovative billing and service revenue models which rely on dynamic and intelligent accounting.

2.6.2 Embedded OS

2.6.2.1 Introduction

To Be Completed in Version 1.1

2.6.2.2 State of the Art

To Be Completed in Version 1.1

2.6.2.3 Target

To Be Completed in Version 1.1

2.6.2.4 Topics and key issues to be addressed

To Be Completed in Version 1.1

2.7 Energetic sustainability

2.7.1 Energy Harvesting

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.

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.

2.7.1.1 State of the Art

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.

2.7.1.2 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.

2.7.1.3 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, …)

• 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.

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.

2.7.2 Energy efficient protocols

2.7.2.1 Introduction

To Be Completed in Version 1.1

2.7.2.2 State of the Art

To Be Completed in Version 1.1

2.7.2.3 Target

To Be Completed in Version 1.1

2.7.2.4 Topics and key issues to be addressed

To Be Completed in Version 1.1

2.8 Conflicting interests and dissimilar utility

To be complete in Version 1.1
Generic challenge, intelligence at execution time involving policing aspects

2.8.1 Stakeholders positioning

2.8.1.1 Introduction

To Be Completed in Version 1.1

2.8.1.2 State of the Art

To Be Completed in Version 1.1

2.8.1.3 Target

To Be Completed in Version 1.1

2.8.1.4 Topics and key issues to be addressed

- Design for tussle : A paper in Sigcomm 2002 ("Tussles in cyberspace: Defining tomorrow's Internet" by Clark et al.) recognized the importance of conflicting interests in shaping the network architecture and determining how it should be used. It remains to more fully understand whether clear design principles can be deduced from this observation and how such principles will be materialized in the future Internet.

To Be Completed in Version 1.1

2.9 Searchability/localisation

(Searchability/localisation, selection, composition and adaptation)

2.9.1 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.

2.9.1.1 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.

2.9.1.2 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".

2.9.1.3 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.

2.10 Beyond digital communication

(Beyond digital communication : semantic, haptic, emotion, etc.)

2.10.1 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.

2.10.1.1 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.

2.10.1.2 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

2.10.1.3 Topics and key Issues to be addressed

It could be interesting to add a human factors topic considering the present usability limitations of 3D

a) 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.

b) 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.).

c) 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 some technical aspects that have to be solved to make the Future Internet 3D communications a reality.

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 automatised 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 (Draft V6) 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.

2.10.2 Behaviour communication

2.10.2.1 Introduction

To Be Completed in Version 1.1

2.10.2.2 State of the Art

To Be Completed in Version 1.1

2.10.2.3 Target

To Be Completed in Version 1.1

2.10.2.4 Topics and key issues to be addressed

To Be Completed in Version 1.1

2.11 Internet by and for people

2.11.1 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. To achieve e-Inclusion for all, including the ageing population as well as any groups of people that are at risk of exclusion, it is an indispensable and essential condition for the NEM Vision2020. Table 1 is just one example illustrating these behavioral changes that contribute to all-inclusion as well as bear the risk for exclusion.

2.11.1.1 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).

2.11.1.2 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.

2.11.1.3 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.

For enterprise:

- Enterprise collaboration and interoperability systems,
- Research on semantic interoperability and modelling of business processes,
- To enable easy dynamic & versatile B2B transactions,
- Interdomain, 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.

2.11.2 Ensure social, economical, legal and cultural viability

To Be Completed in Version 1.1

2.11.2.1 State of the Art

To Be Completed in Version 1.1

2.11.2.2 Target

To Be Completed in Version 1.1

2.11.2.3 Topics and key issues to be addressed

- Make services accessible to all
- Multidisciplinary research to build a theory describing the relationship between organizations and social networks in regards to hybrid service-based systems
- Support emerging business models for innovation
- Understanding OS community collaborative processes
- Understanding OS community collaborative processes

To Be Completed in Version 1.1

2.12 Internet of contents and knowledge

2.12.1 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.

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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 learing with co 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 interoperabiltiy among them.

2.12.1.1 State of the Art

Todays Virtual world 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.

2.12.1.2 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 traveling or shopping, or carry out multiple facets of human dairy life. Augmented reality will be a fundamental component of this immersive worlds 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.

2.12.1.3 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.

2.13 Internet of things

2.13.1 Intelligence/Smart

In the current vision, 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 possible for virtually any object around us to exchange information and work in synergy to increase dramatically the quality of our lives.

2.13.1.1 State of the Art

Today, 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.

2.13.1.2 Target

To Be Completed in Version 1.1

2.13.1.3 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.

2.13.2 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.

2.13.2.1 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.

2.13.2.2 Target

To Be Completed in Version 1.1

2.13.2.3 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:
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.

2.14 Internet of services

2.14.1 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.

2.14.1.1 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.

2.14.1.2 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.

2.14.1.3 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.

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.