1. NETWORK OF THE FUTURE
What do we expect of the Network of the Future? How would the network of the future look like? Why would that interest me?

We will live in a Networked Future. In a world where we will be connected at any time (networks will allow us to stay permanently connected), anywhere (from personal to global environments and everything in between), to anything (all kind of objects and artefacts, and also software virtual objects).

User expectations on what we can get from networks continue to grow and evolve and users will demand it. Society has accepted the new technologies that allow easy to use network services which deliver multi-sensory experiences and contents, thanks to the increased level of integration of intelligence, transmission speed and device storage capacities, forming together the Future Internet.

Today, network and service infrastructures underpin economic progress and the development of our societies. Mobile communications and broadband Internet access were the main contributors to growth in the telecom sector and were identified as one of the most positive, overall market developments. Three billion mobile terminals in use and more than one billion use the Internet.

Research in mobile communications and broadband access was tackled separately but as networks grow together it now merged in one objective "The Network of the Future" in the 7th Framework Programme (7FP).

The goal is the development of a converged communication and service infrastructure that gradually will replace the current Internet, mobile, fixed, satellite and audiovisual networks. This infrastructure would not only be pervasive, ubiquitous, and highly dynamic. It will also offer almost unlimited capacities to users, by supporting a wide variety of nomadic and mobile interoperable devices and services, a variety of content formats and a multiplicity of delivery modes.

Challenges

Furthermore, Future Networks will probably have novel characteristics respect to today's networks. These are some examples:

- They would use flexibly and efficiently radio access, allowing ubiquitous access to broadband nomadic and mobile services;
- They will manage in real time new forms of ad-hoc communications with intermittent connectivity requirements and time-varying network topology;
- They will integrate sub-networks at the edge, such as personal and sensor networks, toward the Internet of Things for the benefit of humans;
- They will eliminate the barriers to broadband access and will
enable intelligent distribution of services across multiple access technologies with centralised or distributed control;

- They will **enable seamless end to end network** and service composition and operation across multiple operators and business domains;
- Finally, to **support high-quality media** services and support critical infrastructure, (e.g., for energy and transport), the existing Internet will be significantly enhanced or even gradually replaced.

This vision requires addressing the evolution from today’s large legacy infrastructures to new infrastructures by striking a balance between backward compatibility requirements and the need to explore disruptive architectures to build future Internet, mobile, broadband, and associated service infrastructures.

To support these ambitious goals, 46 research projects were launched within the Network of the Future objective in the first quarter of 2008, for a total European Commission contribution of 200 millions Euros. This launch is the fruit of an intense collaboration between leading European industry, universities, research institutes, European Technology Platforms (mainly eMobility, NEM and ISI), member states and the European Commission. It was possible thanks to the innovation capabilities, the modernism and the attractiveness of European Research in the area of Network and Communications.

These projects, with the potential given by their cooperative research, are one more opportunity for Europe to deliver a new generation of telecom infrastructure, network and internet technologies that will be used in some years as fundamental building blocks for health, governmental, transport, entertainment, environmental, educational applications and services.

This effort reinforces European industrial leadership in wired and wireless networks, develops more and better Intellectual Property Rights (IPR) for European companies, stronger synergies between various sector actors and contributing to new business models.

It should also give new industrial and service opportunities in Europe, especially in the field of Internet technologies, where Europe has not yet reached a position commensurate to its technological potential.

Finally, it should also impact in the development of global standards to support convergence and full interoperability, for the new services and complex user requirements.

Each project has its own goals, but no project can succeed alone. Every project also contributes to the overall objectives of the Future Network, and the synergies between groups of projects working on similar topics are vital to the overall success of the research.

The projects have therefore been organised into three clusters: Converged and Optical Networks, Radio Access and Spectrum, and Future Internet Technologies, which will be further described below.
Internet infrastructure has been extraordinarily successful and is now a critical part of our economy’s infrastructure. However, its limitations due to the design made in the seventies start hampering its potential.

Evolutionary improvements to the current network will help sustaining up to a point the growth of the Internet, but are not seen as being enough to face the deep rooted weaknesses of Internet as regards mobility, scalability, wireless generalisation, broadband evolution, multiplicity of services, environments and contexts to serve, security and trust to name a few.

Indeed, the Future Internet should be able to sustain by one or many orders of magnitude higher the number of people, devices and objects connected (billions, perhaps even hundreds of billions of users, sensors, tags, processes, micro controllers), ensure efficiency, security and trust in transaction for new services, incorporate mobility and universal connectivity in its conception, cater for various connectivity schemes, include the technical features for easy operations and management including guarantees for privacy, multiparty governance and delivery of new services.

Given that the limitations of the Internet are deeply rooted in the architectural design and its protocols and mechanisms, the expected work aims at complementing/ revisiting the network science foundations of the Internet, not only for its novel system components like wireless or sensors networks, but aiming at advanced approaches as appropriate to architectures and protocols driven by the need for general mobility, scalability, new forms of routing, connectivity in a generalised wireless environment, to be coupled later with their validation in large scale testing and interconnected environment.

The work of exploratory nature is expected to address how various classes of new requirements constrain the foreseeable evolution of the internet and identify the corresponding long term solutions.

Research Activities

The Future Internet networking research activity in ICT in FP7 is largely reflected in the objectives of ”Challenge 1” under the 2007-2008 work programme and the first call of early 2007. A coherent set of projects has started in 2008 to cope with the identified technical challenges.

Several STREPs (Specific Targeted Research Project) and IPs (Integrated Project), completed by one Network of Excellence (NoE) on next generation Internet networks EuroNF and one Think Tank on Future Internet architecture and technologies, (EIFFEL), will constitute the structuring scientific and technological basis for a renewal of the Internet. The ETP e-mobility is also focusing stronger support on Future Internet networks activities.

Amongst the 15 projects representing a community funding of about 80 million €, two IPs presented here, Trilogy and 4WARD, are at the heart of the research to reshape the networks foundations, from an evolutionary and from a clean slate approach.
Today’s network architectures are stifling innovation, restricting it mostly to the application level, while the need for structural change is increasingly evident. The absence of adequate facilities to design, optimise and interoperate new networks currently imposes an architecture that is suboptimal for many applications, and that cannot support innovations within itself, the Internet.

4WARD overcomes this impasse through a set of radical architectural approaches built on our strong mobile and wireless background. We improve our ability to design inter-operable and complementary families of network architectures. We enable the co-existence of multiple networks on common platforms through carrier-grade virtualisation of networking resources. We enhance the utility of networks by making them self-managing. We increase their robustness and efficiency by leveraging diversity. Finally we improve application support by a new information-centric paradigm in place of the old host-centric approach. These solutions will embrace the full range of technologies, from fibre backbones to wireless and sensor networks.

Technical and economic impacts

The 4WARD results will allow new markets to appear, redefining business roles, and creating new economic models. We will collaborate with related European and other region’s projects, and establish the Future Internet Forum, enabling new markets and opening them for old and new players’ alike, increasing opportunities for competition and cooperation, and creating new products and services. To achieve these goals we have gathered a strong, industry-led consortium of the leading operators, vendors, SMEs, and research organisations, with the determination, skills, and critical mass to create cross-industry consensus and to drive standardisation.

Strategic Objective

4WARD aims to increase the competitiveness of the European networking industry and to improve the quality of life for European citizens by creating a family of dependable and interoperable networks providing direct and ubiquitous access to information. These future wireless and wire-line networks will be designed to be readily adaptable to current and future needs, at acceptable cost. 4WARD’s goal is to make the development of networks and networked applications faster and easier, leading to both more advanced and more affordable communication services.

Technical Approach

In our approach, we combine on one hand innovations needed to improve the operation of any single network architecture and on the other hand multiple different and specialised network architectures that are made to work together in an overall framework. We will work on innovations overcoming the shortcomings of current communication networks like the Internet; in a framework that allows the coexistence, inter-operability, and complementarity of several network architectures, in an integrated fashion, avoiding pitfalls like the current Internet’s “patch on a patch” approach. This work is structured into six work packages: three of them consider innovations for a single
network architecture (Generic Path, In-Network Management and the Network of Information), one work package studies the use of Virtualisation to allow multiple networking architectures to co-exist on the same infrastructure, another work package looks at the design and development of Interoperable Architectures, and finally one work package that ensures that all envisaged developments take proper account of essential Non-Technical Issues.

Key Issues

The Network of the Future must be based on a new set of architectural principles, formulated below as four programmatic tenets:

**Tenet 1: Let 1000 Networks Bloom**
We will explore a new approach to a multitude of networks: the best network for each task, each device, each customer, and each technology. We want to create a framework in which it will be easy for many networks to bloom as part of a family of interoperable networks that can co-exist and complement each other.

**Tenet 2: Let Networks Manage Themselves**
What we would like to have is a "default-on" management entity, which is an inseparable part of the network itself, generating extra value in terms of guaranteed performance in a cost effective way, and capable of adjusting itself to different network sizes, configurations, and external conditions.

**Tenet 3: Let a Network Path Be an Active Unit**
We want to consider a path as an active part of the network that controls itself and provides customised transport services. An active path can provide resilience and fail-over, offer mobility, simultaneously use multiple different sequences of links, secure and compress transmitted data, and optimise its performance all by itself.

**Tenet 4: Let Networks Be Information-Centric**
Users are primarily interested in using services and accessing information, not in accessing nodes that hosts information or provide services. Consequently, we want to build a network as a network of information and services where services and information are mobile and may be distributed.

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"4WARD takes a long-term approach to research towards the Future Internet. Compatibility with existing network technologies is less important while innovation and bright new ideas are more important. This approach is needed to create the network of the future which can overcome the obstacles of current technologies."

Henrik Abramowicz  
(4WARD Coordinator)
Now is absolutely the right time to develop a new design for the Internet that is mindful of the competing technical, economic and social demands that must be met by a revitalised network.

Matthew Ford
(Trilogy Coordinator)

Future growth to meet these challenges will require not only new technologies from the leading edges of networking research, but also architectural changes which may be subtle but far reaching. The Trilogy project has a vision of a coherent, integrated and future-proof architecture that unifies the heterogeneous network, offering immediate deployment rewards coupled with long-term stability.

Architecture for Change

There are two key ideas behind the Trilogy Concept. The first key idea is technical; the traditional separation between congestion control, routing mechanisms, and business demands (as reflected in policy) is the direct cause of many of the problems which are leading to a proliferation of control mechanisms, fragmentation of the network into walled gardens, and growing scalability issues. Re-architecting these mechanisms into a more coherent whole is essential if these problems are to be tackled.

The second key idea is more abstract, but fundamental. It recognises that the success of the Internet derives not directly from its transparency and self-configuration, but from the fact that it is architected for change.

The Internet seamlessly supports evolution in application use and adapts to configuration changes; deficiencies have arisen where it is unable to accommodate new types of business relationship. To make the Internet richer and more capable will require more sophistication in its control architecture, but without imposing a single organisational model.

Therefore, our key principles are to retain the ubiquity enabled by the hourglass model, and take the self-configuration philosophy one level further: we seek control architecture for the new Internet that can adapt in a scalable, dynamic, autonomous and robust manner to local operational and business requirements.

Technical Approach

At the core of the Trilogy workplan lies the realisation that internetworking functions can be broadly categorised into two classes. First, functions that establish and control a scalable, dynamic, autonomic and resilient internetwork (‘reachability’). Second, functions which allow a diverse set of parties to use and share this internetwork to communicate according to their dissimilar needs (‘resource control’). Consequently, Trilogy places the emphasis of its work around these two topic areas.

Trilogy explicitly addresses the contention between suppliers and users of internetworking functions through the introduction of a third key topic area. It investigates the socio-economic, commercial and strategic factors that influence the interplay between the technical internetworking functions in order to architect an integrated solution that is ‘designed for tussle’.

This activity will drive the design of the more technical work in the two main work areas in an ongoing manner, and is key for ensuring that the results of Trilogy will not only operate correctly at a technical level but also satisfy the broader goal of actively enabling changes.
Expected Impact

Trilogy takes a holistic view of the fundamental design principles for next generation Internet architecture, derives novel solutions for the dominant technical and economical challenges and disseminates the gained knowledge to the interested and affected parties.

In particular, Trilogy will significantly enhance the reliability, robustness, manageability and functionality of the Internet, and will create new and varied business opportunities based around common core architecture.

The key is to allow the Internet to be different things in different places without hindering interoperability. In enabling tussles to play out within the architectural framework (as opposed to working against the architecture, as often happens today), Trilogy will permit differentiation, allowing greatly increased robustness for customers who really need it and have the means to pay.

In addition, the enhanced flexibility and improved manageability will simultaneously allow service providers to reduce costs and provide additional services; two aspects that are critical in a world of falling communications margins where service providers are wondering where the money to upgrade their networks will come from in ten years time.

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Next Generation Mobile Technologies

In Framework Programme 6 (FP6), research in the area of mobile and wireless systems has been funded by the EU with approximately 263 million euros for 52 FP6 projects. Driven by this programme, European industry has federated in the Wireless World Initiative (WWI) toward a common technological, industrial, regulatory, and service approach to systems beyond 3rd generation (B3G).

As a result, activities in the mobile communications field have made significant progress toward advanced communication technologies, systems, and services, enabling seamless mobile and wireless access solutions across a range of heterogeneous network infrastructures.

In a business environment based on technology standards that are typically associated with very high intellectual property value, the associated goal of FP7 is to maintain a strong European leadership on mobile radio technologies.

Building on the success of mobile telephony and text messaging as a mass market, third-generation mobile broadband services are now becoming increasingly available, with UMTS/HSPA terminals hitting the market and UMTS/LTE prototypes being demonstrated. In addition, IEEE 802 fixed wireless technologies, such as WIFI and WIMAX, have become popular in recent years, especially for laptop users in “hot spots”. Beyond that, envisioned advanced mobile and satellite communication systems are expected to offer broadband mobile applications with access to high-quality multimedia content and offer communication with and among objects, machines, and devices. These systems are aimed to be operated in both available and future candidate frequency bands.

During the World Radio communications Conference 2007, in total “only” 392 MHz additional radio spectrum for mobile communications in Region 1 (Europe, Greenland, Africa, the Middle East west of the Persian Gulf and including Iraq, the former Soviet Union and Mongolia) in relatively small fragmented bands has been agreed on with some remaining uncertainty concerning the availability of these bands.

For new radio access schemes that are aimed to be integrated with other existing radio access networks, ITU has set the target of 100 Mbit/s for truly mobile applications, and 1 GBit/s for fixed/portable radio access.

These objectives are framing the research and the characteristics of the test beds that are currently being developed in various regions of the world.

The fragmentation and shortage of available radio frequency bands and the multiplicity of standards for wide area, local area, and short range communication have raised the demand for better spectrum efficiency, new system topologies, inter-working, and multi-mode systems that might be realised with flexible radio technology.

Micro- and nano-electronics have made significant progress towards nano-scale devices and will enable radio transmission techniques that seemed unrealistic a few years ago.
European research and future activities

The European Technology Platform (ETP) eMobility has been established as an action forum where all stakeholders, led by industry, have come together to define a Strategic Research Agenda (SRA) on mobile and wireless communications for the next seven years.

As stated by eMobility, future research activities should aim at "the improvement of the individual's quality of life, achieved through the availability of an environment for instant provision and access to meaningful, multi-sensory information and content". Realisation of this vision demands a major shift from the current concept of "anywhere, anytime" to a new paradigm of "any network, any device, with relevant content and context in a secure and trustworthy manner".

The future system is seen to be complex, consisting of a multitude of service and network types ranging across Wireless Sensor Networks (WSN), Personal Area, Local Area, Home Networks, Moving Networks to Wide Area Networks. The increasing dependency of society on such communication infrastructure requires new approaches and an emphasis in European research captured in a new concept called the "SET Concept" that underscores the need for a 3-dimensional vision of research activities that will deliver Simplicity, Efficiency and Trust.

A total of 22 projects in the area of mobile and wireless communications have been corresponding to 100 Me of EU funding in the first phase of FP7 covering the Work Programme 2007-2008. In the centre of this topic is the Network of Excellence (NoE) NEWCOM++ that is integrating medium-long term complex, interdisciplinary, fundamental research structures in the field of wireless communication networks.

One important focus topic is 'cognitive radio systems'. Apart from three STREPS (SENDORA, ARAGORN, PHYDYAS) that are developing key enabling technologies for cognitive radio, the flagship project E3 is introducing cognitive wireless systems in the beyond 3G world from a technical, regulatory, standardisation and business perspective.

Related to this topic of cognitive radio are a number of projects focusing on Ultra-Wideband (UWB) radio systems. Besides specific tools like interference monitoring (UCELLES) and UWB test beds (WALTER) that are being developed, the integrated project EUWB is strengthening European key industrial sectors by ICT innovation of manifold cutting-edge short range radio solutions based upon advanced UWB.

To enable an ubiquitous radio access a large number of STREPS are focusing on specific radio technologies (MIMAX, CODIV, DAVINCI, REWIND, WIMAGIC, HURRICANE) and innovative deployment concepts (ROCKET, EU-MESH, CARMEN).

Finally, the integrated project SENSEI is exploring how heterogeneous wireless sensor and actuator networks can be integrated into a common framework of global scale and made available to services and applications via universal service interfaces.

In satellite communication the ETP Integral Satcom Initiative (ISI) has been established to integrate satellite networks in a seamless service provisioning across networks, with increasing focus on the design of end to end wireless systems for heterogeneous connectivity solutions that are increasingly being considered for several market and crisis management scenarios.
NEWCOM++ is an NoE drawing inspiration and shape from its predecessor NEWCOM, and aims at addressing medium-long term complex, interdisciplinary, fundamental research problems in the field of wireless communication networks through identification, placement in the right modelling perspective, and characterization of information-theoretical bounds of achievable performance.

Main objectives

- Enhance the already good cooperation level among research groups reached by NEWCOM and push it to a degree where it will reach an irreversible, steady-state nature.
- Form a generation of young European researchers fully free of any scientific provincialism and accustomed to common work under major, frontier scientific challenges.
- Encourage a fair and vital competition among researchers via the NEWCOM++ Achievement Awards.
- Disseminate its results across the scientific community through jointly written papers, special session and journal issues, and offer to the European industry the benefit of long-term, fundamental research achievements through dedicated events (NEWCOM++ Dissemination Days) and via a number of affiliate partners.
- Identify a selective set of scenarios characterised by a reasonably-sized set of parameters which take into account users’ and applications’ requirements.
- Define suitable performance measures that take into account the wireless channel nature (ergodic and outage capacity, bit-frame error rate, etc.).
- Perform a detailed analysis of the main theoretical results available in the context of theoretical bounds for multi-user, multi-antenna systems.
- Evaluate information-theoretical bounds on the achievable performance of today’s and tomorrow’s technologies, such as multiple antennae, co-operation and relaying, source-, channel- and network-coding (separate plus “joint” versions), adaptive radio resource management, constructive interference handling, and so on. Mathematical tools such as Random Matrix Theory, Game Theory, Stochastic Geometry, Percolation Theory, Convex Optimization, etc. will be extensively used.
- Design and analyse transmitting/receiving algorithms and protocols in order to approach those limits. This will encompass efficient coding (turbo-like and low-density parity-check codes), iterative techniques applied in various receiver functionalities such as decoding, synchronization, multi-user detection, robust pre-coding techniques and channel state information feedback, joint source and channel coding, network coding, adaptive cross-layer radio resource management.
- Analyse implementation aspects of the above algorithms in flexible, energy-aware user terminals.

Technical Approach

The JPA of NEWCOM++ is articulated into the traditional four main NoE activities, namely, Integration, Research, Spreading of Excellence, and Management. The overall organisation of the NoE is shown in the figure: it encompasses 11 core research work-packages (WP R.1-11) spanning physical layer communications (PHY), networking (NET) and cross-layer interaction (X-LAYER). The number of work-packages in X-LAYER combining both concepts from networking and from physical-layer communications is substantial, allowing for a guarantee that the objectives of spectral efficiency and robustness are properly and jointly addressed. The so-called "transversal" work-packages (WPR.A, WPR.B, WPR.C) interact with many core research WPRs and provide tools for realization of
fundamental concepts (WPR.C), for provision of secrecy and security features at all levels of the communication process (WPR.A), and for location information processing to enhance both end-user quality-of-service and system spectral efficiency and robustness (WPR.B). They all naturally involve aspects stemming from PHY, NET and X-LAYER.

The Consortium strength

The present Consortium of 17 partners has been chosen (down-selected) from a much larger pool of participants in former NEWCOM. In the area of iterative/adaptive modulation and coding, NEWCOM++ has some of the best known researchers world-wide, such as the GET group who invented turbo codes, and Politecnico di Torino group (under CNIT) who provided fundamental contributions to the theory and practice of iterative decoding and reception, and the group in Technion which obtained in a unified way tight upper bound to the codes performance.

Expected Impact

The first expected impact concerns the contribution to global standards for a new generation of ubiquitous and extremely high-capacity network and service infrastructures.

The second expected impact concerns the reinforced European industrial leadership in wireless networks.

The third expected impact comes out of a peculiarity on the NoE structure. From this standpoint, the choice has been to act as a "network of networks", in order to avoid the fragmentation of many small partners and to implement this overarching-network vision.

At the same time, by cherry-picking the excellence dispersed within them, we have identified CNIT (a Consortium formed by all Italian universities active in telecommunications research) as the "collection partner" for researchers from the best Italian universities, and similarly we have identified the (only) French partner CNRS as the "collection partner" of researchers from CNRS, the GET University system, Eurecom and Supelec. Under FTW, This choice will eventually have an impact at the national level, favouring the establishment and promotion of similar national networks, and will also have an impact at the European level, by associating the "best of the best" researchers with a selection involving many national institutions.

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The goal of E3 is to strengthen Europe's leadership in the global effort of transforming current wireless system infrastructures into an integrated, scalable and efficiently managed Beyond-3rd Generation (B3G) cognitive system framework. This objective will help to ensure seamless access to applications and services and to exploit the full diversity of corresponding heterogeneous systems.

The approach favoured by E3 addresses this goal in a non-disruptive way by integrating existing and future wireless radio standards into a common framework and contributing to on-going/emerging standardisation bodies with a focus on key convergence enablers. In particular, IMT-Advanced related radio and cognitive system oriented standardisation bodies are targeted.

The E3 consortium will develop and showcase the B3G convergence beyond state-of-the-art and introduce cognition and self-x principles into the different parts of the communication systems. It will contribute to development, regulation and standardisation of the corresponding system following an end-to-end approach. Aspects ranging from self-x and multi-standard functions of the access and backbone network, over corresponding enablers such as a cognition supporting pilot channel, to the self-x functions on the terminal and network sides are studied from a technical and its complementary economic and regulatory viewpoints.

The E3 consortium brings together major key European players in the domain of cognitive radios and networks, self-organisation and end-to-end reconfigurability. E3 builds on several key achievements from the successful FP6 E2R programme, pursuing research into the most promising directions towards removing walls (current technical and regulatory limitations) and building bridges (technical) in order to facilitate the vision of true end-to-end connectivity being as efficient as possible.

Technical Approach

The E3 vision of the future framework, consists of a multitude of heterogeneous standards, building on CR/CN principles where several operators are supposed to be present, each controlling multiple air interfaces, such as cellular (UMTS, HSDPA and LTE, a future 4G, etc.), metropolitan area (WiMAX, next generation WiMAX based on IEEE 802.16m, etc.), short-range (WiFi systems based on IEEE 802.11a/b/g/e/etc., next generation WiFi systems based on IEEE 802.11n, etc.). In this context, mobile terminals are expected to have the possibility of maintaining links to one or several of the air interfaces simultaneously.

To optimise the usage of existing and future radio access resources, the E3 consortium has set out four top level objectives:

- Design a cognitive radio system exploiting the capabilities of reconfigurable networks and self-adaptation to a dynamically changing environment,
- Enable a gradual, non-disruptive evolution of existing wireless networks in accordance to user requirements,
- Define means to increase the efficiency of wireless network operations, in particular by optimally exploiting the full diversity of the heterogeneous radio eco-space,
- Increase system management efficiency for network operation and (re)configuration by building on cognitive system and distributed self-organisation principles.

Key Issues

The key issues addressed by E3 cover:

- Validation and quantitative analysis of cognitive radio systems related business
models including market assessment,
  • Extension of state-of-the-art towards a functional and implementation architecture enabling the exploitation of the full benefits of highly heterogeneous, cognitive radio systems,
  • Development of collaborative (network-terminal, network-edges) and autonomous distributed decision-making related algorithms targeting an efficient operation of the heterogeneous, cognitive system by self-organising principles in terms of fast reactivity to any context change, low parameterisation overhead and distribution of computational complexity,
  • Development of cognitive enablers with the objective to efficiently exchange context information and related optimisation constraints subject to which resource usage optimisation tasks are performed,
  • Development of a reference prototyping system based on cellular, metropolitan area and short-range systems in order to implement and showcase the performance of cognitive decision-making algorithms in various scenarios.

E3 is definitely engaged in a strategy for openness, economical efficiency and technological excellence thanks to strong standardisation and regulatory commitments.

Partner

Motorola (FR), Alcatel-Lucent (DE), ANFR (FR), BNetzA (DE), Beijing University of Posts and Telecommunications (CN), Deutsche Telekom (DE), Ericsson (SE), Fraunhofer (DE), France Telecom (FR), IDATE (FR), Nokia (FI), Ofcom (UK), RA/AT (NL), Thales Communications (FR), Telefónica I+D (ES), Telecom Italia (IT), University of Surrey (UK), University of Athens (GR), Universitat Politecnica de Catalunya (ES), University of Piraeus (GR), Vrije Universiteit Brussel (BE).

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The objective of the group of Projects in the cluster "Converged and Optical Networks" is to meet the challenge of developing the technologies for realising the deployment of the ubiquitous infrastructures and architectures of future networks and future Internet services.

Future network infrastructures will support the convergence and interoperability of heterogeneous mobile and broadband network technologies. Barriers to ubiquitous fast broadband access will be eliminated and networks will provide ultra high speed end-to-end connectivity, with optimised protocols and routing, and optimised traffic exchange between heterogeneous core, metro and edge networks, wired and wireless, in multiple operator domains.

The expected outcome of this FP7-funded research is to deliver reliable, scalable, reconfigurable network infrastructures, which will be an absolute pre-requisite to deliver the upcoming generation of ICT services in a seamless manner.

There is a continuous trend in demand for faster broadband access. In most European Member states typical speeds for home broadband access are today in the 2-4 Mbit/s range. However, in the mid-term future, new services such as HDTV and 3D video will necessitate speeds of up to 100 Mbit/s and later up to Gbit/s, both for the access link between home and network and around the home. This will require the optimised exploitation of a full range of technologies, including cable (CaTV), optical fibres, high-speed wireless, satellite, powerline (PLC) and xDSL lines.

To assist in structuring the work of the Cluster, the projects in the cluster can be further sub-divided into four (overlapping) sub-areas: Ultra High-Speed Broadband Access; Core and Metro Network Concepts; Satellite Technologies; and Enhancement of Broadband Mobile Communications.

Ultra High-Speed Broadband Access is addressed by the IP projects ALPHA and OMEGA and by the STREP projects ReDeSign and SARDANA.

New concepts for ultra high-speed broadband GBit/s access to, and around, the home will be developed, supporting mobile-based services as well as video services, integrating wired, fibre and wireless links. Ring architectures and remote nodes will be developed as an evolution of current FTTH technology, and migration paths will be created from existing cable networks towards future hybrid optical infrastructures.

Novel Core and Metro network concepts are developed by the STREP projects DICONET and ETNA, and the IP project FUTON. They develop new network planning and routing tools, new architectures based on low cost and secure Ethernet technology, and fixed-mobile integration, using radio-over-fibre technology.

The contribution of Satellite Technologies to the future European broadband infrastructure is developed in two Support Actions (sISI, and SFERA), supporting the Integral Satcom Initiative Technology Platform, and addressing opportunities to use the EU Structural Funds in the deployment of broadband, particularly in rural areas.

Enhancement of Mobile Broadband Mobile Communications in future networks is addressed by three STREP projects: Multi-Base, C-CAST and WHERE, in support of context-awareness, multicasting and new location-related services, with enhanced usability of terminals and interfaces between the user and the network.

The collaboration work amongst the group of projects within the "Converged and Optical Networks" Cluster is supported by the BONE Project. BONE is a Network Of Excellence, building on the results of the FP6 ePhoton/ONE NoE, by stimulating a more intensified collaboration, exchange of researchers and building
on Virtual Centres of Excellence that can serve European industry and support the final "Network of the Future" with education and training, research tools and test labs, to pave the way to new technologies & architectures.

By fostering collaboration among very heterogeneous projects researching on a wide spectrum of network technologies, the "Converged And Optical Networks" cluster will enable to answer some fundamental questions, like at which network layer convergence is suitable, what is efficient convergence, how to use multi-mode multi-standards capabilities to reach higher data rates (both in core, metro and access networks), how to adapt bit rate to the requirements at the edge of the network, defining end-to-end requirements in terms of quality of service, data rate, unified signalling across heterogeneous networks, which network technology is making the most sense depending on the deployment scenario.

Answering these questions in a collaborative and concerted approach will help to set some agreed fundamentals among academic and industrial researchers to build further the networks of the future in Europe.
The future Internet will require an extremely high-bandwidth “core” and “access” network, along with the associated developments in transmission and switching that are required to achieve this.

Home access networks play a critical role in achieving broadband penetration, as they act as a communications segment that enables end-to-end services. Extending access into the home and to individual devices is the only way to ensure the success of the future Internet.

The future Home Access Networks must also enrich the lives of consumers, for example by allowing visual communications with their friends or relatives, by enabling interactive experiences through entertainment, by assisting the consumers in maintaining their independence as they age, for example by offering remote healthcare and by allowing them to communicate with their family to reduce any sense of isolation they may have. In essence, they must have the ability to control their virtual as well as their physical environment.

The OMEGA project is centred on the needs of the user: gigabit radio frequency and optical links, combined with more robust wide-area radio and visible-light communications will provide wireless connectivity within the home and its surroundings. Combined with power-line communications this provides a home backbone “without new wires.”

A technology-independent MAC layer will control this network and provide services as well as connectivity to any number of devices the user wishes to connect to it in any room of a house or apartment. Furthermore, this MAC layer will allow the service to “follow the user” from device to device. In order to make this vision come true, substantial progress is required in the fields of power line, optical-wireless and radio frequency physical layers, in protocol design, and in systems architecture.

Technical Approach

The general objective of the OMEGA is to distribute in all rooms 1 Gbps over heterogeneous technologies. Three main technologies without need of new wires in the home will be investigated and optimised in order to meet this challenging target.

Radio Communications

The multitude of systems operating in a single home network and using the overcrowded frequency bands will create coexistence problems. These issues have already appeared; causing difficulties in the standardisation process of IEEE 802.11n, because of the larger bandwidth employed in certain operation modes.

These difficulties will be potentially solved with the complementary deployment of systems such as ultra-wide-band (UWB). Therefore, improving the coexistence and cooperation between these legacy systems is a necessity for reliable communication within the home network. Convergence at the radio layer will consequently be a key concept to be investigated by the project.

Power line communications

OMEGA aims to increase the bandwidth for power line communications up to 100 MHz, as well as develop new understanding of electromagnetic interference and other impairments. This will provide a foundation for new wide-bandwidth power line transceivers that can substantially increase the data rates available by means of advanced modulation schemes.
based on multi carrier approaches.

Optical Wireless
OMEGA aims to combine optical wireless communications techniques in order to provide a range of communications channels, which together can provide robust optical wireless communications. Infrared optical wireless will be used to provide Gbps line-of-sight communications, while visible light communications (VLC) will provide broadcast coverage at lower data rates. In addition, a complete hybrid wireless optic prototype will be incorporated into the OMEGA platform.

Inter-MAC Convergence
The OMEGA project will pioneer a new method of inter-MAC convergence, identifying the advantages and the limits of such an approach in terms of performance, reliability, stability, backward compatibility, costs, and potential impacts onto existing standards.

Continuity from the Access Network
The aim of OMEGA is to build a network that ‘extends’ the access network into the home to make it penetrate to the furthest home device. Access network continuity has therefore a key role to play. It will require novel methods for managing the interconnection of the HAN with various existing networks, as well as novel methods for the interoperability of the different media renderers with the proposed services.

Expected Impact
OMEGA will demonstrate a proof of concept ultra broadband Home Area Network in a scale one apartment and evaluate roll-out scenarios with actual services. The disruptive capabilities of such a network will open up new business opportunities for the entire value chain, from manufacturers to network operators, service and content providers up to the end users.

In terms of impact on the European society the OMEGA project addresses several important challenges. Firstly it will ease and encourage the development of new advanced integrated services to the benefit of both the academy and industry. The expected impact for the citizen is the availability of new services due to ultra broadband penetration to the device.

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SARDANA project aims at extending the limits of passive FTTH networks in terms of scalability, resilience and minimum infrastructure requirements.

Main Objective

Fibre-to-the-Home networks constitute a fundamental segment with the required potential to match the huge capacity of transport networks with the new user communication demands, where deeper research is still to be performed. Network access infrastructure investments are driven by increased number of users requiring broadband access to services enabled by the Internet infrastructure and applications. Fixed access to homes, hotspots, base stations is best served digitally via fibre optic capacity that provides a fundamental boost over the last mile copper solutions.

Dense FTTH Passive Optical Networks (PONs) is a cost efficient way to build fibre access and SARDANA is a way to demonstrate how the huge bandwidth available through the fibre access can be exploited in a cost efficient and reliable manner. The key performances that SARDANA project aims at radically improve are the scalability and the robustness, since constitute pillars of such a cost-sensitive segment:

- Scalability is reached by means of cascadable remote nodes in a new hybrid architecture, allowing smoothest grow and migration, and the new adoption of remotely-pumped amplification, WDM/TDM overlay, and cascadable remote nodes in a new hybrid architecture, while keeping the passiveness of the PON and reducing civil work investments.
- The resulting network is able to serve more than 1000 users with symmetrical several hundred Mbit/s, spread along distances up to 100 km, at 10Gbit/s, in a flexible way, also supporting multi-operator service.

- Robustness is achieved by means of the development of new monitoring and electronic compensation strategies over the PON, as well as by the passive central-ring protection.

The intensive use of the optical transparency and of the latest opto-electronic technologies enables to expand the PON performances and functionality while minimizing the infrastructure requirements at both urban and rural areas. SARDANA will set an evolutionary path for G/E-PON and incorporate functionalities of metropolitan networks, envisaging access-metro convergence.

Technical Approach

The pursued novel SARDANA network transparently combines the WDM (Wavelength Division Multiplexing) and the TDM (Time Division Multiplexing) dimensions to reach the extra-large user-density.

The proposed completely passive resilient FTTH network is based on a WDM ring for the transport of the large amount of downstream and upstream information (up to 1.2Tbit/s if using 64 wavelengths for 2000 users) and TDM trees, transmitting several wavelengths from corresponding operators, sharing a common infrastructure. Passive Remote Nodes (RN), which implement cascadable 2-to-1 fibre optical Add&Drop functions distribute different wavelengths to each of the access trees; remote amplification is introduced at the RN by means of Erbium Doped Fibres (EDFs) to compensate add/drop losses; optical pump for the remote amplification is provided by pumping lasers located at the Central Office (CO), also providing extra Raman gain along the ring. Regarding the digital terminals, the SARDANA project aims at reuse, as much as possible,
standard G/E-PON equipment of current and next-generation 10G-versions, performing a quasi-transparent overlay between TDM and WDM layers.

The work in SARDANA is organised into several inter-related Work-Packages:

- WP-Mg: Project Management and Outcomes.
- WP-Ar: Network Architecture.
- WP-Tr: Transmission and modulation formats.
- WP-Sy: Network Subsystems.
- WP-Im: Monitoring and adaptive compensation of PON Impairments.
- WP-Dm: Demonstrator and Field-trial.

During the project live, a Sardana Network demonstrator will be built, engineered and multi-layer operated; its main features will be also demonstrated in a field trial, delivering new generation bidirectional services to residential users.

In order to fulfill the multi-disciplinary tasks and to reach the challenges, the SARDANA partners join their expertise:

- UPC: Coordination, subsystem design.
- Tellabs: GPON equipment, MAC, lab-demonstration.
- IntraCOM: Management & Control plane, Service platform.
- IT: Monitoring system, non-linear transmission.
- ISC: Remote nodes, non-linear amplification.
- AIT: Electronic PON impairment compensation, Techno-Economic studies.
Expected Impact

The Objectives and expected Impact of SARDANA are:

• One order-of-magnitude extension of current PON performances, “aimed at overcoming the expected long term limitations of current internet capabilities, architecture and protocols”.

• Smooth and increased scalability and backwards compatibility migration from currently deployed PONs. Since operators face a high degree of uncertainty at this level (take rates, user demands, etc) and the necessity of feasibly deferring the investments, incremental scalability has become a major objective, as denoted in the FP7 Target Outcomes.

• Establishment of new intelligent monitoring and compensation strategies to combat impairment and faults for a trusted robust PON.

• Implementation of the MAC, the Control and Management planes, to demonstrate basic resiliency, wavelength balancing and improved service-aware traffic control.

• Economic effectiveness of the extended PON approach.

• Demonstration and field-trial of the SARDANA network.

• Recommendation for a technical solution of a multi-operator shared infrastructure as an input to European and National Regulatory bodies.

• SARDANA will result with experience and IPR that helps European industry and research to develop a competitive advantage.

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**ARAGORN** - Adaptive Reconfigurable Access and Generic interfaces for Optimisation in Radio Networks
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**BONE** - Building the Future Optical Network in Europe
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**CHANTI** - Challenged Internet Access Network Technology Infrastructure
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Project Number: 216714

**CODIV** - Enhanced Wireless Communication Systems Employing CoOperative DiVersity
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**DaVinci** - Design and Versatile implementation of nonbinary wireless communications based on innovative LDPC codes
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**DICONET** - Dynamic Impairment Constraint Networking for Transparent Mesh Optical Networks
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**E3** - End-to-End Efficiency
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**EFIPSANS** - Exposing the Features in IP version Six protocols that can be exploited/extended for the purposes of designing/building Autonomic Networks and Services
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**EIFFEL** - Evolved Internet Future for European Leadership
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**ETNA** - Ethernet Transport Networks, Architectures of Networking
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Project Number: 215652

**List of all the projects**
EU-MESH - Enhanced, Ubiquitous, and Dependable Broadband Access using MESH Networks
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Project Number: 215320

Euro-NF - Anticipating the Network of the Future - From Theory to Design
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Project Number: 216366

EUWB - Coexisting Short Range Radio by Advanced Ultra-Wideband Radio Technology
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Project Number: 215669

FUTON - Fibre Optic Networks for Distributed and Extendible Heterogeneous Radio Architectures
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Project Number: 215533

HURRICANE - Handovers for Ubiquitous and optimal broadband connectivity among CooperAive Networking Environments
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Project Number: 216060

MIMAX - Advanced MIMO Systems for Maximum Reliability and Performance
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Project Number: 219552

MobiThIn - Intelligent distribution of demanding services and applications to mobile thin client devices
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http://www.mobithin.eu
Project Number: 216946

MobiWeb 2.0 - Mobile Web 2.0
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Project Number: 212430

MOMENT - Monitoring and Measurement in the Next Generation Technologies
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Project Number: 215225

Multi-Base - Scalable Multi-tasking Baseband for Mobile Communications
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N-CRAVE - Network Coding for Robust Architectures in Volatile Environments
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Project Number: 215252

NEWCOM++ - Netzwerk of Excellence in Wireless CMmunications++
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Project Number: 216715

Omega - Home Gigabit Access
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Project Number: 213311

PHYDYAS - Physical layer for dynamic spectrum access and cognitive radio
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PSIRP - Publish subscribe Internet Routing Paradigm
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ReDeSign - Research for Development of Future Interactive Generations of Hybrid Fibre Coax Networks
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Project Number: 217014

REWIND - RElay based Wireless Network and standard
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Project Number: 216751

ROCKET - Reconfigurable OFDMA-based Cooperative NetworksEnabled by Agile SpecTrum Use
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Project Number: 215282

SARDANA - Scalable Advanced Ring-based passive Dense Access Network Architecture
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SENDSORA - SENsor Network for Dynamic and Opportunistic Radio Access
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SENSEI - Integrating the Physical with the Digital World of the Network of the Future
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SFERA - Structural Funds for European Regional Research Advancement
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siSI - Support action to the Integral Satcom Initiative (ISI)
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SmoothIt - Simple Economic Management Approaches of Overlay Traffic in Heterogeneous Internet Topologies
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Project Number: 216259

SOCRATES - Self-Optimisation and Self-Configuration in Wireless Networks
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Trilogy - Re-Architecting the Internet
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Project Number: 216372

UCELLS - Ultra-wide band real-time interference monitoring and CELLular management Strategies
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WALTER - Wireless Alliances for Testing Experiment and Research
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WHERE - Wireless Hybrid Enhanced Mobile Radio Estimators
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WiMAGIC - Worldwide Interoperability Microwave Broadband Access System for Next Generation Wireless Communications
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Outlook

Current Trends

The existing research activities envision a Future Internet, which will feature almost unlimited bandwidth capacity, magnitudes of higher computing performance, wireless access anywhere, trillions of devices interconnected, integrated security and trust for all parties, and adaptive and personalised services and tools. This vision emerges as a federating research theme globally, as the ever growing number of networked applications and business models bring novel challenges in terms of scalability, flexibility, security, and robustness of networks and services.

From the network perspective, broadband and mobility will remain key research drivers. The introduction of High Speed Packet Access technology in 3G networks has prompted a 40% increase of mobile data usage. Still, current mobile technology does not meet the ambitious targets set in the global context of 4G systems.

For fixed access, a four fold increase beyond current state of the art represents an imperative. Cognitive/reconfigurable radio and networks are essential technologies capable of meeting the objectives of the EU spectrum policy whilst bringing down networks’ capital and operational expenditure. Sensor networks and machine-to-machine communication systems emerging at the edge of networks bring about important architectural perspectives for the underlying network and service infrastructure. User-controlled (home) networks notably based on femtocells (and community networks) bring new architectural and management challenges.

Altogether, the proliferation of end-user devices, the heterogeneity of network types, the range of mobile and broadband demands, and the imperative for stronger security call for a reappraisal of the current Internet protocols and architecture.

Towards the Network of the Future

With the first call of FP7 the research areas of Broadband Access and Mobile communications were brought together. Now the combined Network of the Future area will provide a major contribution in three areas:

- Future Internet Architectures and Network Technologies, with target outcome of novel Internet architectures and technologies, and frameworks for flexible and cognitive network management and operation.
- Spectrum-efficient radio access to Future Networks, with target outcome of next-generation mobile radio technologies; cognitive radio and network technologies reducing the management complexity and enabling seamless service provision in a radio environment with a large number of heterogeneous radio access technologies; and novel radio network architectures enabling the innovative usage of licensed, unlicensed or unused radio spectrum.
- Converged infrastructures in support of Future Networks, with work in ultra high capacity optical transport networks based on photonic technologies and transparent core-access integration; and converged service capability across heterogeneous access.

This contribution is expected to enhance the positioning of EU industry in the field of Internet technologies and to reinforce European leadership in developing Future Network technologies for integrated wired and wireless networks. The projects will contribute to global standards and develop more and better Intellectual Property Rights (IPR) for European companies European.
Our Directorate

DG – Information Society and Media
The Information Society and Media Directorate General supports the development and use of Information and Communication Technologies for the benefit of everyone.

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http://ec.europa.eu/information_society

Directorate D "Converged Networks & Services"
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The directorate engages in research on converged networks and explores new possibility of development in Europe, considering economic and social impact.
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Further Information

CORDIS – Community Research & Development Information Services
CORDIS is the portal of research and technological development of the European Commission.

To find out more on FP6 and FP7 visit:
http://cordis.europa.eu/

European Future Internet Portal
European Future Internet is the central discussion forum for European activities on the theme The Future of the Internet.

For more information visit:
http://www.future-internet.eu

ICT Event 2008
Lyon 25-27 November 2008
Find out about this and other events at:
http://ec.europa.eu/information_society/events/ict/2008/

Unit AGENDA
Forthcoming events in December 2008
Visit:
http://www.fi-madrid.eu