FUTURE NETWORKS

The **way** ahead!

European Commission
Information Society and Media

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PART II: Bird Workshop: Business Innovation and Regulation Challenges 2009

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Foreword

In September 2009, the "Future Networks 4th FP7 Concertation meeting" took place in Brussels. As the Seventh Research Framework Programme (FP7) is now reaching to its mid-term, this was a milestone event, where flagship EU projects representing a broad range of stakeholders of the research community in the networking area were invited to express their views on the state-of-the art and the future perspectives. As part of this concertation process, a dedicated workshop was organised by the EU flagship project, 4WARD, around the business, innovation and regulation challenges.

The discussions focused in particular on different views within the research community on the design process of the Future Internet. Flexibility should be a key principle in designing the Future Internet, to avoid a new clean-slate approach every 10-20 years and to be able to react to unforeseen developments. A new Future Internet architecture open enough is needed to avoid prescribing the future from the current uncertainty on what the services and their new requirements will look like.

A common point was the need for a multidisciplinary research approach. Stronger scientific emphasis, where more basic research like mathematics is needed, should come in balance with the engineering-wise focus, enforced also with a more business-oriented approach. Academics, engineers, lawyers and economists should design together a Future Internet that combines research, business models and regulation.

There is a strong need for closer cooperation between networks and services, even putting in practise the concept of the «network as a service». Key enablers to this are the dynamic or the composed networks, virtualisation and, at the same time, a new distribution of intelligence in the network. We are moving towards an information or content oriented network, where we use semantic routing to find «objects» or inherent transcoding in the network to name just a few.

The future is more likely to be based both on optical networks and wireless mobile access. Therefore, some unsolved questions have to be answered as optical packet switching and optical memory while some new requirements such as the in-built mobility have to be taken into account.

The answer to the "Network of the Future", which will be more a network of networks, where no one size fits all and that allows polymorphic networks, seems to be based on virtualisation. It is an indirect and abstracter solution, which could allow both innovation and infrastructure sharing in the future communication infrastructure.

The rising of opportunistic networks, mainly at the edge, the bloom of the "Real World Internet" (RWI) and the "Machine-to-Machine" (M2M) communications bring the necessity of more autonomic and higher self-organisation in the networks to handle the complexity, the multiplication of the orders of magnitude and decrease costs. Cognitive networking is one example.

The «Green ICT» was addressed from different perspectives. On the one hand ICT is an energy saver when applied to other sectors, while paying attention to the difference between potential and real impact. On the other hand, improvement in ICT itself to reduce energy consumption is only at an early stage and can be much more progressed, from protocol design to components, optical technologies as an energy saver and info-centric paradigm as part of the solution, knowing that a small percentage of sites carry a rather high percentage of the traffic.
Finally, other important topics were tackled such as the governance role in Future Internet and the increasing importance of privacy, trust and security to validate the solutions.

Future Internet network technologies and architectures, radio access and spectrum management, optical and converged network technologies will be used in the coming years as fundamental building blocks, supporting vital services of our society such as health, environment, government, transport and education. This is why we need to strengthen our efforts and connect all the necessary resources in enabling the future networked society. We need to ensure the right conditions to allow the progress of our societies in a sustainable and inclusive way.

We still have great research challenges ahead of us. This report will certainly not answer all the concerns that could be raised on that matter, but it is for sure setting the scene for a fruitful debate. We hope it will bring closer the research community and the policy makers in defining new directions to be taken today, to empower our citizens and our economies.

Enjoy reading!

Rainer Zimmerman

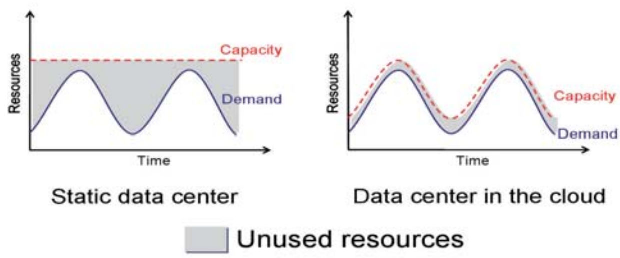
PART I

••• Future Networks in the EU Research Framework Programme (fp7)

Executive Summary

Future networks research, in combination with good governance, favourable legal frameworks and effective standardisation will support the development of new and innovative services, at all levels of the network value chain.

Future networks will support high bandwidth connections (e.g. fiber optics), sharing of resources (e.g. clouds, virtual networks), effective routing, accessible via multiple platforms, fixed and mobile, and truly supporting services for its users. Clean slate research on future networks is necessary if Europe is to push the boundaries in the evolution of our networks as it will inspire innovation. This is a precondition for playing a role with development of new services. Technology research is just one of the factors that will make the future networks develop and deploy. **In this area, a multi-disciplinary approach** *needs strong emphasis, both for technology development in itself, as for ensuring its useful deployment.* **People are central** *in such developments and all products and services need to take into account what users want. At individual level, users request for services that are easy to use, reliable, careful with privacy and affordable. At societal level, public interest developments are required, providing inclusive and green products and services.*



Some technologies, like those that make backbone networks capable of handling large volumes of traffic (e.g. fibre optics, optical switching), and those that enable a better use of the radio spectrum (e.g. cognitive radio) have less direct links to users. However, all technologies **need to take user requirements into account** such as the need to have stable, high bandwidth and seamless end-to-end connections.

The **integration of platforms,** including satellites, and increasing convergence of mobile and internet offers many new possibilities for services that, will be more and more based on **user profiling and context awareness.** However, as privacy requirements collide with those it is not clear yet how a balance can be found by which privacy is guaranteed up to a sufficient level and at the same time services do adapt to specific needs of whichever user.

There is a clear **need to go "green".** Whereas it is recognized that ICT is enabling dematerialisation, reduction of the carbon footprint in many other sectors such as the energy sector itself, and the transport sector, in particular, the energy use by ICT equipment and services represents about 8% of electrical power in the EU, and about 2% of carbon emissions[1] . When we would want to rely even more on ICT in the future, it is crucial to do it in such a way that we can afford to keep the switch "on".

Much can be done to make ICT usage more environmental friendly. Already today, mobile devices such as laptops and mobile phones are relatively energy efficient, but the non mobile devices still need to be improved in that respect.

For instance, in the field of communications, **adding the energy efficiency check** as a factor of meaning in the development of new products and services will bring quickly a move towards less energy use and materials. Already today we see that new mobile cellular transmission sites are much more energy efficient than the traditional ones. It may also lead to **a scalability of usage of energy** which is not possible today.

Using the cloud and virtualisation, is another way of making more efficient use of resources. When opening up networks to use them as

[1] *C(2009) 7604 – Commission Recommendation on mobilising Information and Communications Technologies to facilitate the transition to an energy-efficient, low-carbon economy*

clouds, much less material is needed to serve all, and energy can be used more efficiently. If the energy consumption of ICTs stays the same and ICT deployment continues to grow, we may face energy problems earlier and bigger than expected: it would be a non sustainable trajectory and better ways to reduce energy consumption by ICT itself need to be explicitly taken into account in future developments.

Obviously, the Future Internet will be dependent on a high bandwidth, stable and resilient backbone. This backbone will be fiber, and fiber-optics will play an important role. This backbone will support a cloud of access services, mobile and fixed-line. An increasing amount of services will be integrated in the networks, together offering platforms for specific services to users. Whereas there is more and more intelligence in access devices such as computers and mobile handsets, also the network itself becomes more and more intelligent.

In essence, the future internet is expected to be:

- Open, flexible and participatory
- Information-centric rather than bit-centric (at the network level)
- Predictable to allow critical and machine-to-machine (M2M) applications to operate reliably
- Secure and that leaves the generativity of the network intact
- Low cost to access
- Small carbon footprint

Technology-wise solutions need to be found to support flexible and robust sharing of resources, fiber-optics technologies for high bandwidth switching, efficient routing (e.g. generic path) and quality of service enabling and information object oriented security.

Several common trends can be observed in the networking research area towards the future:

- The optical technology has a very important role, although aspects like optical packet switching and optical memory remain unsolved
- The ICT energy consumption and the ICT solutions for energy saving are areas where major improvements are possible
- The governance is an aspect to be tackled with in parallel to technology development
- The «Network as a service» requires closer cooperation between network and services players
- Self-organisation and autonomy to manage the complexity of the networks is needed and cognitive radio is one example
- The future networks will be opportunistic networks, mainly at the edge
- The virtualisation allows for polymorphic networks, network of networks and infrastructure sharing
- The content distribution requires optimisation and the info-centric paradigm could be one solution to protecting user privacy and also to energy efficiency, knowing that 10% of the sites carry 50% of the traffic
- The mobile cloud computing requires a more comprehensive research approach
- The role of privacy, security and trust is increasing but should not be over-emphasised; the focus should be more at a regulatory level than technological development
- The Future Internet also includes concepts like the Real World Internet (RWI) and machine-to machine (M2M) communications, in which objects will no longer "just" be connected to the Internet, but they will become the Internet.

For creating an innovative environment, further **legal harmonisation** is important to ensure that new services can be developed for Europe as a whole. In particular, data protection and usage of radio spectrum are important in this. By having clear processes and fair decisions towards **standards,** industry will be much more inclined to continue to invest in innovation, as what they develop may actually work out in the larger market place. In this it is noted that the standardisation environment begins to be quite complex: for serious standardisation efforts, we need to invest heavily in people that visit and meet with one or more of the many standardisation institutes. Conversely, again this is one of the areas where European funded concerted actions (e.g. Networks of Excellence - NoEs) can help in sharing the burden of the standardisation effort.

Setting rules, as such, on ICT use and the Internet is difficult as it cannot be done by any single nation. In order to keep the Internet open, end-to-end, stable and accessible for all, we are dependent on governance processes that take place in a global multi-stakeholder environment. Whereas national governments have to face their citizens when things go wrong, on an international level governance issues are under the coordination of the Internet Corporation for Assigned Names and Numbers (ICANN), which is carrying out its task following a so-called "Affirmation of Commitments"(AoC)[2]. ICANN is to be transparent in its actions, and accountable to the world-wide Internet community. It is to ensure through its processes security, stability and resilience of the Internet. And it needs to promote competition, consumer trust and consumer choice. Reviews will take place on a regular basis to ensure transparency.

Useful and important to research in the network area is to continue **"clean slate"** research. While it would be impossible to put the current Internet aside and replace it with a new one, it is widely recognized that the ideas arising from clean slate research inspire new network innovations at all levels, and are such an important contribution to the evolution of the Internet. There is not one single network: the future network, like today, will be a network of networks. This means that attractive clean slate applications may well find their way to deployment, already today.

Yet rather than trying to prescribe the future, the door to the future should remain open, by contributing with further innovations that support the evolution of the Internet.

Economic and Societal Views[3]

In line with Maslow's priority of needs, an order of priority of needs for Internet scale-up – both for users and service providers has been developed. First of all, coverage needs to be ensured. This includes functionalities like accessibility and connectivity, which requires the allocation of address space and routing tables, as well as the "last mile" access (wired and/or wireless). When that is basically there, capacity begins to matter, both the backbone and radio access. Elements like layer rationalisation, fibre-optics and traffic prioritisation are significant.

Figure 1: Hierarchical model for Internet scale-up

Beyond capacity, quality begins to count. Is availability and quality predictable, can one really count on it? Is there extra capacity to ensure that in peaks the service is still good, wherever we are? On top of that features like security, trust and control come to tackle issues like spam, Distributed Denial of Service (DDoS) Attacks, taking specific measures to ensure privacy and being able to establish identity. At the basis of this are engineers that design systems, and business managers that deploy it. But there is also a clear role for law makers and government, to create an environment in which this can thrive without too much risk for those deploying and/or using it.

Increasingly, internet traffic is moving over to wireless: in absolute value, the traffic goes up very fast, yet the volume share of computer originating traffic is growing as well.

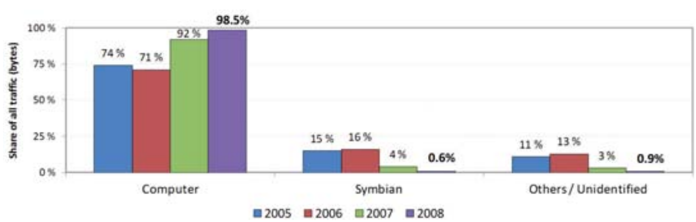


Figure 2: Traffic by Mobile Device Type - Finland

While recognizing that the volume of computers has grown, comparatively as well, the speaker expects that the volume share of mobile will

2 http://www.icann.org/en/announcements/announcement-30sep09-en.htm

3 *Based on the intervention of Prof. Heikki Hämmäinen, Helsinki University of Technology*

grow again. Either way, the point is that mobility needs to become an integrated part of the solution in the architecture.

In terms of payment models, the flat-rate preference is strong among Japanese users (Mitomo et al 2007). This is an opportunity for providers, as you can ask for higher rates if your service is experienced more. It has a fundamental impact on the architecture of wireless access, and is likely to get broadly adopted, also for wide area wireless networks.

However, energy costs are high and may go up when usage goes up, even if the rates don't change. And if Internet innovation slows down this might eventually become a hurdle for the "flat rate model" as well and might lead to introduction of charge-for-use again.

At the moment, memory is getting relatively cheaper than transmission and processing. This may result in the network becoming the major bottleneck again, and back-up principles may be changing, as well as the way content is spread (might be on user devices already, upon sale). In the Internet, this may lead to new cache architectures. This requires a big role of access providers.
On a framework of Future internet, scenarios result from the consideration of two streams of uncertainty:

- The network structure (one network vs. fragmented network)
- The openness of content, applications and hosts (open vs. closed)

The scenarios are important to link together the technical architecture and the business architecture.

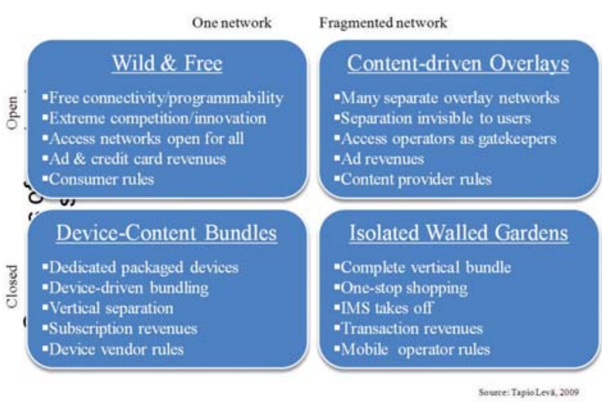


Figure 3: Future Internet scenarios

Still work-in-progress, an Internet Society (ISOC) perspective on Internet evolution[4]

The Internet has not reached the point of completion. It is still holding, it is not perfect, and it keeps on expanding, so there are still a lot of things to do, a lot of room for improvement and change.

Already 40 years ago, convergence of television and telecommunications was foreseen. What was not foreseen at that time is the development of the platform, the participatory network that goes much beyond information delivery, with uses that were unique. This has developed into the "Internet model". This term embodies a common set of operating values shared among many of the key communities and organisations that have been central to the development and ongoing evolution of the Internet. It includes support for:

- Open, globally interoperable technical standards
- Freely accessible processes for technology and policy development
- Globally distributed responsibility for technical, management, and administrative functions
- Transparent and collaborative governance

Continuing to support this model is a necessity to keep the internet growing, stable, and open to all.

Today we recognize the successes of the Internet, and we take pause to identify shortcomings and issues in the collaborative internetworked technology platform. It is too easy to say "the Internet as a platform is not evolving to meet needs". The challenge is to see how we can transform it in such a

[4] *Based on the intervention of Ms Leslie Daigle, Chief Internet Technology Officer, Internet Society (ISOC)*

way that it may support new developments for the next 40 years. What is needed? What is the common infrastructure? Evolution of the platform itself is less visible, but it is really an evolving foundation.

Today, the future internet is more secure, better secured, yet has also the danger to develop towards "walled gardens" unless we manage to include this in the basic building blocks in the platform. We need to ensure continued growth and reach to users, both in the developed world and in parts of the world where internet usage is still in a less developed phase. We need to work on:

- Continued growth of reach of Internet (users and uses)
- Openness and ease of access (for new users, new networks and for new types of devices and networking)
- Open standards (including access to the parameter resources, such as domain names, IP addresses)
- Unfettered innovation (for applications on the network and applications of the network)
- Global in all dimensions (not balkanisation or walled gardens)
- Resilience, robustness and reliability

Open standards are essential and unfettered innovation will drive it. It all needs to be seen in a global context. From the ISOCs perspective, the evolution of the Internet develops through continuous cycles of collaboration between R&D, open specification and deployment. Pieces of the platform are under evolution in one or more of the areas.

Research for the internet of the future is imperative. It should explore the tough questions: thinking in the long term. The Internet does not evolve through research alone, but also through implementation experiences that sometimes lead to very interesting new insight that again may inspire research. The future of the internet cannot be limited to a small group of minds, and its development should involve all brains in the world.

The EU Research Communities Perspectives

EIFFEL Think Tank[5]

EIFFEL has been focusing some grand debates that go beyond single technological claims or techniques towards Future Internet Architectures. A first step in refining the discussion around this topic was the "agreeing on disagreements" approach which will help EIFFEL to provide a different view and added value for the research community in the networking area.

The major questions to tackle turn around several disagreements:

- The end-to-end design principle (precisely what additional caveats does it need? Is it broken?)
- Evolution vs. Revolution
- Design for tussle vs. Gratuitous indecision
- Single architecture vs. Several interconnected architectures
- Protocol adoption by incentive vs. Imposed by regulation

Designing a large-scale system is more than a technological challenge. Do we need to approach this as a joint design problem that is technological, economic and legal? In such a challenge it is essential to make sure that the players understand each other, across expertise. In addition, a clean slate system is virtually impossible to realise and that is the key dilemma in developing a large scale design. However, it is of great importance to have a positive dialogue and the aim to build a sustainable solution that continues to be open to innovation.

There is a need for evolution as a gradually developing process: in this it is important to recognize that scope and dynamics ("speed") of change is getting faster, and in some ways even more random. Therefore we need to think about our processes, how we design our solutions. What are the right processes

5 *Based on the intervention of the EIFFEL project representative, Prof. Petri Mahonen, RWTH Aachen University*

for driving innovation? The current processes are still old-fashioned, starting with the use-cases. However, when working on a global scale, it is difficult to truly catch the concerns and interests of billions of people. One of the requirements for future projects should be to have such a design process that this becomes the platform for evolution itself.

Does the Future Internet influence the way society will be governed or will current governance forms influence the shape of the Future Internet? There is no full agreement on this, and trends go either way. Examples of this are the rise of Twitter, and the on-going debate on IPR and copyrighted material. It would be great if there could be a value-free architecture or set of solutions for this.

We need to find a balance to address immediate problems as well as potentially missed opportunities. This requires integration of rational and empirical research styles, and a continuous dialogue with current operations. The empirical research cannot expect to be "representative" in general. Google testified that they are not worried about anything, the Internet will evolve: their operational problems were elsewhere. A multidisciplinary approach is necessary.

A balance needs to be struck between a scientific approach and engineering approach. In the past, it has mostly been dominated by practical engineering, yet this may not do towards the future anymore, as complexity goes up. Yet it should remain practical at the same time.

'Experiments', 'Big Science', and 'Reproducibility' are three key issues to be taken into account in developing the future research agenda. Experimental verification is very important for societal innovations, and sharing of findings will stimulate and inspire the emergence of new findings. This needs to be stimulated, and the Commission can (and does) play a role here.

The biggest danger is to set out the design of a future – for today. There are great challenges on making interdisciplinary approaches. Not everything can be or should be solved by technology, yet at the same time it should not be left to regulation or market, alone. Not everything should be protected and locked, as this will kill innovation and interaction. The security problems should not be overemphasized.

A more scientific approach with regard to Future Internet and Future Networks is needed. Bringing in more basic research to complement the engineering approach is one concern to be addressed, together with a business oriented multidisciplinary approach, involving also economists and lawyers. In support of sharing information and bringing together a mix of players from various fields, EIFFEL launched a platform on line, based on the Wikipedia model, called FI-pedia and which is open to all for contributions and feedback on future internet views.

Euro-NF Research Agenda[6]

Our society experiences a movement from a homogeneous networking paradigm towards a service/application aware and a dynamic interconnection of a wide diversity of heterogeneous networking paradigm. Transport technologies are often not visible anymore, and in the global architecture we move more and more to semantic gateways, instead of addresses and routers. Examples of new gateways include mobile phones connecting the personal networks and wireless sensor networks (WSNs) embedded in our cloths to the global network and mobile robots allowing the connection of selected active RFIDs clouds.

Towards composable networks

The concept of Service Oriented Architectures will apply to larger systems, encompassing the future networks. In a loose definition, a service component is an autonomous element that provides a function and that has the required interfaces to be integrated with other autonomous elements in order to build a service. Following this definition, a network can then be considered as a service

[6] *Based on the intervention of the EURO-NF project representative, Prof. Günter Haring, University of Vienna*

component, leading to the concept of "network as a service".

In a recursive way, the network of the future can be seen as the composition of various heterogeneous networks, each of them being considered as a service component, which itself is composed of service components of finer granularity. In particular, networks will become "dynamically programmable".

Increasing capacity requirements in core networks

High-performance networking, including optical switching for instance, is becoming again relevant after several years of drowsiness. Moreover, new inter-domain routing paradigms will emerge and intelligence will be introduced through concepts like semantic routing and the separation of identification and location. The combination of the new optical networking paradigms and semantic routing will reshape the present core network architectures.

Rise of ubiquitous, context-aware and composable services

Whereas the issue of ubiquitous, context-aware and composable services was discussed in the research community for a long time, the time has come to move from slideshows to deployment. Personalized, location and context aware services will become ubiquitous, accessible through a large diversity of access technologies, and globally mobile (mobility of services across any type of borders). Service composition will become the rule, and services and network architectures will be jointly designed based on new paradigms such as publish and subscribe. Content distribution will be optimised through a better integration within the network, a better distribution of intelligence among the end-to-end chain of value, and the active and monetised participation of end-users.

Innovation is happening mostly at the edge

The research community observes a more polymorphic bundle of network paradigms, ranging from a set of networked terminals to spontaneous and opportunistic edge networking. Disruptive development at the edges already started with solutions such as wireless mesh networks, vehicular networks and disruption tolerant networks. With that we see a ring of self-organised networks, based on heterogeneous networking paradigms, in some cases cooperating with the infrastructure.

Boundaries between virtual and real world are fading

The virtual environment will merge with the real world, as the real world collides with the new generation of WSANs and RFIDs. Virtual reality, augmented reality and the 3D Internet will facilitate this merge. The «Internet of Communication Things» will become the «Internet of Cooperating Things», in which objects will no longer "just" be connected to the Internet, but they will become the Internet. The next generation of the Internet of Things will be based on coordinated and cooperative interactions among things, providing an integrated experience in the context of an ever increasing diversity of services.

From the Internet of things towards the real world Internet

We will no longer talk about the Internet of information, the Internet of entertainment, the Internet of communication, the Internet of things or the Internet of energy to name just a few, but about the fusion of all of them into the real world Internet, which will be "green".

All together we will see the development of new services and a better integration of networks and overlays. Part of the functionality provided today in overlays will move into the network itself, and become part of the "infrastructure". Examples of such functionality that are expected to move into the network itself, for the short and midterm, are content distribution, support of mobility and transcoding. In general, the intelligence of the global system will be distributed in different ways between the network and the overlays and this distribution will change depending on location and time. In order to achieve global optimisation new paradigms for content distribution will develop. In this we will see more and more of use of customer located equipment and participation in production by end-users.

In order to be able to make good use of resources, and to master the ever increasing complexity self-organisation will play an increasing role, partly replacing centralised policy based management and control. An example of this is the recent development towards cognitive radio for advanced spectrum sharing approaches. Basically, this is based on looking for “empty slots” and when the primary user for that slot arrives, you move on to a next slot.

The required implementation flexibility will be introduced through virtualisation and programmability. Started with virtualisation of large network equipment virtualisation and data centres, increasing amounts of grid computing will be extended to small devices (e.g. terminals), links and other type of resources (e.g. sensors).

The implementation of a system like the Internet of the future may not be based on value free assumptions. There are complex governance challenges, in particular that the Internet Governance of the future should be decentralised, diversified and adjusted according to the special needs of given issues globally or locally. Global Internet Governance of tomorrow should be a federated system where all stakeholders - governments, private sector, civil society and the technical community - will be involved in their respective roles.

More thought needs to be given also to theoretical considerations with invention (engineering) and discovery (scientific). The mathematical skills are needed for considering qualitative research, especially that in the development of a vision towards the Future Internet different paradigms in the core and in the edges will be faced.

evolution. The main forces to move towards the «Network of the Future» are «market push» and «technology pull».

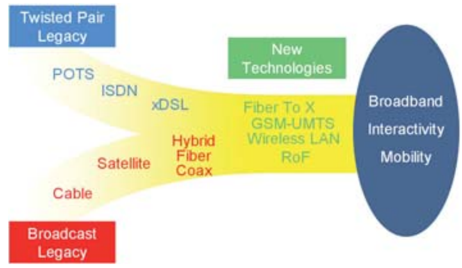


Figure 4: Roadmap towards the Network of the Future

The evolutionary path towards the broadband connectivity can trace its origins from two sources. The traditional telecommunications route is from the twisted pair legacy supporting POTS, XDSL and now ISDN. The Broadcast route is from cable, satellite and hybrid-fiber coax systems. Both these approaches now support broadband communications, each delivering fibre closer to the user, and capable of supporting GSM-UMTS and wireless LAN connectivity.

Broadband access and market is quite different around Europe, for instance if we look at current installed base and population density. The network is likely to develop towards optical in the last mile.

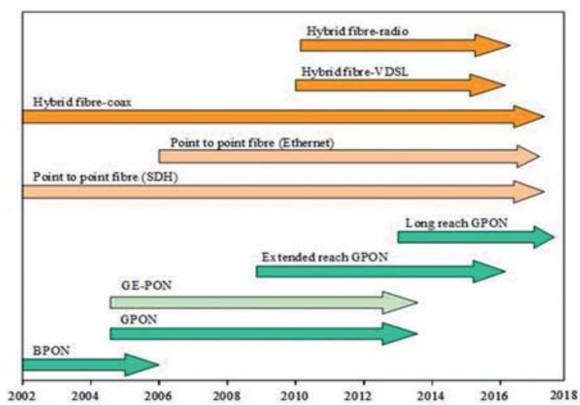


Figure 5 – Deployment of network access technologies in Europe

BONE Research Roadmap[7]

BONE considers industry, standards, research, regulatory framework and application end users as the drivers in the Networking

BONE considered several access scenarios, taking Sweden as assumed market. When considering the services people would want in the future, HDTV is high on the agenda, and high speed internet access is essential.

[7] *Based on the intervention of the BONE project representative, Prof. Mario Pickavet, Ghent University*

Another bandwidth-consuming application could be storage area networking. With all these high bandwidth requirements (~45 TBps to ~450 TBps per country) the following key challenges need to be addressed:

- Scalability
- Flexibility and reconfiguration
- Quality of service (QoS)
- Interoperability
- Management issues
- Power consumption

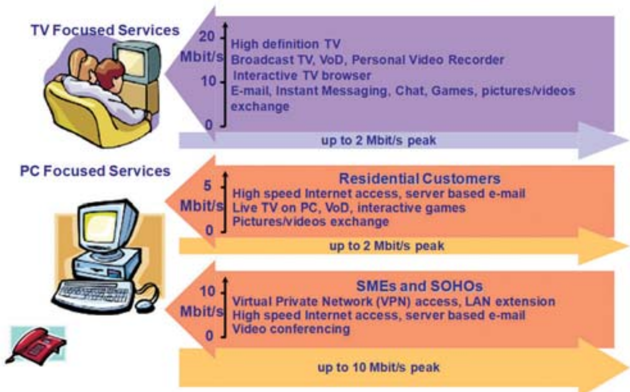


Figure 6: Future services and bitrates in Sweden

Power consumption of different types of equipment today is one of the biggest challenges. Already in 2007, the power consumption of ICT (including TV) was about 4% of the global electricity consumption, moving towards 8% in 2020.

At the same time, ICT solutions like video conferencing can lower the footprint of other sectors. And for ICT usage there is much room for improvements. One example is at equipment level: desktop power consumption is still today much higher than that of a laptop with similar performance. Other opportunities can be found at component level, network paradigms and by use of policy and regulation drivers. It will be necessary to consider the energy impact of different network paradigms when developing new networking concepts.

Challenges range from the energy consumption of network equipment and terminal equipment (e.g. FTTH) to material load of equipment itself (for instance with equipment replacement) and specifically the use of scarce and hazardous materials. Both access and core networks require higher bandwidth, hence optical networking is the way forward, and it has to ensure several functionalities:

- Provide end-to-end connectivity and be highly dynamic
- Simple with low CAPEX and power efficient
- Provide the common infrastructure for all the available services and provision for mobile and fixed access
- Flexible and provide a variety of services that each user can choose
- Scalable, flexible and interoperable
- Controlled in an efficient and uniform way

Transmission will move to higher speeds, and we will see an increased deployment of 40 GBps and optical switching. For the latter, challenges remain on optical burst and package switching. In terms of the highest important challenges to tackle, after electricity comes interoperability, and finding effective ways to come to standards. For dealing with electricity, it will be important to get the energy network "load" sensitive, and there are already today some initiatives that look into the possibility to move towards variable use of energy, depending on behaviour. Today, it is still hardly possible.

Newcom++ Research Agenda[8]

A typical research vision is simple, and can be user-driven (man to moon) or science driven, requiring solid state investments. In the first case, politicians can play a bigger role; in the latter scientists are needed. The project distinguishes three types of visions:

- Type 0 –man on the moon
- Type 1 – dealing with scientific hurdles towards realizing type 0
- Type 2 – scientific vision of which impact is still to be determined

[8] *Based on the intervention of the NEWCOMM++ project representative, Dr Jossy Sayir, Cambridge University*

Newcom++ is working on TYPE 1 visions like *Wireless Internet* and *Green communications*. It is considering how to deal with the practical challenges that emerge when pursuing those visions. For the realisation of Wireless Internet we need to deal with the fact that with today's technology, limited cellular systems with minor relaying extensions are possible. The scaling laws for wireless networks are still a major hurdle: some progress has been achieved by replacing the interference-limited PHY layer by multi-user processing, but much remains unsolved. In addition, it is noted that advances in Network Information Theory and Multi-User Communications are necessary, and approaches are pursuit by the network. With regard to green communications, reducing the use of power as much as possible is as important as for computing.

Examples of Type 2 visions (technology originating) are *Wireless PHY Layer Security*, where scientists' ability to ensure secrecy and the ability to eavesdrop have been interchanging possible over time and *Network Coding*, like the ability to have nodes in a network to encode packets and spread them over the network, instead of routing packets. This would lead to clouds of information drifting across networks instead of packets. In terms of wireless applications, we need to address the limits between multiuser communications and network coding. In a few years the business community will find it is possible to establish a perfect provable security in wireless communication links.

In addition, the best practices for long term research investment are stable funding, research limited by ideas rather than resources, problem-driven research, support and a clear link to industry.

The Satellite ISI (Integrated Satcom Initiative) Research Agenda[9]

Europe is in the process of becoming a global power, competitive in satellite, by establishing a Global Space Navigation capability and establishing a Global Monitoring capability. In order to be able to fully respond to major societal challenges such as security threats, disaster management and ubiquitous access to ICT, Europe needs to develop and operate a Global and Secure Communication Infrastructure. Over recent years, activities in Europe have been too dispersed, and therefore costly and with too many interoperability problems.

ISICOM stands for Integrated Space Infrastructure for Global Communications and will realise a secure communication capability complementing Galileo and GMES, as an integral part of future advanced «network of networks", fully compatible with the Future Internet principles. It will use advanced generation GEO satellites with high data rate telecommunications capabilities (including inter-satellite links) for this purpose.

In this frame, different user domains need to be addressed. In the security and defence domain for instance, the user community is highly differentiated and include civil and defence governmental institutions, private companies and individuals European citizens. The defence capabilities need to be integrated with civilian ones provided by the police, tax and customs officers, judges, administrators, aid providers and human rights specialists.

Underlying the ISICOM concept are four different levels of convergence, namely at terminal level (one device fits all), service level (convergence of traditional fixed, mobile and broadcast services as well as service personalisation with location based and context aware functionalities), transport and network level (thanks to a common and standardised set of protocols) and at the access layer thanks to the harmonic coexistence of different access technologies, with different characteristics in terms of data rate, coverage, availability, performance, and employed frequencies.

ISICOM recognizes the need to implement an innovative roadmap when it comes to deployment of a fully integrated network, embedded with terrestrial backbones. It needs to be fully coherent with the aims of the European Space Policy and needs to pursue an R&D and

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[9] *Based on the intervention of the sISI project representative, Mr Vincenzo Fogliati, Telespazio, also Chairman of ISI, the European technology platform for satellite communications*

innovation path, to build the complete system that is to consider all user requirements and fill the remaining technological capability gaps including large aperture antenna (as this is the only way to enlarge useful bandwidth trough multi-spot coverage and frequency reuse), optical links with bit rate higher than 20-30 GBps and on board switch, which will be capable to connect all spots with each other and with the optical link, and will be based on IP protocol in order to permit self routing of each packet.

As the Future Internet must be *always on, really globally available "anywhere-anytime"*, satellites will be a necessary component. The Internet becomes a fundamental service that communities (both developed countries and developing countries) use and rely upon. Any communication system requiring ubiquitous access to the Internet, must consider satellite as a part of its portfolio of bearer technologies. No truly ubiquitous worldwide connectivity can be achieved in absence of a satellite component: an internet capable to provide same performance and services to users located anywhere around the globe. New satellite systems can improve the provision of ubiquitous broadband connectivity, and mobile and transportable terminals will effectively support a wide range of applications and services that thus become possible.

Future Internet must also be capable of *assisting society in emergency situations*. Capability to be rapidly deployed is important, offering a quick response to customer needs. Most of emergency applications and services rely on continuous communications, which can only be achieved by the integration of a range of communications technologies. In many of these applications, satellite communications, whilst not replacing the need for terrestrial services, can complement them and lead to a superior overall solution.

Future Internet must obviously be *trustworthy* because it must support the exchange of a large and heterogeneous set of information among people in their daily life, which includes both business and private interests and it must also be used for public interest. Trustworthiness must imply different concepts, and among them security, content reliability, user safeguard and preservation. Satellite systems can assume a very important role because its infrastructures are easy to be protected and all the techniques or algorithms needed to protect data access and reliability can be developed on purpose to match the target requirements within the satellite segment. In addition, the network management is centralised and under control of the operator, the access to the network is strictly under control of the NCC manager, and technology and standards are mostly proprietary.

Future Internet must be *seamlessly integrating all available networks,* terrestrial, wired and wireless, and satellite links, as to be able to offer the fundaments for supporting any kind of service and application. A tremendously increasing number of users are asking not only for high-speed connectivity, but also for ubiquitous and "on-the move", seamless connections. The final goal is to guarantee a seamless service provision over a multi-technology multi-network platform, particularly in the mobility scenarios. In this scenario broadband satellite links bring several essential benefits to the network because of their many advantages: global coverage, bandwidth flexibility, reliability and multicast capability. Hence satellites must be included in the Future Internet architecture, internet protocols should be adapted to make it possible.

Future Internet must be an *environmental-friendly* system, being able to reach the carbon neutrality objective in CO_2 emissions (power consumption) and using as much renewable energy as possible (power source). The satellites' energy source is typically the solar energy, thus contributing remarkably to the carbon neutrality objective.

In essence, from a satellite perspective, the following issues should be considered for the future research agenda:

- Smart and efficient spectrum and resource management for increased spectral efficiency and 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, to ensure maximum market acceptance
- Exploitation of higher frequency bands (e.g. Q/V band)
- Increased coverage and global availability of Future Internet services, even in critical emergency scenarios

e-Mobility Research Agenda

e-Mobility and X-ETP Strategic Research Agenda (SRA)[10]

The main objective of the European technology platforms (ETP) is to draw up a strategic research agenda including a long term vision on mobility. It is important to analyse both the technology and the non-technology barriers to development, deployment and use of technologies and focus on specific applications.

Currently, there are over 4.1 billion mobile phones worldwide, which is significantly more than the 1 billion wired Internet terminals. A significant portion (~20%) of these phones provides an IP service, and therefore Internet capability, through the 2.5G and 3G cellular services. Within 4 years, all mobile phones are expected to be Internet-capable devices. In addition, sensor deployment is just starting but expected to grow significantly over the coming years, with some estimates of 5 to 10 billion units by 2015.

In this rapidly growing on-line environment, the network we design now should be adaptable, as we cannot continue to re-design the networks every 10 years. Core to the vision for 2020 is the improvement of individuals' quality of life, achieved through the availability of an environment for instant provision and access to meaningful, multisensory surrounding. In that, the focus is on simplicity, efficiency, and trust for end-to-end integrated solutions.

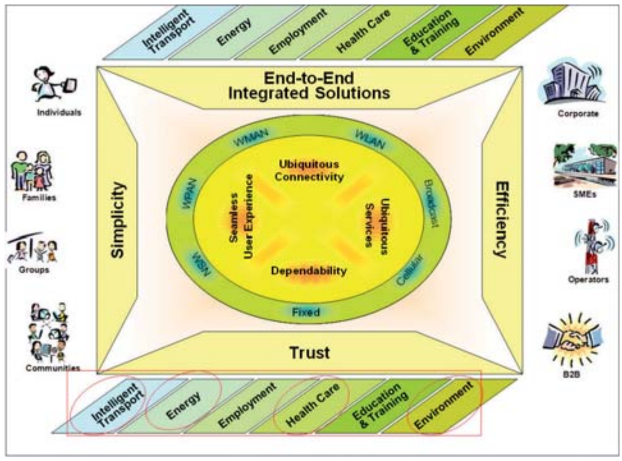

Figure 7 – Landscape of vision on e-Mobility

The challenges to overcome when developing an e-Mobility vision have to do with technologies and costs (multi-parameter), managing complexity, and achieving efficiency in use of spectrum space and energy. The future will be one, in which people are likely to have multiple devices, and in which we will see increasingly device to device and peer to peer communications. We will no longer talk about ABC (Always Best Connection) but about ABCs, simultaneously and in parallel.

Networking will become increasingly intelligent, self-organising, and offering Quality of Service (QoS) management, which will lead to energy, spectral and operational efficiency. From networking of networks, the focus will move towards service networking, increasingly integrating the physical and digital worlds in 3D applications and services. These networks will need to be secure and dependable, and pay high attention to privacy and trust. Delivery of service will be ensured via a variety of modes, video communications will be "normal", and personal broadband communications will be possible everywhere, at home and on the move. Challenges and constraints to overcome include

[10] *Based on the intervention of the e-Mobility project representative, Prof. Rahim Tafazolli, University of Surrey*

dealing with the small screen, radio spectrum and energy limitations, and the dependency on Internet protocols and architecture.

Future priorities for research are short (and even shorter) range communications (that do not always require a backbone network), management of complexity and efficiency (in particular spectrum and energy use). In its basic set-up, the «Network of the Future» communications are expected to follow the same model as other utility services like gas and electricity. The user will be central, and privacy, trust and security will be of great importance.

e-Mobility and Green Wireless Communications[11]

Sustainability is a key aspect of any future research agenda. Also in ICT, and even more specifically mobile communications, so far energy efficiency has been hardly taken into account. Emphasis was on efficient use of the spectrum and capacity of throughput. Mobile operators are already today among the top energy consumers. For instance, Telecom Italia is currently the 2nd largest energy consumer in Italy, and energy consumption of mobile networks is growing very fast. Worldwide, ICT already consumes about 10% of electrical energy in industrialized nations, and power consumption of ICT is currently rising at 16-20% / year.

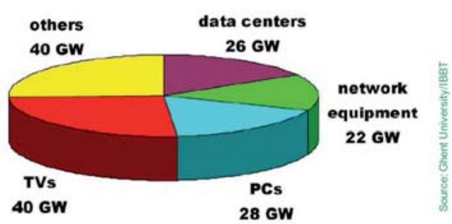

Figure 8 – Global energy consumption by ICTs

A positive aspect is that already today wireless communications are used extensively to save energy in other industrial sectors (like teleconferencing). And there is a lot of potential in saving energy consumption. This energy savings will be mostly found in the networks, not the devices. NTT DoCoMo has calculated that, for 52 million subscribers in 2006, the energy consumption of their network per mobile user per day was 120 times greater than the daily energy consumption of a typical user's mobile phone. At the moment, energy consumption in the networks is hardly scalable. 10% of the stations handle 50% of the traffic and all stations use equally much energy.

In mobile networking, energy consumption is growing much faster than in the rest of the ICT industry. This has to do with the growth of internet usage by mobile subscribers, the rapid traffic growth and build-up of broadband coverage, and the fact that mobile communications replace fixed communications in many areas.

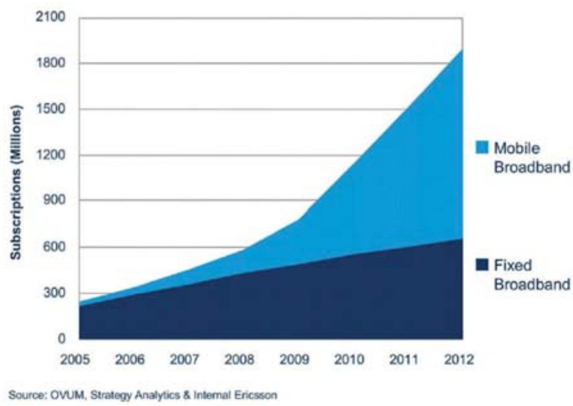

Figure 9 – Mobile vs. fixed broadband subscribers

A first gain has already been made. Modern cellular transmission sites are already much more energy efficient than "traditional" ones. Much more will be gained by scalability of energy consumption. It would make sense to assume energy efficiency as one of the key metrics for innovations in the mobile networks.

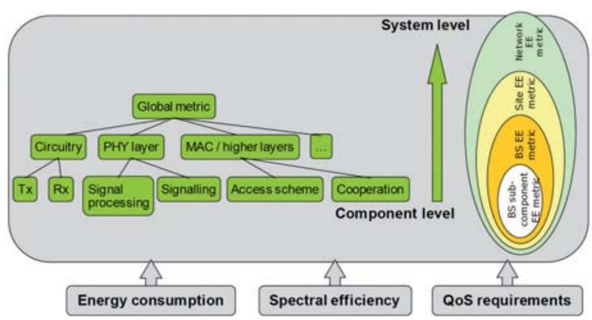

Figure 10 – Energy consumption metrics in the light of overall requirements

[11] *Based on the intervention of the e-Mobility project representative, Dr Laurent Herault, CEA – Leti*

Metrics should be defined to measure energy consumption (e.g. Watt-Hour or Joule) on component, node and system and network levels, in relation to delivered QoS and system spectral efficiency.

Towards «Green Radio» (i.e. energy efficient) the following aspects can be considered:

- Technologies and components: power scalable transceivers, power control on component (front end and system level) and adapting matching networks
- Radio Interface techniques: including base station power adaptation, introduction of "sleep mode" and associated signaling, transmission mode adaptation, dynamic load adaptation, and cross layer optimisation
- Application of innovative radio transmission techniques: MIMO, adaptive antennas, coordinated multipoints and advanced retransmissions.

Green networks, in their design, will be set up not only to serve high load efficient operation, but also for low and medium load conditions. For this deployment scenarios include optimal cell sizes, introduction of a mix of cell sizes, hierarchical deployments, multi-RAT deployments and new relays and repeaters. Management algorithms will include coverage adjustment, capacity management, multi-RAT coordination and base station sleep mode instead of "always on, on a level able to deal with high capacity demand". RRM algorithms will include cooperative scheduling, interference coordination, joint power and resource allocation, and a growing emphasis on energy efficiency next to the spectral efficiency.

Possibly even more efficiency can be gained by developing and adapting more disruptive approaches, including multi-hop transmission, use of ad-hoc networks, direct terminal-terminal transmission, cooperative multipoint architectures and adaptive backhauling.

ICT can help society and has the potential to reduce society's CO_2 emissions (carbon footprint) by 5% to 20%[12] and is a cornerstone, a key enabler of dematerialisation towards a low-carbon economy with significant energy savings.

e-Mobility and Future Mobile Internet[13]

The future is mobile, which becomes apparent when we see that already today many more mobile devices are in use than fixed stations. The internet was not set up to support mobility, yet mobility and Internet are rapidly converging.

Therefore we have to prepare for all kind of new demands, including scalability (many more), reliability (counting on connection), context based services (geographic as well) and … all mobile. Mobile networks deal with scarce resources, so efficient resource sharing is a necessity. However, there are many things that keep players from working together, including conflicts of interest between players and groups, which need to be addressed. Roles may also change and even users may become operators.

A major challenge is that there is a high information demand, and information sharing among nodes, networks, providers and users or between services and network elements. Any disruption of this would be most unwelcome.

A research priority is to create a platform for collaboration on the technical level. We need to create an environment in which dynamic formation of coalitions becomes more likely. Static and offline agreements are often not flexible enough for this purpose. We need built-in incentive models, accountability, reputation on network layer and a very explicit calculation of benefits vs. cost. Information sharing and cooperative decisions will underpin this, and needs timely delivery of information for decision-making.

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12 *See GESI/Smart 2020 report, 2008*

13 *Based on the intervention of the e-Mobility project representative, Dr Tanja Zseby, Fokus*

For this, lessons can be learned from other collaborative environments.

Privacy will be a key factor if we want acceptance of clouds. This will require safe storing of data and user-controlled privacy-levels, and a balance needs to be found with information demands for context-aware services. Next to technical and process solutions, self-regulation and regulation need to be considered.

To enable and emphasise self-management and self-protection is also needed, involving the users (as they will decide who will survive in the cloud) who should have real choice. This pushes competition and innovation. As regards the standardisation and the regulation, a push towards global standards is needed and a focus on technical (non-political) reasons to stimulate innovation and competition while protecting values. Future internet assessment methods should be defined with assessment criteria that would help players to move ahead with sufficient trust in doing so in a sensible way.

In essence, there is a need to push the mobile – internet convergence, in which it is critical to consider explicitly the demands of mobile world. We need to support the emergence of mobile clouds, which requires cooperation, and involvement of the user. The latter requires further embedding of self-management and protection, underpinned by privacy preserving technologies. It is important to agree on Future Internet assessment methods: what is important towards Future Networks, and how do we measure the potential contributions of new innovations.

e-Mobility and the "Mediation Bus"[14]

The end users profile has dramatically changed over the last decade, and in 2020 it is expected that a critical mass of elderly people with different needs and expectations will be active users of Future Internet. When accepting that the future developments will be user based, the realisation of the uniqueness of end users brings to the foreground diverse demands for Perceived QoS (PQoS) and Experienced QoS (EQoS) that subsequently affects the handling of Network QoS (NQoS). Over the coming years, a large spectrum of services and applications are going to be released to fulfil end users demands in a totally heterogeneous communication environment in terms of terminals, stake holders, bandwidth constraints, mobility patterns and environmental aspects.

Research is focused towards an open Internet of Services and ultimately a global cloud for ubiquitous service provision, that comprises all ICT resources, in a lightweight way, end-to-end and vertically optimised. It will enable mediation between ubiquitous user oriented services and transport. In order to make this possible, a mediation bus to support it is needed.

A mediation bus is a "distributed environment that achieves an optimized operation of Future Internet by performing mediation operations among the service and network/transport layer entities that are plugged into it enabling both service and scenario-oriented end-user treatment by instructing the involved entities to execute the appropriate commands in an efficient and network agnostic way."

Mediation operations are executable commands that are planted in the bus. These include translation of policies (rules, constraints and requirements of the optimized operation of the Future Internet) and context view (e.g. spectrum, energy status, user profiling, etc.) to executable transport workflows (functionalities) optimizing the usage of both computing and network resources, wrapping functionalities for creation (open APIs) and delivery (adaptation, orchestration and execution enablers) for existing and future Internet services; and searching, negotiating, reasoning, subscribing, publishing, security/ privacy global capabilities through appropriate generic enablers and facilitators.

It will need to support a transition path from the current networks to the future network

[14] *Based on the intervention of the e-Mobility project representative, Dr Georgios Kormentzas, Aegean University*

infrastructure, vertical control and management functionalities for bus optimum operation (e.g., for green aware performance) and self-organisation.

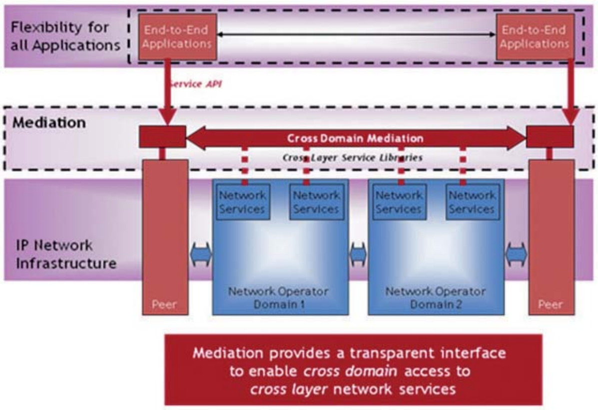


Figure 11: Mediation between services and transport

The mediation bus is both a layer and a management mechanism, which is dynamic and able to adapt to the needs of specific elements of the environment. This should lead to a reduction in costs and expedite service rollouts, manage and simplify complex service interaction and composition, and alleviate complexity of heterogeneous future Internet network architecture through efficient abstraction enabling optimum network and computing resources utilisation.

It will deliver the same, seamless service experience to pre-IMS and NGN/IMS and post-IMS users, cover demanding PQoS/EQoS requests of a radically changing end-user profiling, and increase network and end-user equipment selection flexibility. In this way it allows to move towards a green aware framework.

New business models become viable and maximize investments through service virtualisation enabling new business roles (e.g. separation of the resources from the service developers and owners). In the end, the Mediation Bus is to ensure end-to-end connectivity at the mediation layer, rather than at the network layer.

e-Mobility and the User context and profiling[15]

The motivation for developing user context and profiling is that there is a need for a filter between user and ubiquitous communications, without making the user miss important communications: in a way to develop a kind of "secretary services" build in the network. For instance, mobile advertising is currently big and growing, and if only part of this budget could be used to do better profiling and user-context aware services, that would be a lot of money, as better targeted advertising becomes possible. Therefore the advertising industry may well be the prime investor, and therefore driver, in this area.

Context is any information that can be used to characterize the situation of an entity. Types of context include both human factors (the user, its social environment, user's tasks) and the physical environment (location, infrastructure, physical conditions). The context provisioning and user profiling need to be developed as re-useable service enablers. Basically, contexts are very variable, and user profiles are rather static.

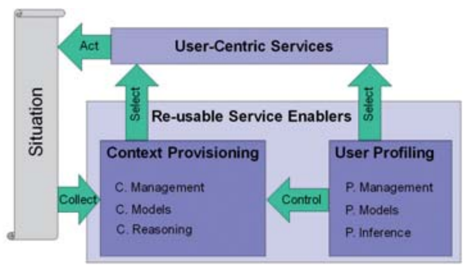


Figure 12: Context aware services

Scalability is a challenge with regard to context provisioning. The behavioural patterns are also important while fault tolerant methods for reasoning to deal with incomplete, imprecise and uncertain information are required.

User profiling depends on user models, profile management, security trust and privacy and user acceptance. Research priorities include situation-dependent sub-profiles, social network information, novel privacy and trust metrics

[15] *Based on the intervention of the e-Mobility project representative, Prof. Ralf Toenjes, Osnabrueck University of Applied Science*

(with "visibility scope"), and there is a need for simplicity and transparency in order to allow user acceptance.

Selected research priorities do not include only technical issues, but also very much cooperation models for actors of the service ecosystems, and meta-models for the description of context-aware applications. Standardisation processes have already started on this, in OMA (Open Mobile Alliance) and W3C (context awareness and personalisation). In terms of regulation, there is a need for harmonisation of legal frameworks, as to allow context aware services to be rolled out throughout Europe without needing to adapt to specific legislation per member state.

Recommendations are to enhance support of privacy (key for user acceptance), and to develop and agree upon reference metrics (to monitor and compare progress of different approaches). We need to move from hidden context-aware services to common reusable context-awareness components (including standardised interface for interoperability). Services need to be user-centric which means that we need to move from any services at any time anywhere to the right service in the right context (including meta-models for service description to select and adapt the service according to the context). User profiles and situation-dependent subprofiles need to be set up in a standardized structure, and need to include metadata from social network information. It will also be important to develop algorithms that support fault tolerant selection and adaptation of services based on uncertain and incomplete context information.

e-Mobility and Cognitive Communications[16]

The rationale for cognitive radios and networks can be found as there are high costs for licenses, and there is a perceived scarcity resulting from the rules according to which spectrum is used. At the same time we see large swaths of licensed bandwidth unused or very lightly used vs. fully overloaded mobile communication systems in unused contiguous spectral bands. There is a strong need for a more flexible and dynamic allocation of the spectrum resources and this requires cognitive radios. They must be able to accurately sense spectrum occupancy, and make better use of temporarily unused bands. For this they need to be capable to reconfigure transmission parameters (modulation scheme, band, transmit power, etc).

In order to enable cognitive behaviour, there is a need for context information (including monitor location, time, traffic demand, mobility levels), profile inputs (candidate network configurations), and policies regarding rules to be followed in handling contexts: maximised QoS levels, minimised cost factors (e.g. resource consumption).

Theoretical considerations and physical layer realisation of cognitive radio include:

- Fundamental limits of communication systems and scaling laws
- Interference channel: interference avoidance (spectral-gap filling), controlled simultaneous transmission, opportunistic interference cancellation schemes
- Rapid and accurate spectral sensing and estimation (adaptive)
- Low SNR regime or cooperative sensing
- Compressed sensing
- Modulation waveform adaptation: multi-carrier based
- Source and channel waveform adaptation: trade-offs

Having rapid and accurate spectral sensing techniques is a major challenge, yet also a necessity. In the lower SNR regime it is important to ensure cooperative sensing that also lower energy radio is recognized.

Interference is a major problem to be tackled in cognitive radio networks. In order to improve this, one could think of combining SINR and PU activity patterns with predictive traffic models. Other conservative approaches that apparently gain some momentum is a combination of geo-location and databases.

[16] *Based on the intervention of the e-Mobility project representative, Dr Carles Antón-Haro, CTTC*

Other challenges include routing: (SUs routing over multiple hops, routing related signalling, and cognitive network coding); security issues and trusted system policies (trust policies in cooperative sensing, objective function attacks, cross layer attacks, and primary user emulation), and seamless operation of heterogeneous radio networks with cognitive principles.

On cognitive radio platforms: cost- and energy efficiency is also important. A large range of bandwidth may need to be scanned, which is not evident. The platform has to sense the environment, and needs reactive as well as proactive actions, triggered by management strategies based on user preferences.

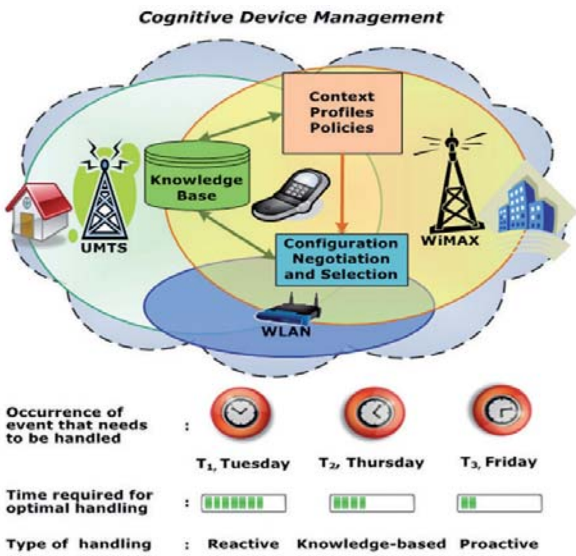


Figure 13: Cognitive device management

Cornerstones are management of user preferences and behaviour, equipment capabilities and network policies; acquisition of context information; and negotiation with the available networks and RATs, and selection of reconfiguration action. Standardisation efforts are important, and on their way, with ITU, ETSI, IEEE, SDR Forum, CogNeA and ECMA.

In essence, there are many open issues in the field of cognitive systems, which demand additional research work in the coming years. Efforts need to be directed towards challenges in cognitive radios, networks, and practical implementation aspects alike, whereas the tracking and provision of inputs to standardisation bodies is crucial.

e-Mobility and M2M Communications[17]

Machine-to-machine communications (M2M) is an increasingly important area and market opportunities are abundant, when considering the enormous growth of internet "connections". During the past years (2005 – 2008) we witnessed the fixed-mobile convergence and we are now moving towards the M2M communications.

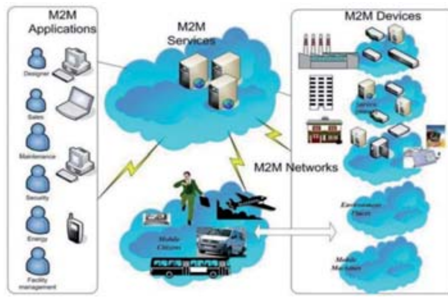


Figure 14: M2M communications

This will require a combination of short range radio and cellular technologies in order to enable the functionality needed, in an affordable way. It is a market worthwhile investing in, considered its size the expected growth from 720 million € in 2008 to 1 billion € by 2011, according to Gartner (June 2009).

This leads to a new M2M value chain that is embraced by a lot of mobile operators, as it is seen as a profitable market with a lot of room for everybody. Examples of applications include car telematics, fleet management, parking & traffic management in urban areas, positioning systems, smart metering, POS-terminal, security, remote monitoring of Green Energy power plants, remote management of assets & products, environmental monitoring and ICT support to a sustainable economic growth, and in eHealth.

Trends in key functionalities help as well. These include the upcoming of Intelligent devices (processing power, sensing and context

[17] *Based on the intervention of the e-Mobility project representative, Dr Thierry Lestable, Sagem Communications*

awareness, communication), the efficient internetworking of heterogeneous networked embedded devices, the emergence of a platform for shared information that allows access to information in a secure and trusted manner, the distributed decision making, the end-to-end reference architecture, the interfacing from capillary network technologies to telecom networks, and from M2M capabilities to service platforms. Security privacy and trust is also recognized as keystone. Identity management, not only for people, but also for machines and objects is important as this is the central organizing principle for data.

New developments include object discovery services, associated with additional information such as location, time, sensor information and object classes (identifiers, sensors, actuators, transmitters/bridges, processors). Further miniaturisation thanks to nanotechnology leads towards smart dust. The hierarchical communications networks (from short-range to wide area) and the pervasive communications are also emerging. Real-time infrastructures and increasing resilience (ability to respond to failures) are required. A major measure of success is the contribution to energy efficiency and the ability to use alternative energy sources, where the autonomous operation is a key factor.

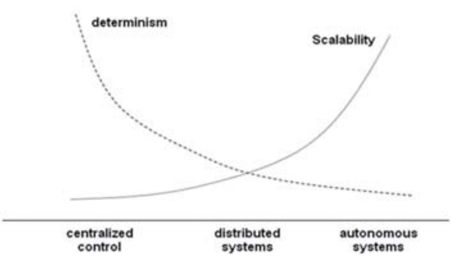


Figure 15: Autonomous operation vs. network management

Autonomous operations are self-configuring, self-healing, self-optimizing, self-securing and self-auditing. This enables better use of power at micro level and efficient sharing of resources across the cloud. It should bring together wireless and wireline technologies. A next step is 3GPP NW optimisation for M2M. M2M middleware is under development to enable all this.

e-Mobility and Optical Fibre and Radio[18]

The requirement to communicate a very high data rate such as rich multimedia with low power and low cost are the reason behind the integration between wireless and Radio over fiber (RoF) as this integration is the only way to allow high data rate with low power and low cost. The integration will make the networks more transparent, dynamic, faster and greener.

Future research items are related to the expected big expansion of broadband (FTTH – Fibre to the Home). This also puts high requirements to the core network: the future is high capacity broadband, and for this we need fibre networks in the backbone.

Optical network switching for hybrid traffic requires the integration of optical segments and multi-technology wireless meshes. This is only possible with efficient control plane architectures and routing algorithms. Furthermore, the optical domain in metro and access segments must provide functionalities to support mobility among heterogeneous wireless technologies. GMPLS is currently one of the most promising control plane architectures for hybrid networks.

The interconnections between wireless and wired equipments that are performed imply processing delays between the lower layers in the protocol stack and in the higher layers this delay is not compatible with the Gigabit data rates. Furthermore, this can not guarantee a global QoS from end to end. Therefore, new approaches have to be taken into account especially at the lower level protocol stack in order to guarantee end-to-end QoS and smooth transitions between wireless and wired networks. One possibility would be to define at the MAC level the interoperability and cross layering between both wireless and wired networks. Cross-layer between wireless and wired networks needs to be considered. The optical switching elements should provide various functionalities to cope with the hybrid wired/wireless networking, such as advanced traffic mapping, services delivery, and dynamic traffic allocation, in order to

[18] *Based on the intervention of the e-Mobility project representative, Prof. Hamed Al-Raweshidy, Brunel University*

support the demanding user driven applications in mobility scenarios covering a large set of wireless technologies, such as WiMAX, LTE, Wi-Fi, characterized by different QoS metrics and radio resource allocation mechanisms. The issue of the coexistence of digital and analog transmission becomes very important. The technical challenges of implementing next generation PON (GPON) technologies include new architectures to support migration path from already deployed 1Gb/s systems towards 10 Gb/s along with analog video overlay on the downstream. In this context requirements for coexistence between 1 Gb/s and 10 Gb/s and analog signals is mandatory to assure a smooth migration path.

In order to achieve green radio over fibre, we need minimum power devices for users. Estimates of the power requirements for digital television in the UK indicated that two or more power generation plants would be required to support the set top boxes. What is the best scenario for high bandwidth delivery at minimum power? Should CPE be required to have a sleep mode? This might lead to power savings up to 70% in some applications. As part of the investigations into RoF technologies the reduction in power consumption compared with a more conventional approach using optical and radio backhaul networks with either SDH/SONET or Ethernet switching should be a key topic for research.

Fibre as near as possible to the user will largely contribute to higher bandwidth communications. FTTH is coming to the home, including new short range wireless technologies, POF (Plastic Over Fibre) and Rich Multimedia at home (PAN, sensors and high data rate medical application).

We will need to further look into GMPLS, and Radio over Fibre. Most current RoF links that are available commercially have relatively limited frequency ranges. Most commercial systems are narrowband and only carry a single or at most a low numbers of radio services. Consequently if a system is to carry a multiplicity of services, it will need multiple parallel RoF links. Ultimately, there should be a broadband solution which is attractive for providing a single infrastructure able to support multiple services.

Towards the Network of the Future

Society is becoming more and more dependent on the Internet today. There is no plan B anymore, hence there is no other way than an evolutionary approach towards improving the Internet. That evolution will also face a network, or networks, with clouds of information with a massive growth of wireless links, including “things” like sensors.

Nevertheless, “clean slate” ideas are still an important contribution to stimulating the evolution. In addition, in the understanding that there is a cloud of networks, new “clean slate” networks could merge in, during the evolution.

Issues like security, scalability, electricity consumption and wireless systems are to be addressed. Simplicity, especially for the user, is significant. Different issues will be solved in different ways in different places. Both packet switching and circuit switching will have their place in this. The networks will get richer. The future network will consist of a mix of all, and will use the same model as we use for other utility models such as gas or electricity for instance.

Future internet will need to have an energy efficient architecture and complex combinations of different factors need to be taken into account for realising it. Energy efficiency should be a mandatory requirement for all projects funded under the EU research framework.

A project has the ability to change the behaviour of the people towards science in the problem space. A clear example is the founding of the Software Engineering institute by the US, aimed at development of software services. There is much more than what can be dealt with by any individual project. New ways of working together could be explored and find the right form to do interdisciplinary research to integrate other relevant research communities inputs for the networking area. A classical example is the Bell Labs case, which grouped its activities around "problems", where both people who can solve problems and people who could "pose" problems were involved. Such an approach automatically leads to multidisciplinary answers.

Today multidisciplinary research has little ground for publication in scientific publications, and is thus not stimulated. Setting up a new institute that supports multidisciplinary research could be one solution. While we must be aware that standardisation can also limit innovation, the real challenge is to understand the difference between interdisciplinary and cross disciplinary.

The continuity in research is essential, but the research funds available for telecommunications research are subject to political decisions. Therefore it is important for the community to make clear why this ongoing investment would be needed.

In the communications area, research has become even more important for society, and therefore it should be easy to argue that ongoing innovation in the networks is crucial to the economy. It is accurate to assume that ICT in the world like today is very important. At the same time we need to argue that there is still work that can be usefully done at European pre-competitive level. What work needs to be done, and why? And how can one convince decision makers that it is needed? Different approaches are possible:

- Telling compelling stories about possible blocks that may come up in economy or society, that need to be addressed
- Explain how it would be if the European research community walks away and leaves it to the rest of the world
- Explain that, whereas clean slate as such is unrealistic, that there is an evolution to continue on the Internet, everybody accepts that. Yet clean slate ideas have driven and will continue to drive the evolution, as well, as "the Internet" is in fact a heterogeneous collection of networks.

It is crucial to have a good understanding of the network industry when aiming at developing a good service industry. World wide standards still come out of Europe today. A closer link between infrastructure development and applications fosters new innovative services. Also in mobile we can only keep the leading edge when we can handle the Internet edge as well. The question to ask back to politicians would be: "Does Europe want to play a role on global level, or not?"

It is recognized that in the networking research community there is a technology push approach. It might be important and useful to explain and emphasise how what is on the offer side that could really improve the life of citizens. Network technologies enable social interaction and dematerialisation but with the tools we have developed so far we have just set one step on the way.

If we start from next generation networks, we have the idea that we have service control, access and a core, all using IP. Today the multidisciplinary research approach is the right way forward. We have Future Networks, Networked Media Systems, Internet of Things and Security research areas, which also get together in the Future Internet Assembly (FIA) process. This process was originally limited to cross disciplinary research. However, the links between the network and the software services layers should be strengthened. Developments towards the «Network of the Future» will be multidisciplinary, and rather evolutionary vs. clean slate, even though it is clear that clean slate research is important to get new insights, as part of the process towards continuous innovations, while allowing flexibility. But the future cannot be prescribed and the Internet model needs to preserve an open door to the future developments.

Important issues to be considered are the transition towards a market of mainly wireless, mobile users and the need to follow a scientific or engineering research approach or find the right balance between both."

In essence, the main concerns of the networking research community for the future research agendas are:

- The optical technology has a very important role, although aspects like optical packet switching and optical memory remain unsolved
- The ICT energy consumption and the ICT solutions for energy saving are areas where major improvements are possible
- The governance is an aspect to be tackled with in parallel to technology development
- The «Network as a service» requires closer cooperation between network and services players
- Self-organisation and autonomy to manage the complexity of the networks is needed and cognitive radio is one example
- The future networks will be opportunistic networks, mainly at the edge
- The virtualisation allows for polymorphic networks, network of networks and infrastructure sharing
- The mobile cloud computing requires a more comprehensive research approach
- The role of privacy, security and trust is increasing but should not be over-emphasised
- The Future Internet also includes concepts like the Real World Internet (RWI) and machine-to machine (M2M) communications
- The content distribution requires optimisation and the info-centric paradigm could be one solution to protecting user privacy, where the receiver is expected to take the initiative and also to energy efficiency, knowing that 10% of the sites carry 50% of the traffic
- Developing methods and proofing their viability to understand and mature the services in a multidisciplinary way.

PART II

BIRD Workshop: Business Innovation and Regulation Challenges 2009

Executive Summary

Today, the Internet is invading most aspects of life and society. It changes life, work, communication, social interaction, and in doing so it brings many benefits but also threats. Governments around the world are concerned about it, and are seeking for their roles in ensuring an Internet they want for the societies they are responsible for.

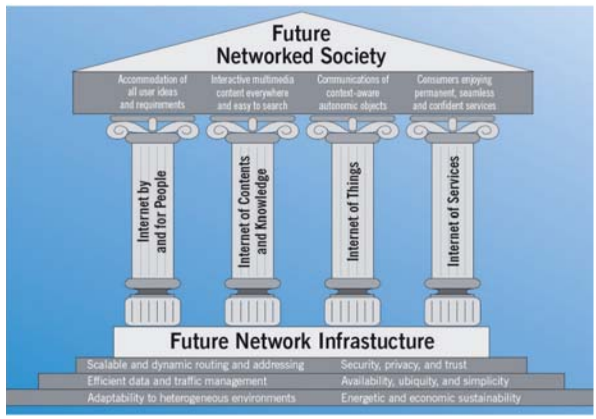
The public 4WARD project workshop on Future Internet 'Business Innovation and Regulation Challenges' 2009 focused on the impact of non-technical drivers and covered society aspects (mobility, accessibility, virtual environments, less pollution, and the need for security and balance between privacy and sharing); business aspects (market opportunities, opening of new markets, business models and value chains, and new players), and policy, governance and regulation aspects (including the impact of existing regulations, e.g. legal interception, non-discriminatory access to network resources and service providers, and impact of hypothetical regulations on the future Internet).

Time wise, this workshop takes place at a crossroads in Commission ICT policy development, with the ending of the current policy plan, i2010, and the renewal of the Commission itself. While this means there is a moment of standstill in policy decisions, policy preparation is at its highest effort. Policy priorities for the new European Commission for the years to come are under discussion, but all signs indicated that the "Digital Society" could well be at the heart of the vision towards a competitive and sustainable Europe, for all.

The Internet is at the basis of many new developments, and the Internet is currently undergoing massive change. Maybe the most important ones are the emphasis shift towards identification of individual objects (and people) on the web, and increasing use of mobile devices.

In policy, there is a lot of debate on the network neutrality issue. The European Commission is clear in its position: open, with a neutral role of ICANN, championing freedom of expression (except for harmful and illegal content) and with respect for privacy of individuals.

Technically, we see a shift towards network services, and the research community is developing the concept of virtual networks. These networks will develop on a core backbone with high capacity fiber, on which virtual layers will share resources and enable effective delivery of what people need: a service, rather than a one-off product.



Vision on the Future Networked Society

The development of the future network infrastructure is responding to the needs of the future networked society and incorporates a focus on ensuring stability, high bandwidth, adaptability to heterogeneous environments, energy and spectrum efficiency, efficient data and traffic management and scalable and dynamic routing and addressing. It needs to meet the following key requirements:

- Become the common and global information exchange of human knowledge;
- Leverage and evolve information and communication technologies and capabilities and services to fulfil increased quantity and quality of Internet use;
- Be scalable to provide cultural, scientific and technological exchange among different regions and cultures, and within single communities;
- Accommodate unanticipated user expectations together with its empowerment;

- Be ubiquitously accessible (from physical, to connectivity and information level) and open;
- Be secure, accountable and reliable without impeding user privacy, dignity and self-arbitration;
- Support mobility, have widespread ubiquitous coverage, and be capable of assisting society in emergency situation;
- Support means for various performance adaptability features based on context and content;
- Support the innovative business models that are emerging (and may emerge in the future) involved in providing any particular instance of a service;
- Be carbon neutral, energetically sustainable and respect the environment.

Today, there are more than 1.5 billion people on-line. Traffic is increasingly global and the amount of time we spend on-line compared to time we spend on other activities goes up, as well. Mobile plays a bigger role every day. At the moment, mobile internet grows 8 times faster than fixed line internet. The impact on real life was explicitly witnessed when President Obama launched his campaign in 2008, with great emphasis on use of the new media. Changing behaviour is seen also in services: in January 2009 the traffic on social networks surpassed email traffic.

Cornerstones of the future internet are fairly similar around the world. Technically, the requirements as indicated below mean the Internet needs to be:

- Open, flexible and participatory;
- Information-centric rather than bit-centric (at the network level);
- Predictable to allow critical and M2M applications to operate reliably;
- Secure - nevertheless, that leaves the creativity capacity of the network intact;
- Low cost to access;
- Small carbon footprint.

We need to develop network virtualisation to allow more efficient use of resources and a smooth migration, to move towards an information centric approach that puts content at the core and thus enables a mobile-friendly internet, and to accept the need of self-management, that should be enabled and supported from the outset in new designs.

A clean slate research approach allows the development of new ideas that may change the Internet – without anybody thinking that there will be a day where we turn the old Internet off, and the new Internet on. Yet the ideas that emerge from clean slate thinking will be important to inspire and support the evolution of the Future Internet. As the Internet consists of many networks, this will lead to direct implementation of new ways in parts of the network (like the social network concept is doing, and as earlier search engines like Yahoo and Google have done, window browsers like Mosaic, and the introduction of the World Wide Web). Experimentation in real life settings is important in this, and is taken up in different parts of the world. What the limitations of the current internet infrastructure are and what can be added in layers, where adding is possible, needs to be tested in practice.

Virtual networking is a first aspect that makes it possible to share resources and be much more efficient, both in its routing and its energy use.

Information oriented networking would bring innovations that focus on the delivery of information, and would include in the delivery the guarantee of quality of information, and privacy when security is embedded in the identifiers. It is also location independent, thus allowing mobility.

Generic path approaches represent truly a new concept of traffic flow on the Internet and adopting such an approach is not easily done. Yet the thinking about generic path approaches does generate insights and inspirations for better ways to ensure quality of service, in many different ways.

The Network of Things will bring all kind of new ways to ensure efficient use of resources by having full access to the state of resources, as they are all connected. By not only allowing our environment to detect and measure, but also to act on our behalf, we truly insert intelligence in our environment.

A further growth of community oriented applications, like Wikipedia and social networks, can be expected. In the future, these environments are likely to become more volatile and flexible, which means it will be less possible to rely on multi-source trust mechanisms and will need profile based access and security.

In terms of business models, a revenue sharing model needs to be defined where all parties get their share of the revenues. The advertising model although attractive will not sustain and maintain development of infrastructure.

In terms of regulation, it is clear that concepts change, markets change, and the combination of services supplied by service providers changes. In this, it is very difficult to find the way ahead for regulation, although the key principles, as expressed in the telecommunications regulations handbook, remain the same. One thing is clear, in order to be able to benefit from future Internet developing here in Europe, further harmonisation is needed to counter what otherwise would be experienced fragmentation of the market (unlike the US market or China for that matter).

The ultimate target of regulation is customer welfare, and economic efficiency contributes to that. Network virtualisation and the network of information concept both support the latter. The Future Internet will be a critical infrastructure and there will be different types of virtual networks for delivering different types of services, ranging from voice to different types of data and broadcasting services. There is already legislation for media and content, and media and content move increasingly to the Internet. In the future national borders will mean even less than today, the networks and services go across borders. The Internet cannot be left unregulated, but what and how remain the key questions. Regulation should not mean limitation to freedom, but it can be seen to mean freedom to live in a secure way.

Last, but not least: standardisation will be important to ensure interoperability in the network. While it is currently pursued by participation in multiple platforms, it is clear that a revisit on how this can be done effectively and efficiently would have merit as it is very time and resource consuming today.

Internet of the Future, Opportunities for Europe[19]

The preparations for the overall strategy framework that is to follow i2010 are well under way. The President of the Commission, Mr. Barroso, has given out some broad priority statements for the new Commission that include mention of activities related to "digital Europe.

Currently Internet and Broadband are high on the political agenda, with some emphasis on the network neutrality debate, both in the US and here in Europe. It is crucial that policy makers understand how much Internet has become an enabler. Up to 1995 the economy in US grew at 1.2% rate. This went to 2.3% after 1995. It is said that before 1995 "we saw computers everywhere except on the bottom line"; after 1995 the Internet started to make a clear difference, also on the bottom line. Europe lags behind to the US as it has not been as good in implementing ICT technologies in business processes. And the same now seems to be the case for Internet 2.0. Accessibility to investment funds in a fragmented market seems to accept blame for some of this. It is very difficult for service providers to negotiate contracts in 27 countries, rather than in one (e.g. US). For instance, under the eCommerce Directive you are protected by the country of origin principle. However, if you offer Italian services as an Austrian business, you will be confronted with Italian courts in case of difficulties with Italian clients. These kind of uncertainties, when it comes to implementation of this or other Directives (e.g. Data Protection), make business difficult.

[19] *Based on the intervention of Mr Ken Ducatel, European Commission*

The Internet is a global phenomenon, and further globalisation of the Internet as an infrastructural backbone will continue. Key changes coming up are in identification of individual objects on the net, and increasing use of the IPv6 protocol. The Internet, based on open standards, has become the enabling infrastructure for social and economic interaction, and a continued growth in both fixed and mobile systems connected to the Internet is expected. The ecosystem will become increasingly complex, and increasingly critical to society. Looking into a possible change in how we "do" the Internet becomes both more important and more difficult. A balance needs to be found in how the Internet works, how it stays stable and scalable, and how at the same time new services can continue to develop (financial services, geo-location) that require streaming, transparency, and security. IPv6 is an important element in this, as it offers enough address space to open up a wealth of opportunities. An Internet based economy has a tremendous potentiality, for growth and much more. It may help taking measures in the areas of health that were never possible before, and in the area of environment. A lot will depend on how the Internet functions and how it is used.

Within the Commission there is a lot of activity on this, in research and other activities. The telecommunication framework includes most of the tools needed to guaranteeing openness and networking. Many new regulatory tools are there on top of the "traditional" ones like Universal Access. The Commission thinks this is a good, practical basis for "openness" in Europe. The new rules need to be implemented now, and need to work out well by member states and the role of the Commission in this phase is to monitor and adjust, when necessary. Trust and privacy are crucial elements in this. The Internet has the potential to become a transactional infrastructure for a large part of the economy, and has enormous potential to help address challenges in health and environment and the Commission is currently committed to do what it can to retain the openness and network neutrality.

In order to influence developments, from a policy perspective, there are three types of tools available to the Commission:

- financial instruments;
- legal instruments to create conditions for innovation (telecoms framework with emphasis on keeping networks open, yet implementation is dependent on national regulators; ecommerce, copyright rules and we have to see how these fit together);
- policy instruments, through which we try to encourage and inform people. Currently in the Internet area regulatory tools are important and that there is a need for digital market policy.

In terms of global outreach, the Commission is actively working towards keeping the internet open and has a focus in this on ICANN in its neutrality. This neutrality of ICANN is continuously being emphasised, and that it will be possible to stay away from a UN type approach as that may lead to breaking down of the Internet in islands. Last but not least the Commission continues to stand for the freedom of expression. While the fight against harmful content like, hate generating content, child pornography, etc., will continue, the Internet is to be a place without limitation of content and the Commission is committed to do what it can to guarantee this.

Future Internet trends and initiatives[20]

Today, the Internet is converging towards service enablement at network and service Level. There is a lot of information on the network itself and its intelligence is likely to increase. Whereas data transport used to be the overlay over voice networks this has changed fundamentally: today voice traffic has become an overlay of data networks. There will be an increasing move towards content networks: not so much as an overlay but built in from the beginning. Next to best effort data traffic, future networks will need to be able to deal with QoS sensitive multimedia traffic. The challenge is to bridge networks and applications and implement new design principles.

[20] *Based on the intervention of Mr Klaus Wuenstel and Mr Didier Bourse, Alcatel-Lucent*

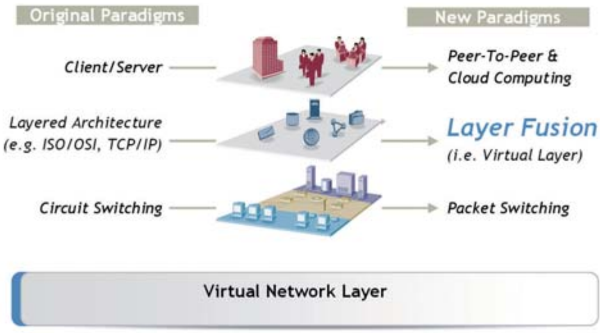


Figure 1– New design principles

When we compare the classical IP model with the clean slate approach for generic connectivity we have on the lower layers a lot of cross layering, upon which applications and information objects "rest". Supported by multiple access platforms, like today, this approach will be yet more seamlessly integrated. Today we are in a not well fitting situation, with a small top link between the web world and the network. This gap is to be filled with application enablers, building in what is needed to create a much more beneficial environment that will allow open innovation and building in trust. The network will be fibre optics in its core layer, upon which wireless and wired broadband will reach the users, using an

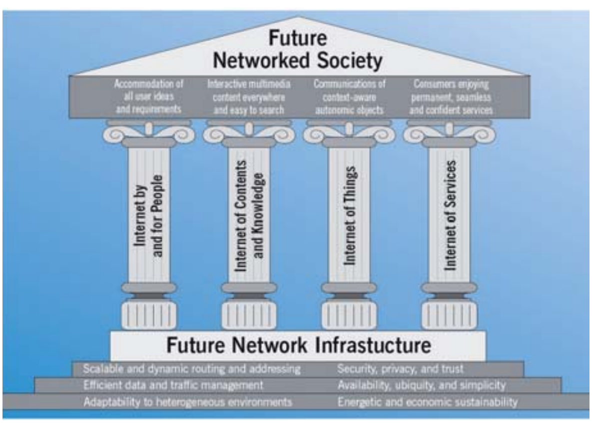


Figure 2- Future Internet PPP context

IP protocol or novel Future Network protocols for establishing end-to-end connections. As we cannot foresee what will come up, we need to make sure we retain open platforms. In order to address topics like these, a Future Internet PPP (Public Private Partnership) is being set up.

The Future Internet PPP will build upon different visions of a Future Internet, as shown in the picture above. European research brings together the efforts that take place at national level, with different time horizons. Research under the Seventh Research Programme (FP7) is important, but also Eureka and FIA. The PPP for the Future Internet is aiming to fill the gap between national level initiatives, international research and European efforts. Today, 16 global partners are committed to invest up to 50% of 1 billion EURO over the coming years in this initiative. It aims at developing (vertical) applications and (horizontal) technologies/enablers. In addition, there is also a need to closing the standardisation gap. The ambition of the partnership is to come with new approaches, new imagination that will inspire Europe's move towards the Future Internet. The Future Internet needs to meet the following key requirements:

- Become the common and global information exchange of human knowledge
- Leverage and evolve information and communication technologies and capabilities and services to fulfil increased quantity and quality of Internet use
    - Be scalable to provide cultural, scientific and technological exchange among different regions and cultures, and within single communities
    - Accommodate unanticipated user expectations together with its empowerment
    - Be ubiquitously accessible (from physical, to connectivity and information level) and open
- Be secure, accountable, and reliable without impeding user privacy, dignity and self-arbitration
- Support mobility, have widespread ubiquitous coverage and be capable of assisting society in emergency situation
- Support means for various performance adaptability features based on context and content

- Support the innovative business models that are emerging (and may emerge in the future) involved in providing any particular instance of a service
- Be carbon neutral and energetically sustainable

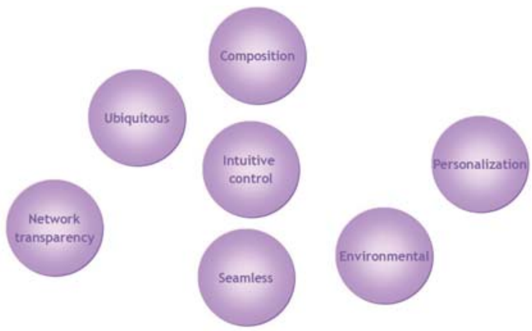


Figure 3 - Future Internet trends and initiatives, as seen by the PPP

Policy makers will need to address the governance issues. What is needed most from policy makers is a common approach across Europe, which will be a major incentive for industry to move ahead.

The Future Internet in the USA[21]

In the US, research on the future Internet started in 2005, with a focus on dealing with: limits of current Internet protocols (security, QoS, mobility …), new core technologies (storage, wireless and virtualisation) and emerging new applications (content delivery, vehicular networks, healthcare, …).

The objective was to do research on clean-slate architectures, and thus develop novel network/protocol concepts, new Internet architecture ideas, influence current IP standards, develop approaches to cellular-Internet convergence, propose possible clean-slate deployments and suggest new applications. The clean-slate architectures as such were never meant to replace the current Internet, but to be implemented for the benefit of the evolution of the Internet. Efforts can be divided in three broad categories:

- Ongoing R&D and academic work
- Mainstream industry
- New 'clean-slate ' initiatives, supported by NSF funding (FIND, GENI, …)

FIND, the Future Internet Design project[22], was started by the NSF in 2006. It started as a collection of many small bottom-up activities of which some will continue to grow. Currently a first phase of concept development has been completed and initial evaluation of this takes place around now, and should lead to a selection of projects based on peer review that go on to the next phase of research. Projects are most between 0.5 and 1 million US dollars.

The Global Experimental Network Infrastructure[23] (GENI) initiative is aimed at construction of a global experimental infrastructure for clean-slate Internet research. Projects have started in 2005, with a planning phase which led to a selection phase in 2007. The selected projects are currently in the so called "spiral 2" phase, which means a second round of peer reviewing that should lead to a next phase of deployment and experimental network operations.

Some examples of internet research are interesting to mention:

- Economic models for net neutrality; the model by which ISPs cooperate is looked into from a game-theoretic perspective
- Security and privacy is another area. How can you ensure anonymity enough to prevent traceability?
- Cache and forward architecture for mobile content delivery. Delivery can be made much more effective by introducing new technologies that support better the different volumes of info that need to be routed
- Multi-protocol virtual mobile network concept, as brought forward by the 4WARD projects covers a very important part of the space.

21 *Based on the intervention of Prof. Dipankar Raychaudhuri, Winlab*
22 *www.nets-find.net*
23 *www.geni.net*

- Open flow switching: creating enterprise networks with programmable switching, using an open architecture and supporting cloud computing with reprogrammable hardware
- VINI virtual network interface, which is connected to PlanetLab and uses layer 2 technologies.
- ORBIT: radio grid test bed ORBIT which has a 5000 ft^2 room with fully programmable access for testing, now also an outdoor test bed infrastructure. One of the things explored is virtualisation of WiMAX networks.
- Vehicular nodes: equip cars with devices, and they carry this and measure results as they move around, and send the information to the analysis team thus enabling large scale experimenting.

GENI is to address science issues, barriers to innovation as well as social issues. It is set up as a programmable and federated system. With the selected «Spiral 1» type of projects GENI now moves into a phase of meso-scale prototyping on the level 2 networks across the US. It is now the intent to develop a number of GENI campus prototypes, all with different emphasis (e.g. WiMAX, Open Flow).

This next phase will be supported with a funding of about 20 - 30 million US dollars per year for FIND and an equal amount for GENI, excluding the network itself. Industry is involved, but there is no strategic level push towards the future Internet yet from industry. An important development is that now a number of important vendors have committed to open flow standards. If you believe in programmable network components, we need open flow research.

New Service Offerings enabled by Future Networks[24]

When we think about future networks, it is important to recognise the following key drivers:

1. Technology drivers:
- Nano Technologies, Devices, Ambient
- Neuro Science & Communication
- Robotics
- Memory -1TByte portable
- Objects Interconnected
- WABO - Wireless Always Broadband On
- Interaction Design, Information and Semantics

2. Business drivers:
- Emerging needs, in particular sustainability (social, environmental, energy) and competitiveness (or: economic sustainability)
- Process discontinuities: ICT should become the constitutive element for redesigned processes, reduction of negative externalities, new economic models and ecosystems
- Emerging applications for business, with software as a service, telepresence, eManufacturing and logistics
- Further European productivity increase due to ICT (today, 40% for Europe vs. 80% for the US)

3. People behavioural drivers:
- People born after 1990 have a totally different attitude. Whereas the "Analogue Natives" had the habits of analyzing, taking time, to learn before playing and then play to win or lose, the "Digital Natives" are more inclined to filter, react immediately, play and learn, and when the game is over … play again.

Digital natives go mobile. At the moment, mobile internet grows eight times as fast as PC based internet growth. And the way we divide our time over different media changes as well. Time spent on life TV is more and more replaced by web use, other PC use, game consoles and mobile communications. New screens are coming up both for witnessing real-time and other information streams.

[24] *Based on the intervention of Mr Flavio Faraci, Telecom Italia*

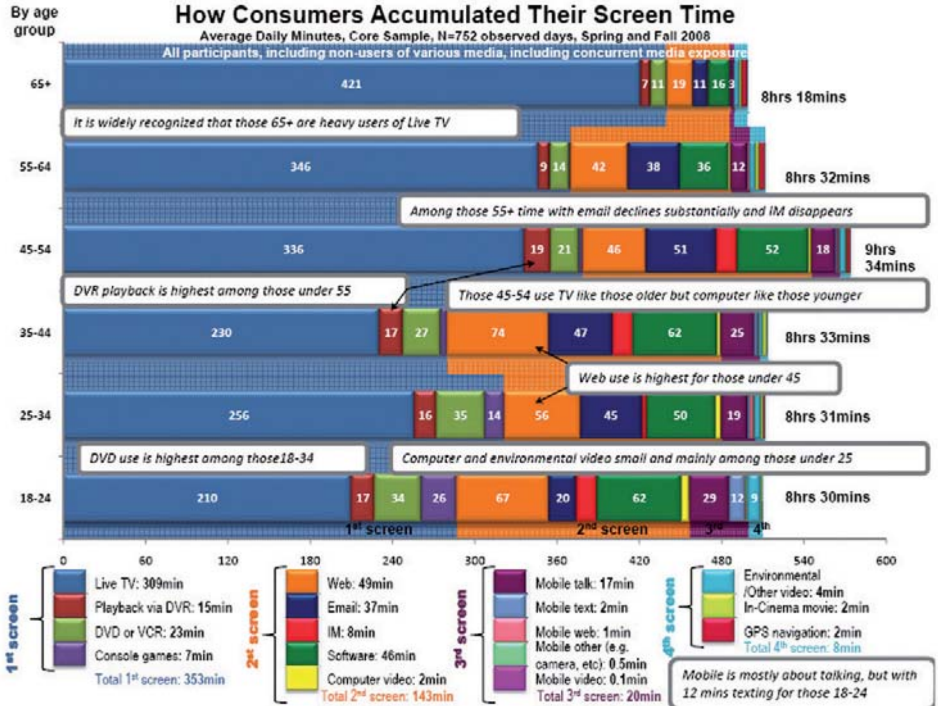


Figure 4 – Spending time on screens

The birth of the new media is underlined by the way the use of media by the US President Obama has helped him win the elections. What the radio did for Roosevelt in the 30s and the TV for Kennedy in the 60ies is what the converging media have done for Obama in 2008.

Figure 5 – Changing on-line habits

Not only has the time we spend on different screens changed but also our on-line behaviour. In January 2009, social network surpassed email and has become second after video. All signs that future services will be real time, social, contextualised, and in support of multitasking – clearly supported by the instant popularity of the iPhone. New services are under development and get launched every day.

With this changing behaviour, the challenges for traditional telecommunication companies are tremendous. Prices for communications continue to go down over the last ten years, whereas everything else got more expensive. Operator traffic and income is more and more decoupled now data becomes dominant and is mostly on flat rates. Broadband usage, worldwide, is taking up. Europe is now lagging behind to some parts of Asia. Telecom Italia is very surprised to see the enormous uptake of broadband per mobile and have to find ways to deal with increasing large amounts of traffic, coverage and technology.

In terms of networks, we are preparing for a next generation network with the NGN2 architecture in mind. Telecom Italia moves from a convergent approach in access, metro and backbone network to full services, applications and integrated support systems convergence, which should become an open platform, allowing services from 3rd parties, high quality, and user friendly.

In order to make all these developments possible, European governments and regulators need to speed up their contributions to NGN2 development. A pro-innovation policy is important and multi – utilities infrastructure sharing and innovative cost effective digging technologies should be allowed and encouraged. Regulators should not regulate what still has to be borne and allow the sharing of infrastructures thus to enable all this to happen.

Future Internet Innovations from 4WARD[25]

The cornerstones of the future Internet are fairly similar around the world. Obviously the challenge will lay in the implementation, yet the current situation should give us good confidence for a positive evolution. Time for experimentation has come. Penetration of Internet has gone up to 25% by June 2009: more than 1.5 billion people are on-line.

This, and expected further growth, does come with challenges, like the need for a continuously increasing capacity for transport. But also the need to change the way electric power is used in ICTs, in particular in core routers and data centres. Other challenges range from the guarantee of adequate bandwidth to the ability to continue routing with an increasing amount of complexity, which may get further enhanced with multi-homing.

Nevertheless, there seems to be quite some convergence in expectation of the future internet. It is expected to be:

- Open, flexible and participatory;
- Information-centric rather than bit-centric (at the network level);
- Predictable to allow critical and M2M applications to operate reliability;
- Secure, that nevertheless leaves the «generativity»[26] of the network intact (Zittrain);
- Low cost to access;
- Small carbon footprint.

Obviously, a first step is that we need to move beyond the limitation of addresses in IPv4. 4WARD is seen as a clean slate project. It does clean slate research, not to replace the "old" internet, but to look at solutions from a clean slate perspective that can advance the network evolution. 4WARD does not only look at connectivity, but also at facilitation. Similarly, 4WARD is considering how the Internet looks like, from the viewpoint of the mobile phone. How can it help in business and social interaction?

Network virtualisation allows creating a playground. The intent is not necessarily to put a new layer 3 network in place, but to create the opportunity to experiment. Virtual networks are to follow demand in a much more flexible way.

4WARD works on the following innovations:

- Architecture

- network virtualisation architecture developed including players, services and interfaces together with an XML based Resource Description Language
- initial analysis of business aspects arising from network virtualisation
- Lifecycle of a VNet described and analysed

- Provisioning of Virtual Networks

- framework and algorithms for the scalable mapping and embedding of virtual networks into physical infrastructure developed
- interfaces and protocols for signalling and control of virtual networks identified and defined

- Virtualisation of Resources

- design and evaluation of a software virtual router platform running within a shared physical box

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[25] *Based on the intervention of Mr Norbert Niebert, Ericsson*

[26] *The generative capacity for unrelated and unaccredited audiences to build and distribute code and content through the Internet*

- concepts and techniques for the virtualisation of wired and especially wireless links (particularly WiMAX and UMTS/LTE) and infrastructure-less wireless networks (such as MANETs and VANETs)
- a concept for facilities to provide interworking between virtual networks

- Feasibility Tests and Demonstrator

- first demonstration in March 2009 (project review) & large scale router virtualisation testbed
- innovations and achievements
- create new network solutions

Over the last years, new network architectures were not designed. By reusing and patching existing protocols we forgot to develop tools for clean slate design especially for the more detailed network architecture specifications. We want to develop such a design toolkit and use it. For this we need reusable components that are interoperable.

What is in place to create a new service, a new network profile? Network design should include customisation, efficient design processes to reduce deployment time for new services, no more patchwork (that needs to be managed as well), and ensured interoperability also supporting new business models. Building blocks come from basic principles and repositories supporting the design process.

We are used to think a network consisting of nodes (end plus forwarding) and links: what if we start to network the information we are looking for? Triggered by Van Jacobsen and other researchers, a new view on interconnecting information has emerged that would change the way we engineer networks fundamentally: a Future Content Centric Internet in which emphasis will be on content in the network.

Content today is a hostage of location. Problems resulting from the host-centric view include:

There is no common persistent naming scheme for information: URLs and IPs are overloaded with locator and identifier functionality: when information is moved, it cannot be found anymore. So flat namespace is needed for persistent identification, yet a world-wide scalable Name Resolution for flat names is difficult, as DNS requires hierarchical namespace. There is no consistent representation of information (copy-independent), no consistent way to keep track of identical copies, and different encodings (e.g., mp3, wav) worsen the problems. Even the security is host-centric, the information on unsecured hosts can be compromised.

An information centric approach would change this. When we design a new network architecture based on an information-centric paradigm rather than based on a host-centric paradigm, innovations that the Network of Information brings would include:

- Naming scheme for naming information;
- World-wide scalable Name Resolution mechanism for flat names;
- Information Objects (IOs) as representation of information;
- Efficient information dissemination;
- Secure information-centric architecture by embedding security into identifiers.

We can have different paths through the networks to find the best ways to deliver information. The aim is to use the network much more effectively to deliver information.

A second innovation would be to develop a generic path approach towards transport on networks. This means truly re-thinking the end-to-end principle: how can the state information in the network be confined? A generic path consists of two or more endpoints. For this we design a recursive architecture based on Generic Paths and aimed at facilitating the development of applications and the implementation of techniques which are difficult in today's Internet, like mobility management. Introduction of interlayer and multipath routing is a third innovation that would enable QoS and novel techniques like network coding. It would require design of a general framework for describing resources in future networks: an ontology-based approach to resource description to facilitate the design of services.

A third one has to do with enabling self-management: development of an in-network management paradigm. This would need to be built-in at design time, with monitoring and optimisation functions as embedded capabilities of network components. The reliability and cost-effectiveness of network management will be competitive advantages, so incentives are in place to make this happen.

At this stage innovations need to be developed, and connected in all areas of the network. The start is from a clean-slate perspective, defining radically new solutions for the Network of the Future – but then introducing the innovation in the current network at the edge, overlay, underlay or tunnel and such gradually transforming the Internet. Time to experiment has come, with commercial use in mind. The hard work is the integration of concepts towards the Network of the Future as a family of networks.

Use cases and business models

Future Internet Business Aspects[27]

Services are driving the economy and the service sector is growing faster than any other sector. There is globalisation of transport and market. This is reflected by the emergence of global business networks. The Future Internet will facilitate the route towards a web based economy. In these web-based service industries the assumption is that access to the services is quite easy. For the Internet of Services, it is cloud computing that is leading to lowering entry barriers of scale. Clouds come up, today, already, and reflect a sustainable way forward towards the future Internet.

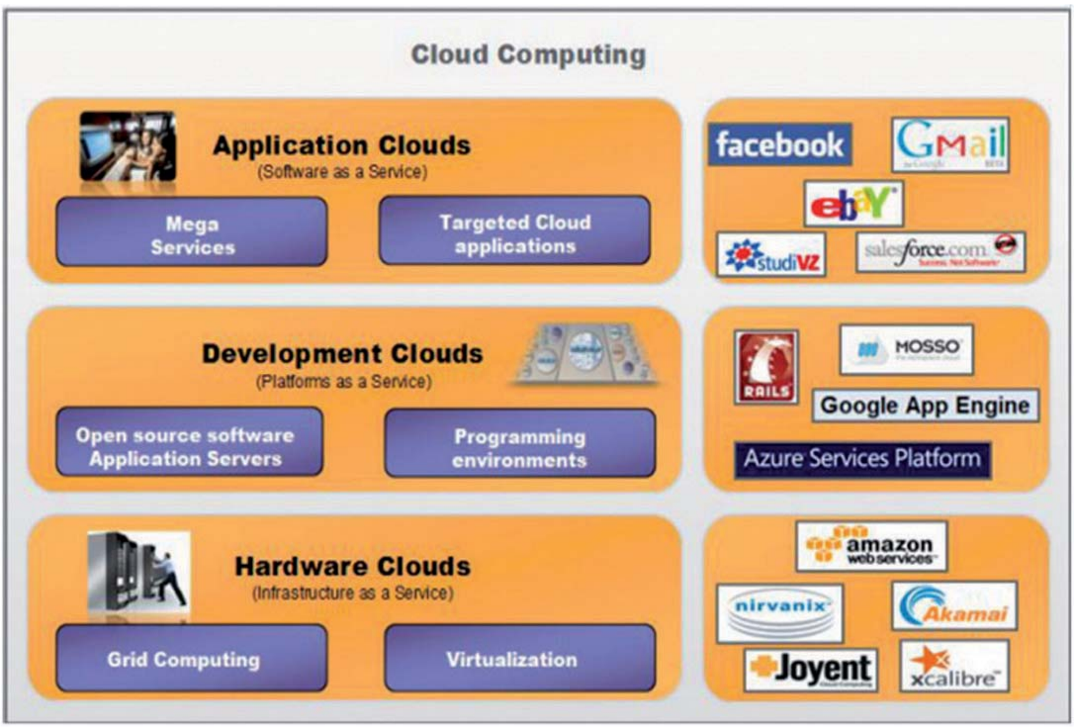

Figure 6 – Clouds lowering entry barriers to the Internet of Services

[27] *Based on the intervention of Mr Thomas Bohnert, SAP*

Software-as-a-service has many advantages in terms of resource use and flexibility. There is now more chance for a user to customise it, adapt it to specific business needs, even after "delivery". Advantages include simpler customisation, quicker updates, subscription based, with clear SLA, and no need for action by the user after engaging in the contract. As the price of delivery can go down dramatically, software services can be affordably delivered to customers for very low prices. This will make it possible to meet much higher demand, and enable the market as a whole to grow much more. Challenges will be in identity management, functional integration and clear understanding of quality of service levels.

An example is application in the automotive industry. It takes 2 to 3 years to get a penetration of 6 – 10% of "smart networked things" in cars, before car-to-car communication begins to make a bit of sense. The principle is simple: you collect and store the information that is available in a car and share that. An example is a Vehicle Relationship Management service that handles the lease and care of cars. Another one would be automated insurance handling at incidents, including arranging the pick-up and repair of the damaged car by the service supplier the insurer prefers to use, to reimbursement of costs – and adjusting the annual premium.

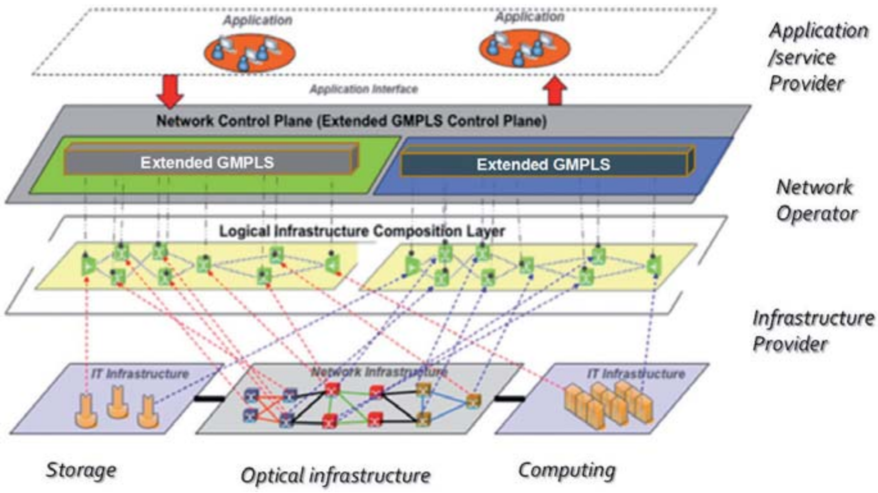

Figure 7 – Infrastructure as a service

Infrastructure could also be delivered as a service. This requires putting in place a holistic approach in which network operators also offer IT resources in an integrated platform, with clear SLAs between service provider and its users.

We also witness the emergence of a world of smart networked things: the Internet of Things (IoT). The biggest challenge in rolling out the IoT is that there are no true economic business cases behind it.

However, together the Internet of Services and the Internet of Things will shape a new world in which (intelligent) things and people can truly service users in unprecedented ways.

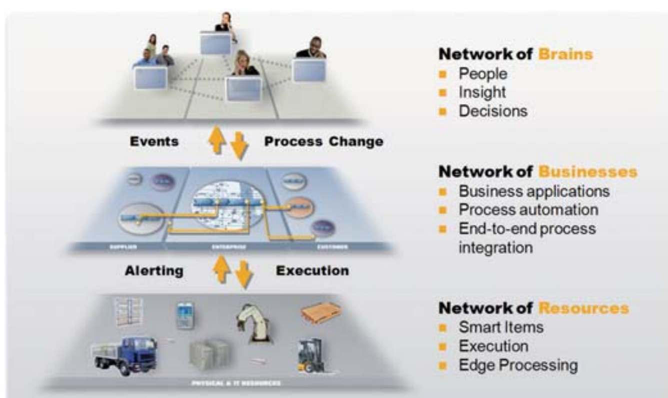

Figure 8 – Combining the internet of services with the internet of things

A web based industry will emerge on the enabling Future Internet that exists from core business services on a global service delivery platform (Internet of Services) and core internet infrastructure services that contain networks and sensors that think and communicate (Internet of Things).

Web-based Service Industries are fundamental to sustain Europe's competitiveness, and in fact there are already some in selected industries. There is a good body of knowledge and technology out there, but at the moment the "knowledge landscape" is too fragmented. The unique opportunity for the Future Internet PPP is to bring all this together.

4WARD Business Ideas and Use Cases[28]

If we think of a future Internet, it is important to consider its larger context: how will the world evolve, and what habits and needs will people have? The future internet is influenced by, and will influence, family life as well as the business environment. Communication will be supported by a mediation environment, using all devices to collect information and organise access to it. And all this will be available for us at home, in the work place and on the move.

4WARD will contribute to enabling this by further developing the concept and realisation of network virtualisation, the Internet of Things and community based applications.

Network virtualisation is a way to enable different architectures to co-exist and inter-operate in a secure and cost-efficient manner by making efficient and flexible utilisation of resources so they become commoditised.

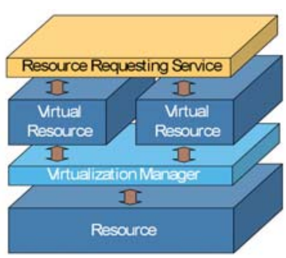

Figure 9 – Network virtualisation

Sharing of physical resources becomes possible by using virtualisation overlays. This makes many new business models possible, all based on service delivery rather than delivery of specific goods that people own and cannot share, and making best use of the resources in the network, while the quality (stability) of service will be dynamically protected by load balancing systems.

The Internet of Things (IoT) will come with enormous changes. Connectivity that already exists with many devices will eventually expand to everything around us. In this, the number of devices could range from some (augmenting personal network at home) up to billions (for instance: traffic sensors in a city). The information that becomes thus available will be used by applications in the network or on the device. All kinds of communications are possible, and this will be essential to ensure appropriate capacity for data transfer as well as appropriate security measures to counter abuse and ensure privacy.

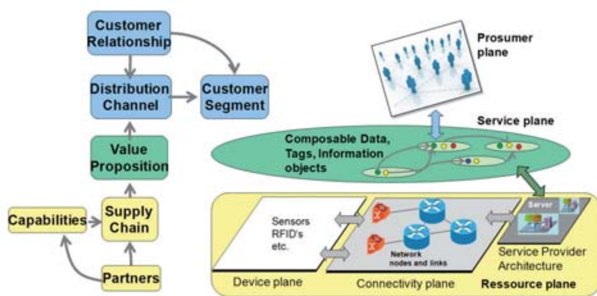

Figure 10 – Internet of Things eco system

This will enable many different applications, ranging from healthcare to transport, from environment to energy, at home, at work and on the move. Community oriented applications have come up very much over the recent years. Wikipedia and the like, social networks have been booming. For now these are mostly based on building trust by using multi-sources, and success in addressing the right needs resulted in expansion. Future Internet community oriented applications will develop "rooms" in a very flexible way, with short life relations, using profiles and metering success by the

[28] *Based on the intervention of Mr Thomas Monath, Deutsche Telecom*

value of brand (for trust purpose), security and easy to reach critical mass. The volatility of this new environment puts specific demands on profile related access, security, and support of disadvantaged social clusters. It requires self-organisation and automated processing, reducing the need for manual intervention in current network operation; distributed monitoring and control for better situation awareness, resulting in faster and more precise proactive and repair processes; virtualisation concepts which include autonomous management in a common framework and improved control and reporting functions for business management.

Usage Patterns and Revenue models of Mobile Internet[29]

Assuming that there is a flat rate model for the coming year is a key assumption for the way innovation will be driven (and financed) on Europe. With this assumption, several usage patterns of mobile have been analysed in Finland.

There is hyper competition at the moment. It is a battle about milliseconds. Switching from Google to Yahoo costs nothing. This puts high demands on competition and the need to respond to any rising issues. It has become quite difficult to estimate the value of services to customers. Helsinki University of Technology tried to measure services indirectly, by analysing how much time is spent on a specific service. Measuring usage was both done on the handset and in the network.

Network based measurements show that, when not considering iPhone, 98% of all traffic in mobile networks originates from PC's and less than 1% from Symbian based cell phones. On average, 1 PC generates 100 times the traffic of 1 mobile phone. PC's seem to do mainly P2P closely followed by web browsing and mobile handsets do mostly mobile web browsing.

If we compare at what time of the day browsing takes place, it is apparent that mobile handset based web traffic is much more stable during the day than PC web browsing or email. The top 5 websites in the mobile domain are also in the top 15 of the PC domain. New is also mobile banking and gambling.

Handset based measurements, done by implementing a chip in the cell phone of a group of volunteers, show that over the years the proportion of voice telephony in usage of the phone gets relatively lower. When asked, people indicate a usage of applications that is generally an overestimate of the real usage. The biggest thing that keeps people from using mobile services is the high pricing (42%) followed by technology implementation problems (31%).

Roaming is still a problem, as prices are experienced as extremely high: people do not want to use their handsets for Internet when abroad. Introduction of a flat rate (as there is no cost justifying the higher prices for roaming than for using access services in the home networks) would truly open innovation of mobile services in Europe.

In terms of revenue models, there are different examples out there. Revenue is also shared between different players in the networks. For instance, Google maps revenue model sees a revenue sharing between mash up sites and Google. The business logic of Google maps is more complicated than the preceding ones. It is like a hybrid of several business models.

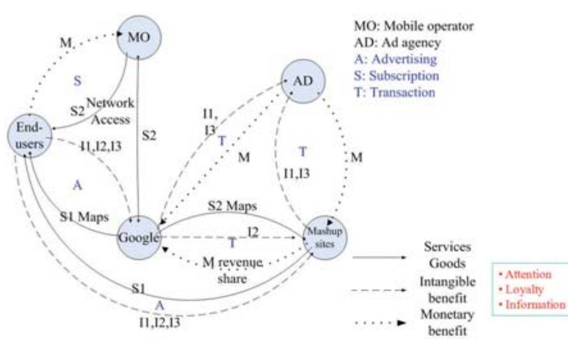

Figure 11: Google Maps value network

[29] *Based on the intervention of Prof. Heikki Hämmäinen, Helsinki University of Technology*

Google maps have open APIs for mash-up sites to integrate Maps into their services. Google's openness to the use of its maps does have limits, though. Once a mash-up turns into a large-scale commercial enterprise, Google looks to share in the revenue. Google seems to be pursuing revenue-sharing deals with sites that make money from Google Maps.

On the other hand, Google has Adsense for Google Maps which applies the generic two-sided business model. Likewise, some of the mash-up sites achieve to attract more visitors in order to sell more ads by integrating Maps into their applications. In a sample of top 20 mobile services, among other things, the advertising category outnumbers the other two, transaction and subscription, in all respects. Firstly, there are 13 services that embrace advertising model out of the top 20 selected mobile Internet services. Secondly, on the subject of market penetration rate (i.e. number of tryers)[30], the advertising category overwhelmingly dominates, with more than three times the sum of the other two groups. Thirdly, due to a large tryer base, the advertising set also exceeds in terms of the number of users. Nevertheless, the predominance is not as significant as it is on the topic of penetration rate. A potential explanation for this relatively less prevalence is services using advertising model mostly have a lower barrier of entry. People can try out these services without any cost or consequences. Yet not all the services could offer satisfactory user experience. According to Weinstein & Johnson (1999), repeated fulfilment of customers' expectation results in high customer loyalty. Loyalty in turn brings about enhanced business performance and increased customer retention rate.

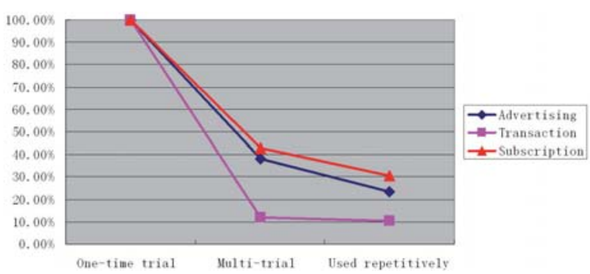

Figure 12 – Users trying services

The diagram above shows a comparison of average customer contention rates of three categories. Subscription tops in this regard. On average, 42.84% of its one-time tryers turn into "multi-trial users", of whom more than seventy percent end up with using the service repetitively. In contrast, "multi-trial users" and "repetitive users" take up only 11.90% and 10.32% of tryers of transaction services respectively. Advertising is in between, which is moderately left behind by subscription but transcends transaction with a big margin. The outcome demonstrates the advantage of subscription model, namely reduction of risk. Not only do users additionally get attached to the services, but they also pay the bill in advance which helps secure the financial standing of firms providing services.

Mobility has a big value to users, as we see on the willingness to pay. The biggest impact on the user profile comes from the personality of the user.

Policy, Regulation & Governance

Regulator View on Future Networks - The Finland case[31]

Finland is an exception on the rule that countries needed to move in telecoms from a monopoly towards competition. In 1930, there were over 800 small operators, with a total of 100,000 customers (100 customers per operator) and they had only one product: landline connection. Today, there are 200 operators with millions of customers, and many different products ranging from different qualities of landline and mobile connections to DSL services, SMS, WiMax, e-mail, etc). Resources for standardisation were lacking and there was a great need for harmonised mechanisms to ensure interconnections between local operators. Also to bridge the large distances in the sparsely populated

[30] *A "tryer" is defined as a one-time buyer to distinguish from a customer*
[31] *Based on the intervention of Mr Sami Kilkkilä, FICORA*

areas, technical telecom regulation was necessary. With strong reference to the ITU regulation tool kit, digitalisation, computerisation and packet based switching are the fundamental technological changes that have massively revolutionised the communication landscape during last two decades, and that these changes have directly influenced the communication markets and the regulation framework.

In particular, the following changes are important to note when considering regulation:

- The boundaries between IT, telecom, broadcasting and other media are constantly moving. ***New services*** combining elements from two or more of these subsectors are being created.
- The boundaries between different types of ***networks*** are also moving.
- Provision of universal access ***is one of the most important*** policy objectives of telecom regulation.
- End-to-End architecture and extension of ***intelligence*** from the core to ***the edge of a network*** is another factor that moves the development and innovation activities to the edge of the network
- The ***separation*** between the underlying ***network*** technology and the ***services*** removes entry barriers for the service providers.

It should also be noted that the emergence of mobile communication has influenced the telecom regulation at all different levels. One of the important services in the future mobile networks is data (including Internet) services.

Another complicating factor is that the telecom market has developed from a single service to a multi-service market. This raises a number of questions for regulators and a need for reformulation of the concept of network access. Is access to fixed telephony more important than access to mobile or Internet services? Can barriers to access be reduced for all services? Should different services be regulated differently?"

When the liberalisation of the telecom markets took off in the mid-1980s, it was foreseen that the former national markets would be replaced by an international market dominated by transnational operators, and that the sharp distinction between national and international communication would vanish. Partly, this has happened. The concept of end-to-end services, where a monopoly operator is responsible for all parts in the value chain, is being replaced by a more disintegrated market structure.

Now, with the development of the NGN, it is important to leave the decision of technological changes to the market, and not implement a new regulatory doctrine to already pre-empt where things may go. The future of regulations is not clear yet, as there is:

- Network – service divergence, which leaves the question whether the focus of regulation should be on networks, or on service? And what happens to network dependant numbers as that should be service dependant (i.e. E.164 numbers)
- Service change: it is no longer abundantly clear what is communication service , what is not and what of it should be regulated.
- Globalisation, which brings the challenge of regulating international players. Who would be the regulator? How can a balanced regulation between different operators be ensured and what about interconnection of global services?
- Operator business change: Which parts of the «service" should be under regulation and which not?

All together, there are more questions than answers. One clear thing is that more harmonisation will be needed towards the future, recognizing that all countries have different pasts.

4WARD Views on Policy, Governance and Regulation[32]

To investigate implications of policy and governance and regulation on the networking technologies and vice versa is one of the activities of the 4WARD consortium. The Telecommunications Regulations Handbook from the ITU lists the following generic objectives for regulation:

[32] *Based on the intervention of Mr Jukka Salo, Nokia Siemens Networks*

- Promote universal access to basic telecommunication services
- Foster competitive markets to promote
  - Efficient supply of telecommunication services
  - Good quality of service
  - Advanced services
- If competitive markets do not exist or fail, prevent abuses of market power such as excessive pricing and anti-competitive behaviour of dominant firms
- Create favourable climate to promote investment to expand telecommunication networks
- Promote public confidence in telecommunications markets through transparent regulatory processes
- Protect consumer rights, including privacy rights
- Promote increased telecommunications connectivity for all users through efficient interconnection arrangements
- Optimise use of scarce resources, such as the radio spectrum, addresses and rights of way

The list of these issues, which may be relevant also in the future networks, is already quite long and is still growing due to the increasing complexity of the systems and business environments. The Policy-Governance-Regulation working group (PGR) focuses on interconnectivity, security, privacy and confidentiality, IP Trace-back facilitation, and all this while recognizing the enormous number of actors, the variability of different nation's rules and the convergence from areas, very much dependent on historically different backgrounds. The different key suggestions from the 4WARD project have been considered from a policy, regulations and governance point of view for network virtualisation and network of information concept.

Network virtualisation
For interconnection the concept of network virtualisation (NV) (which allows joint use of resources) is an important new concept. Here is a short intro to the NV concept which was studied from the PGR perspectives.

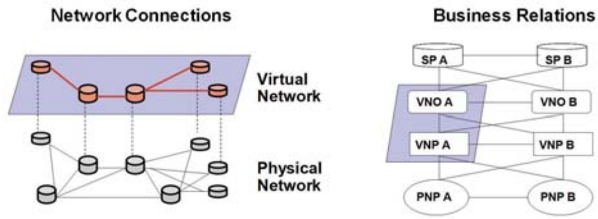

Figure 13 - Network Virtualisation

The basic elements of the Virtual Network (VN) are shown on the left hand side of the figure: at the substrate level, or Physical Network (PN) level, the substrate node is a network component capable of supporting virtual nodes by means of any virtualisation technology. A single substrate node typically contains a number of virtual nodes located in different virtual networks. Virtualisation of substrate nodes, in combination with virtualisation of the links interconnecting those substrate nodes, enables the creation of virtual networks, functionally equivalent to a physical network. It is important to realise that one single virtual network (VNet) can be created across multiple physical networks.

Virtualisation ecosystem, on the right hand side of the figure involves several business roles: (1) The virtual network user, not shown in the picture, is the end customer accessing applications over virtual networks provided by the service provider. (2) The virtual network operator operates, maintains, controls and manages a virtual network. This can be done once it has been composed or built from the virtual resources. This composing is the task of the virtual network provider. (3) The virtual network provider requests virtual resources from (4) various physical network providers, who may locate even in different countries. The Physical Network Providers (PNPs) extract a part or the entire virtual networks from their own physical resources for the Virtual Network Providers (VNPs) for later use by the end users and service providers.

The different relations between the players have been shown on the figure. The number of relations between the players can be numerous. Generic Interconnection issues are, according to the Telecommunications Handbook, divided into three categories:

- **Framework and procedural issues:** Availability of Interconnection with incumbent operators for various types of services and non-discriminatory access to Interconnection facilities and services
- **Commercial issues:** Level and structure of Interconnection charges, unbundling of Interconnection charges for different network components and related services and confidential treatment of competitive and customer information
- **Technical and operational issues:** Open network standards and technical compatibility, location of Points of Interconnection (POI), Quality of Interconnection and Interconnection capacity

The ultimate target of the regulation is customer welfare, and the economic efficiency is the key contributor to that. This is why the economic efficiency should be used as the key assessment criteria when considering potentially required regulatory actions.

Economic efficiency is defined as the best use of resources (allocation efficiency), least cost production (productive efficiency) and incentives for innovation and investment (dynamic efficiency). These dimensions of efficiency may conflict so that determining the optimal charging (Interconnection) model may require balancing differing impacts.

In the current Internet, which is made up of tens of thousands of interconnected networks, Interconnection has been normally implemented on voluntary agreements between IP Service Providers. These freely negotiated arrangements have resulted in a richly interconnected Internet and have not depended on regulatory obligations. The Future Internet, which will be more complex having several different technical and administrative domains (e.g. virtual networks) and carrying new types of traffic, make concerns rise whether the old approaches are sufficient in the future.

The Interconnections were studied having a VNet in the central point. For enabling a subscriber of a VNet to access different services and to be in connection with other subscribers, the VNet needs to be interconnected with other VNets.

As a result of elaborations of the user cases, several potential Interconnection issues were identified:

- **Point of Interconnection:** The cost of routing a message depends on the number of routers, which a message has to pass through. In a "hot potato" routing the costs are minimised by handing messages over to another network as close as possible to a network's own retail customers. This may take place also in VNets. From the total cost perspective of transporting a message, this practice may not be the most optimal. A message monitoring function would be needed to assess whether an Interconnection operator has used the most optimal routing.
- **Interconnection capacity:** For a new entrant, Interconnection with incumbents or with other entrants can be seen to be a prerequisite to start any business. Unbundling and structural separation are the approaches used for instance in the fixed networks business. An incumbent operator could prevent competition from the new entrants by providing insufficient amount of capacity for interconnecting networks, or by providing only such Interconnection capacity which is of low quality. Playing with Interconnection capacity and quality could also be used to discriminate between different Service Providers.
- **Quality of Interconnection:** The future networks will support the different classes of QoS. This is true also with respect to Interconnection. A lot of harm would be caused to end-users, if Interconnection would be of a low quality. And providing Interconnection of a low quality would benefit mainly an incumbent operator, who has the major share of the customer base. Because different classes of QoS may have different prices, they should be measured class by class. The measurement capability is important also for controlling the non-discrimination between operators and the measurement information may be required by a Regulator in order to check that the rules are followed.

- **Interconnection discrimination and Net neutrality:** Potential areas for discrimination regarding Interconnection are the discrimination by the PNP between different VNPs and VNOs, the discrimination by the VNO or Interconnection VNet operator between different VNOs, the discrimination by the VNO between various content providers (a form of second-line discrimination) and the discrimination by the VNO between third-party content providers and its own subsidiary content provider (a form of first-line discrimination). One type of discrimination, which can be fatal to the prospects of competition, involves providing insufficient network capacity to VNOs or interconnecting operators from an incumbent's PN. Network congestion can be a deadly anti-competitive barrier.

One regulatory approach to reduce, or at least assist in the identification of discrimination between a dominant firm and its competitors involves the establishment of structural or accounting separations or divestiture. Under structural separation approaches, a dominant firm is required to move its competitive operations into a separate affiliated company, with separate management, accounting records, etc. How unbundling applies to virtual resources needs to be studied further.

Another less interventionist approach that is commonly used by regulators and competition authorities to prevent undue price discrimination by a dominant firm is an "imputation approach". Addressing Interconnection of networks, including VNets, implies that their addressing is based on the same addressing scheme, or there are mechanisms for address translation at the point of Interconnection. However, since it is quite unrealistic that the addressing schemes in different types of networks would be the same, not implementing Network Address Translation (NAT) would prevent new entries to the market. Joint approaches and rules are needed for number of translations and for allocating numbering and address space for different players.

The cost of Interconnection depends on the capacity of interconnecting links, the required level of QoS, and operating costs. The cost based charging is often recommended for enabling the new entries to the markets. However, the costs need to be identified (separated) in order to prevent a dominant operator to demand high price for terminating calls that originate from a new competitor's network. Unbundling of Interconnection from the rest of the Infrastructure Provider's business would ensure that there would be fair prices for all VNet operators (including incumbent's own VNet). New charging models are needed and they should be based on the better understanding on the costs of Interconnection.

The convergence of IT, telecom and broadcasting sectors will result in that different services will be delivered in the same networks, including telephony, data transfer, information and other value added services (e.g. IPTV). The operators will have different capabilities (e.g. capacity, classes of QoS) for service offering and they may have different interests to deliver or not different services. It is also probable that the horizontal convergence of the service offering will take place independently or concurrently at different levels, which leads to Interconnection needs between domains. The different service sectors have been regulated differently and the regulatory question here is, like above: which regulatory rules apply.

For sure virtualisation of resources leads to a much more efficient use of networks and resources. The functionality of virtualisation should be regulated. There needs to be a basis to also ensure investment in keeping up sufficient capacity of interconnection. As said earlier, the ultimate target of the regulation is customer welfare, and the economic efficiency is the key contributor to customer welfare. This is why the economic efficiency could be used as the key assessment criteria when considering potentially required regulatory actions. Based on the study, the following statements can be listed under the different dimensions:

- **Best Use of resources:** Since NV means the better efficiency in the usage of the network resources and especially if several virtual networks share the resources of a few physical networks. The availability of the respected functionality in the physical network should be promoted by the Regulator. The availability of the sufficient amount of Interconnection capacity is also a 'must', but there has to be an incentive for a physical network operator to invest in the new capacity.

- **Least cost production:** For ensuring the fair competition between the VNet operators and vertically integrated operators, unbundling of the network resources and the structural separation is an option. This enables the transparency of pricing of the Interconnection resources. However, it is not clear at the moment which resources on the physical network level should and could be unbundled for the Interconnection of the virtual networks.
- **Incentives for innovation:** Currently, the different classes of QoS are not supported in Interconnection. Commonly quality parameters for different network types, globally, have to be standardised. It is expected that different classes of QoS and respective pricing would boost new innovations.

Today, cost based pricing is the approach used in Interconnection of networks. The costs arising from interconnecting virtual networks, have to be elaborated further, but could be an approach to be applied here as well. For ensuring a fair competition between a new entrant and an incumbent, unbundling of resources may be a 'must', as well as the structural separation.

Network of Information concept

The current networking technology is based on a device-centric paradigm, which focuses on the interconnection of devices. The information objects themselves are lacking identity independently of the devices they are stored on. The prevailing naming schemes, where DNS host names are part of the information object names effectively tie those information objects to the hosts (devices). In the network of information concept created in the project, the users interact at the information level irrespectively of where the information is actually stored. The network of information concept provides a uniform mechanism for accessing content, services and other digital entities and a key enabler to this approach is the notion of Information Objects. Using the notion of Information Objects means that all that is needed is the identifier of the Information Object to be retrieved.

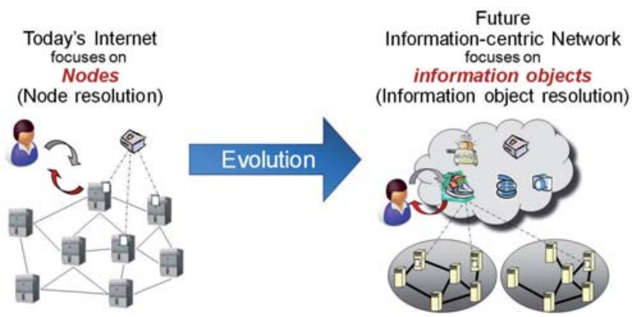

Figure 15 - Network of Information concept

The network of information infrastructure will then decide what the optimal source or sources of information are. Information may be stored at different locations in the network, including caches or user devices that have already retrieved this file and make it available to others.

Information Security is related with the requirement that the use of electronic communications networks to store information of a subscriber or user is only allowed on condition that the user concerned is provided with clear information about the purposes of such information storing and processing. Here the concern is that user information, or a part of it, may be located on different administrative domains, on the PN level, on the VNet level and even on the service level. The risk that information is accessed by unauthorised persons increases. An additional concern arises from the fact that user information may locate in different countries. Since several organisations may store user information and need access to that information, standardisation of information classification is needed. A tool is needed for a regulator to verify that the rules are complied with. The system shall support the deletion of information from all storages and cache memories and the IDs of Information Objects from the Dictionaries if so requested by the information owner. Similar rules have to be applied across country borders.

Network Security means protecting sensitive data from unauthorised access and from accidental disclosure to prevent network based attacks. In addition, a concern is that a middleman may be able to modify any information being delivered. The hierarchy of System, where the highest level is administrated by a commonly accepted authorised entity is that the hierarchy has to be accepted across country borders. License may be needed to run and administrate a System (Dictionary). Information storages and cache memories shall be protected from unauthorised access. The predetermined rules for storing and removing information shall be created (e.g. by the Regulator) and followed.

Communication security ensures that information flows only between authorised end points. This dimension deals with measures to control network traffic flows for prevention of traffic diversion and interception. It prevents unlawful interception of information and end-points of communication may not be those whom they say to be. Maintaining the data integrity of information in different cache memories may be difficult and the updates to information may not take place simultaneously to all cache memories (update may be critical for a society).

The Availability security dimension deals with ensuring that, due to network interruption, there is no denial of authorised access to communication systems for exchanging information, services and applications. Access to critical information may be endangered in different emergence situations. Authentication is the provision of proof that the claimed identity of an entity is true. Entities here include not only humans but also devices, services and applications. There are two kinds of authentication: data origin authentication and peer entity authentication. And the last dimension is user privacy. Sensitive information of a user may be unnecessarily copied to several cache memories which increases the risk that it will be illegally accessed. Combining information from several sources through data mining may result in the sensitive findings, which could be widely distributed. Different countries have different views on User Privacy, even within the European Union, despite the harmonising Data Protection Directive and the Privacy Directive.

In summary, several potential issues have been identified when elaborating 'Network of Information' concept against the requirements for Security, Privacy and Confidentiality. Potential solutions include:

- compliance by the operator with the requirements for running the system
- common rules to be established for ensuring end-to-end security
- system hierarchy with the root system operated by a globally accepted authority
- standards for exchanging information between different hierarchy levels
- identity management only by the highly trusted parties (at root of the trust chain a non-commercial entity)
- tools and approved processes to handle information (e.g. access and deletion)
- classification of information (high/low integrity and privacy requirements)
- the same rules to be applied across country borders

The study has shown that there are several potential regulatory issues related to the exploitation of the new concepts of the Future Internet. Interconnection and Security/Privacy/Confidentiality are among the key issues to pay attention to when designing the new concepts and business models of the Future Internet. The issues cannot be resolved locally and have to be applied globally (or at least be harmonised up to a certain common level). The ultimate target of regulation, the consumer welfare, will have more dimensions in the future, including community and social welfare.

The Future Internet will be a critical infrastructure and there will be different types of VNETs for delivering different types of services from voice to different types of data services, broadcasting services. In some countries Internet is regulated even today, but in the future national borders mean even less than today, the networks and services go across borders. Internet cannot be left unregulated, but what and how remains to be seen. Regulation does not mean limitation to freedom, but it can be seen to mean freedom to live in a secure way.

Research meets Standardisation[33]

The world wide research takes place towards developing the future internet, it is not only in Europe. A large part of those are within the EU framework research (FP7), but also in the US, Japan and Korea important research takes place:

- FP 6 had a number of large projects looking partly into Future Internet. From this, the Ambient Networks project was a prominent one, adding a control layer to IP but also looking at some clean slate approaches for internetworking. Another project called Nobel had also been looking into how to make use of Carrier class Ethernet instead of IP, and there were networks of excellence such as Euro-NGI, as a meeting ground for researchers across Europe. Under the current Framework Programme (FP7) there is an allocation of almost 400 M€ for network of the future research and a smaller amount for FIRE experimental research (test beds).
- US activities started through FIND, Future Internet Design, an initiative that has approved more than 25 projects mostly with 3 to 4 persons and short term oriented (1 year), with the intent to continue funding the best projects, thus spreading the remaining budget over fewer projects after every phase. There is no real coordination between projects. The budget for this activity is 10 million US dollars per year, for 3 years. GENI, the Global Environment for Network Innovations initiative, is in planning phase and has no budget approved yet by Congress, but asked for 100 million US dollars per year for 5 years.
- Japan has just recently launched a new initiative through the National Institute of Information and Communications Technology (NICT). Core is a test-bed like Onelab in Europe, but dedicated to experimental research like GENI is planning.
- Korea, through Ministry of Information launched a 3 year programme (4.4 million US dollars). Korea is a leading broadband country (by far the best fibre coverage) and these activities are also promising.

The issue is how to transform research results into standards? We need to create interoperability. A business perspective is important while maturity of research results and a commercial setting for the application is needed to make a "business case".

Network virtualisation changes the play here. Thanks to network virtualisation there is more space for novel approaches, as innovations sometimes land better in enterprise environments.

There are some attempts to investigate the need for and even start Future Networks or "Future Internet" standardisation. Some examples are:

- ISO JTC 1/SC6 is driven by Asia, with a secretariat in South Korea.
- ITU-T Focus Group, SG13 (Focus Group on Future Networks) chaired by NTT Morita-san
- IETF (and subsection IRTF), specifically for the research on internet. ISOC in particular has expressed the interest in bringing the community together to discuss cross-regional issues for Internet research, as done with Future Internet Research @IETF75. There is a need to bridge the different communities both internationally and across institutions.
- ETSI organises in March 2010 a workshop on Future Network Technologies
- Wireless World Research Forum is also interested specifically to bridging fixed Internet and Mobile Networks and across regions

Standardisation is seen as important, widely, as it helps ensure interoperability and clearly requires exchange of knowledge at several

[33] *Based on the intervention of Mr Henrik Abramowicz, Ericsson*

levels of the development process. The landscape is wide and complex and some level of simplifying the standardisation processes would be welcomed to reduce costs of the effort of standardisation.

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This work does not necessarily reflect the view of the European Commission.

Project glossary

eMobility is a Coordinated Action (CA) in the ICT area funded by the European Commission under the Seventh Research Framework Programme (FP7). The strategic objective of the eMobility project is to facilitate the emergence of a common understanding, between the European sector actors, leading to agreed road-maps and contributing to the global competitiveness of the European telecommunications sector on a number of key challenges for the networking community. Project website: *www.emobility.eu.org*

EIFFEL is a Coordinated Action (CA) in the ICT area funded by the European Commission under the Seventh Research Framework Programme (FP7). The objectives of EIFFEL are to create momentum, build cohesion and support the research, governance & policy communities by providing the European discussion forum and road mapping service that will give Europe leadership in the creation of the Future Networked Society.
Project website: *http://www.fp7-eiffel.eu*

sISI is a Support Action (SA) in the ICT area funded by the European Commission under the Seventh Research Framework Programme (FP7). The project aims at stimulating the participation in future Community ICT research of a large number of interested actors through facilitating their involvement into the Integral Satcom Initiative (ISI), the European Technology Platform (ETP) for Satellite Communications.
Project website: *http://www.isi-initiative.org*

Euro-NF is a Network of Excellence (NoE) in the ICT area funded by the European Commission under the Seventh Research Framework Programme (FP7). The project main target is to integrate the research effort of the partners to be a source of innovation and a think-tank on possible scientific, technological and socio-economic trajectories towards the network of the future. Project website: *http://www.euronf.org*

BONE is a Network of Excellence (NoE) in the ICT area funded by the European Commission under the Seventh Research Framework Programme (FP7). The project validates the results of the ePhoton/ONe NoE by stimulating a more intensified collaboration, exchange of researchers and building on Virtual Centres of Excellence that can serve European industry with education & training, research tools & testlabs and pave the way to new technologies & architectures.
Project website: *http://www.ict-bone.eu*

NEWCOM++ is a Network of Excellence (NoE) in the ICT area funded by the European Commission under the Seventh Research Framework Programme (FP7). The project is 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.
Project website: *http://www.newcom-project.eu*

4WARD is an Integrated Project (IP) in the ICT area funded by the European Commission under the Seventh Research Framework Programme (FP7). The project is running for two years, from January 2008 until December 2009. 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.
Project website: *http://www.4ward-project.eu*

List of Acronyms

3GPP	Third Generation Partnership Project
API	Application Programming Interface
CAPEX	Capital Expenditure
CogNeA	Cognitive Networking Alliance
DNS	Domain Name System
ECMA	European Computer Manufacturers Association
ETP	European Technology Platform
ETSI	European Telecommunications Standards Institute
FIA	Future Internet Assembly
FP7	Seventh Framework Programme for Research and Technological Development
FTTH	Fiber To The Home
GALILEO	European Global Satellite Navigation System
GBps	Giga Bytes per Second
GEO	Geostationary Earth Orbit
GMES	Global Monitoring for Environment and Security
GMPLS	Generalized Multi-Protocol Label Switching
GPON	Gigabit Passive Optical Network
GSM	Global System for Mobile Communications
HDTV	High Definition Television
ICANN	The Internet Corporation for Assigned Names and Numbers
ICT	Information and Communications Technologies
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IMS	IP Multimedia Subsystem
IoS	Internet of Services
IoT	Internet of Things
IP	Internet Protocol
IPTV	Internet Protocol Television
IRTF	Internet Research Task Force
ISDN	Integrated Services Digital Network
ISO	International Organization for Standardization
ISOC	Internet Society

ISP	Internet Service Provider
ITU	International Telecommunication Union
ITU-T	International Telecommunication Union -Telecommunication
LAN	Local Area Network
LTE	Long Term Evolution
M2M	Machine-to-Machine communications
MAC	Media Access Control
MANET	Mobile Ad Hoc Network
MIMO	Multiple Input, Multiple Output
NCC	Network Control Center
NGN	Next Generation Networks
NSF	National Science Foundation
NW	Network
P2P	Peer-to-Peer
PAN	Personal Area Network
PHY Layer	Physical Layer
PN	Personal Network
PNP	Physical Network Providers
POF	Plastic Over Fibre
PON	Passive Optical Network
POS	Point-Of-Sale
POTS	Plain Old Telephone Service
PPP	Public Private Partnership
PU	Primary User
QoS	Quality of Service
RAT	Radio Access Technology
RFID	Radio Frequency Identification
RoF	Radio over Fiber
RRM	Radio Resource Management
SDH	Synchronous Digital Hierarchy
SDR	Software Defined Radio
SINR	Signal to Interference plus Noise Ratio

SLA	Service Level Agreement
SME	Small and Medium-sized Enterprise
SNR	Signal-to-Noise Ratio
SOHO	Small Office, Home Office
SONET	Synchronous Optical Network
SU	Secondary User
TBps	Terabyte per Second
UMTS	Universal Mobile Telecommunications System
URL	Uniform Resource Locator
VANET	Vehicular Ad Hoc Network
VN, VNet, VNET	Virtual Network
VNO	Virtual Network Operator
VNP	Virtual Network Providers
VOIP	Voice Over Internet Protocol
W3C	World Wide Web Consortium
Wi-Fi	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access
WSAN	Wireless Sensor and Actuator Networks
WSN	Wireless Sensor Network
xDSL	Digital Subscriber Line

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