Technology Futures

Technology Evolution in Information and Telecommunications: Challenges and Opportunities ahead for Developed and Developing Countries

Roberto SARACCO[1]

Abstract. *The telecommunications evolution in the next ten years or so will be steered more and more by what is happening "outside of the network". Since its birth, innovation in the network provided the "clock" for the evolution of services and the communications as perceived by the users. This is already changing and it will change even more in the coming years. Stretching it a bit, in twenty years time, we may be communicating without a communications network, at least what we are used to call "network" today. This paper aims at presenting a number of technology evolutions suggesting the type of impact they may have on our business, as operators, and on our way to communicate as human beings.*

Some of the technology evolutions will lead to a sharp change in the "market": these are called disruptions and a number of them will be addressed in the second part of the paper. No claim is being made that what is forecasted will, actually, come to pass; however it may be as much important to foresee what "might be" as would be to "know" what it will be. Indeed assuming one knows what "will be" one would have nothing to say or do about it. Understanding what "might be" generates action and eventually may contribute to make it happen or to hamper its happening.

In the last part some considerations will be given to the challenges facing developed and developing countries. Evolution in technology and market provides plenty of opportunities …and threats.

Out of these evolutions we can imagine changes in the service offering and impacts on many "ambients".

Country wide policies and enterprise strategies are often taking different paths. Five main challenges will be outlined to better emphasize the different perspectives of these constituencies[2].

Introduction

The communication world has kept evolving and will obviously continue to do so. Sometimes we might get the impression that the speed of evolution is accelerating: actually it is a perception deriving from a steady progress that, measured in time, is actually creating a "crunching" effect. The Moore's law by

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[1] TILAB Telecom Italia, *via* Reiss Romoli 274, 10148 Torino

[2] Note: this paper summarizes a talk given at the Bucharest Fistera Workshop in Fall 2004. It draws on previous papers and more specifically the one submitted at the WTC conference in Seoul, May 2004 and the one submitted at the UNIDO conference in Budapest in 2003.

predicting a steady progress of computing power, a doubling every 18 months, is actually meaning that in the next 18 months we will see an increase in computation power equalling the one we have experienced in the previous 35 years. No surprise that it seems we are in a whirlwind. However, as swift telecommunications evolution is, the real big changes are coming from quite different directions. Our networks have been leading the way, more, have been showing the way services can and should evolve (take advantage of the network intelligence, exploit the digital revolution, leverage the increased capacity offered by the broadband…). No more so. Now it is what is happening at the edges of the network that is steering network operators' strategy to upgrade and restructure their networks. Service providers are looking at the terminals and people "moods" to invent and propose new services. If a network is not able to provide what is needed to accommodate the request, well, another one will be and it may take little investment and time (relatively speaking) to create instant local networks …in the future even this may be unnecessary. Terminals, by their very existence, may create the fabric of communications.

This is the consequence of several innovations in various technology areas. Actually today's, and tomorrow's, technology offer is so rich that it is becoming nonsensical to focus on the evolution of a specific one, although important. What is needed is to look at many technologies serving a given purpose and see their global evolution and interplay. This is what may be called technology trajectories and it will be addressed in the first part of the paper.

Something new has happened in the last 10 years, something that is likely to create a significant imprint on the direction of evolution.

Twenty years ago the discussion was on whether the evolution was technology push (technology evolved and push towards its adoption thus changing the world) or market pull (the market was dictating the adoption of technology, hence its impact).

Research funding today has become more difficult and researchers have to present prospective financers with an understandable proposition. Research money will go to those areas that seem most promising from the financers point of view. But giving money in certain area leads to a faster evolution in those areas: today we are looking at a market push, the market is not just adopting innovation it is steering the evolution of technology.

This is not very good in general terms. It is not good for enterprises in the long term, it is even worse for countries. The risk is to pursue linear innovation setting in motion a machine (technology evolution) that has a significant inertia. The market may shift suddenly and displace those companies and countries that bet on the wrong horse.

Technology evolution may be linear, or may lead to discontinuities. This is irrelevant. What really matters is understanding if there may be a point where the rules of the "communications" game are changed, when a disruption in the business, as we see it today, may occur. That will be the aim of the second part of the paper.

Notice how the important changes, from enterprise and country point of view, are those happening at the value chain. Market and technology evolution may shift value along the chain annihilating a number of actors on the way.

Think about the companies that sold spelling checkers twenty year ago. That feature is now embedded in any word processor and their business has disappeared.

Think about the equipment providing the digitalisation of voice at the edge of the network (PCM). In GSM and UMTS network this happens within the terminal and that business simply vanished. Think about Skype or the bundled offered made by cable companies in the USA to carry voice over IP or cable. The voice market as operator are seeing it today may well disappear.

The ideas presented derive partially from work carried out in a EU funded project, FISTERA, aiming at forecasting evolution scenarios in telecommunications with the ambition to help decision makers to direct research funding where it could be more effective.

Technology Trajectories

There are several technological evolutions that will play a significant role in our business. Table 1 lists a number of technology trajectories and the impact they may have. Here I will consider two of them in more details: storage and processing as a point in case.

Table 1

Technology Trajectory	Expected Evolution in the 2010 - 2020 timeframe	Expected Impact
Storage	More and more capacity available at a very low cost. Storage infrastructures play a key role. See text for details.	The traffic quality (and quantity) may vary significantly. New architectures may be required. See text for details
Processing	The cost of processing spirals downward. Processing power will be embedded everywhere. Grid architectures are not going to play an important role beyond 2010.	Progressive growth of autonomous systems, more objects become "users" of communications facilities generating significantly different types of traffic with respect to voice traffic.
Information Visual Display	Low cost flexible screens make image display possible on many objects. Large screen will become, beyond 2010, a usual sight in homes. Better capabilities for image manipulation.	Increasing demand for image transmission, including on the move. Demand for bandwidth to "fill in" large screen so that close range vision is not blurred. Images become an important part of interactive communications.
Printing	Possibility to print tags along with text and images make printed stuff interactive, when needed. Possibility to print 3D objects extends the range of demands. Foils may come to embed printing capability.	The amount of printed material, that will keep growing, will turn into a generator of traffic. Interactivity will see printed matter as an important component. E-books become terminals and will play a significant role in service offering.

Table 1 (continued)

Information Retrieval	The amount of information produced in various format will keep increasing (doubling every 3 years for the next 15 years at least). Retrieval will become a fundamental issue and will be context sensitive.	The value is shifting from accessing information to getting the information that makes sense to the retriever in that particular situation. Profiling, context aware, "push", "hyper linking" services will make a difference.
Communications	Alternative ways of communications will be the norm, a variety of access types mostly hidden from the user perception. Voice remains the leading perceived communications, plus lot of backstage "traffic".	New network and service requirements to support seamless synchronisation among different communications streams, merging of network and local data, piggyback on a variety of access points in a seamless transaction.
Bandwidth	Growth of bandwidth offer pushed by technology availability, very seldom driven by market demand. Fibre spread in the distribution network, wireless in the home environment and public access.	Burst communication takes the upper hand because of economic advantage. Information transfer speed becomes a premium service offering (diverging from bandwidth which will tend to become a commodity).
Human Interfacing	Terminals become more sophisticated supporting a variety of direct and background communications, local storage, local environment exploitation. Affective computing, agents play a significant role.	Local area networks are becoming a crucial part of the network. They may over-ride the network itself by being perceived as the ones really important for the service (not just for service delivery). Will there be any network service left?
Data Capturing	Millions of low cost sensors, organised in local networks, able to detect a variety of parameters. Local processing capability and, in perspective, the potential to react to perceived changes in the environment also on command.	Sensors networks may be seen as terminals accessing the network through a gateway or become part of the network. Operators may consider management services and deploying sensors networks, then selling data as services.
Pin-pointing	Localisation information available everywhere, potentially to any object. Tracking capability, with features to protect privacy, makes it possible to link with any inanimate or living thing.	Significant amount of transaction oriented traffic. Very low revenues unless it is priced in terms of service. Who will provide the service: the telecom operators or some independent service providers?

Storage

Storage will keep evolving in three directions: the ROM, the Read/Write and the infrastructure. All of them are going to have significant implications on the telecommunications business. ROM is provided by technologies like silicon (13 nm in the next decade providing 100 GB memory chip), polymer (TB capacity by the end of this decade at very very low cost) and holography (TB capacity offering very interesting local retrieval capability). The vast amount of storage capacity at low cost means that one can imagine going to a movie and for the price of the ticket receive a plastic, credit card size, memory containing 2000 movies. Once back home one could peruse the movies at whim for, say, 3 minutes each and if interested "order" one of them through the network. No downloading involved, just the sending of few bytes with the credit card information and receiving the decryption code. No broadband requirement either.

Read/Write memory is also increasing storage capacity, compact flash will be up to 100 GB in the next decade, hard drive are already as tiny as a coin sporting 4 GB and fitting in a cell phone for 10$ or less, massive hard drive containing hundreds of GBs. This means that information can be transferred by the content provider to the local storage with –normally- no need for streaming. A movie can be requested to be seen, let's say, three hours from now. The content provider can negotiate a cheap transport of 2 GB from a number of network providers with the sole requirements to have those 2GB downloaded within the next three hours. Hence, burst communication, no more "costly" streaming.

Storage infrastructures are going to change the architecture of information management with big implication on telecommunications. Huge local storage means that people will download lots of information (as it is already the case with Divx movies); this coupled with flat rate stimulates local cashing. One may access a web page and an application in background downloads all pages linked from that page. Once you click on a link the page is already there and the cycle repeats. This is wasting a lot of transmission capacity, which can be an issue in the metropolitan area.

Distributed storage architectures are taking up a new meaning: rather than being used to achieve higher reliability they may become a way to integrate data available in different DB into a single information as it is already happening with the National Virtual Observatory, NASA, where requesting a picture of the sky from your computer results in the access to hundreds of DB having a picture of that part of the sky and integrating those into a single picture shown on your screen. This gets rid of all noise existing in the original pictures by carefully eliminating inconsistent data. This can go far beyond, like it is proposed in the OceanStore project, resulting in a completely different way of archiving personal information. The telecommunication network may find a huge request of traffic from software agents trying to convert data into valuable information. Finally the infrastructure for synchronised storage will become a significant service offering. It will ensure that information each of us (and enterprises) is harvesting during the day, and years, independently of where it has been stored, can be seen seamlessly and adapted to the specific situation. Locally stored information may be constantly updated or just when it is required. As we roam through a city our information in the PDA may be constantly and seamlessly updated as we cross convenient hot spot where bandwidth is abundant and cheap. The concept of virtual transaction maintained across a variety of access points will become a selling factor for those able to provide it.

Processing

Processing technologies have evolved in these last ten years to differentiate significantly depending on the application area. We need to look at these areas one by one to understand future evolution. Specifically, it is useful to consider processing for *calculus*, for *information capture*, for *displaying of information* and the one used in *communications*.

In the *calculus* area, microprocessors are most likely to continue the spectacular trend epitomized by the Moore's law for the next 6-8 years, a doubling in the number of transistor on a chip, and thus of the processing power, every 18 months. We should be reaching 28 GHz processors' speed within the next decade with parallel computation architectures delivering TFLOPS to the desktop (thousands of billions operation per second). Supercomputers will leverage on microprocessors capacity by clustering hundreds of thousands thus reaching capacity in the order of 100 PFLOPS (millions of billions). Supercomputers are likely to remain a niche sector with USA and Japan playing as leading actors.

The increasing processing capacity is unlikely to be absorbed by the consumer market (that is the one making the pricing structure) and we can expect a saturation of demand within the next 3-4 years. The first signs of this market slowdown are already visible in the USA with a resulting lengthening of the PC life cycle. Today we are seeing a clear shift of manufacturers towards an offering that merges PC and television, rather than keeping on stressing processing capacity.

These gap between offer and demand is leading to a slashing of microprocessors prices (as it had happened for low performance microprocessors, like the over 20 years old 8080 that we find today in electronics keys or electronics locks in many hotels). Within the next decade the drive towards an ever increasing processing capacity is going to to slow down significantly and it may result in invalidating the Moore's law well before reaching physical barriers.

Microprocessors leadership in the medium period will continue to remain in the USA hands. China may become a player in the next decade (look at the sale of the PC IM unit to Lenovo) but given the excess of processing capacity this may not be a real issue.

Another important component in processing evolution in this decade is the Processing Grid. We are likely to see significant developments in scientific and in some business sector, such as pharmaceutical products. Within single enterprise it is likely to see the adoption of GRID architectures based on the enterprise Intranet. However if we look further into the future, in the next decade, it is likely that the GRID as a tool to deliver massive processing capacity may lose interest given the continuous increase of local, low cost, processing capacity (something similar happened to the idea of the network computer in the nineties).

Europe and USA have, so far, the leadership in the GRID area and this is unlikely to change in the coming years.

In the *information capture* area the coming years will see a progressive penetration of microprocessors in sensors and more generally in any object. This kind of microprocessors, at least for the next ten years, will be characterized by a very low power consumption and therefore will be different from the ones used in calculus.

In spite of the low consumption their processing capacity will keep increasing reaching the MFLOPS level. Besides it will become important to acquire auto-configuration capability, local storage and capability to interact with many others via ad hoc networks. These networks will be used as ways to achieve local intelligence and to decrease the power request for communication over wider areas.

The digital signal processing (DSP) will be an integral part of these microprocessors and it might even be that they will result from an evolution of current DSPs.

The United States are presently on the leading edge in this evolution but Europe and South Korea may become major players leveraging on their assets in cell phones manufacturing.

The *information display* area has seen a progressive specialization of microprocessors resulting in a separate industry for graphic boards as add ons to PCs.

At present the technology provides few hundred millions polygons per second (the usual way to measure their processing power) and by the end of this decade we can expect to hit the billion polygon per second.

The demand, taking into account the evolution towards 3D visualization (also in the movie market) may level out around 100 billions polygons, a threshold that can be reached in the first part of the next decade. At that time we might be seeing an integration of this kind of processors in the ones designed for calculus.

Today USA are leading but Japan may become the major player within the next 2 years as result of the significant investment being made in research today. The computer graphics has already over flown from the scientific application area into others and is now being led by the consumer gaming (as witness by The Cell, the joint microprocessor developed by Sony, Toshiba and IBM that is sporting an integration of the processing and the graphic application on a single chip).

Consumer electronics is paving the way to the evolution in the television area. High definition television, its evolution towards the digital is already happening, the connectivity to internet to foster interactivity and integration of human like communications fit to the living room are all elements pointing to an increasing role of South Korea and Japan in the second part of this decade. This trend is likely to continue since there are no signs of significant investment form Europe and USA in this area. Notice how this same actors are also heavily investing on the evolution of display technologies (like SED and NED) as well as on the evolution of home connectivity (both local –wireless- and to the network with ADSL reaching 40 Mbps speeds and optical fiber providing connectivity in excess to 100 Mbps).

The evolution of microprocessors in the *communication* area is partly mirroring the general increase in performance we see in calculus but has some specific characteristics, such as the low power demand (specifically for the cell phones area) and in the capability to support a direct interconnection with optical fibers.

In this area the evolution of the SIM card has a particular interest for telecom operators. Today most applications run in the cell phone itself (the client part, of course) but Operators would rather have them running in the SIM. In perspective the SIM may slip off the cell phone to enter (physically or virtually) in many appliances. In this case the evolution of the microprocessor will play a significant role and due to its packaging it has to be considered as separate from the other areas of microprocessors. The evolution is towards increased storage capacity (in the tens of MB within the next two years) and possibly in a merging with memory cards. Additionally we should expect much greater communications speed between the SIM and the cell phone.

Fixed and mobile operators have a lot at stake in this area. It remains to be seen if they will succeed in achieving the required technical and political support to steer the evolution. Surely a much stronger cooperation with smart card it is possible, in a market that is dominated by East Asia.

All discussion made so far has been focusing on the microprocessor, that is on a processing structure based on the “von Neumann” paradigm of computation. Looking at the next decade it may be worth considering that we may expect other kinds of computational paradigm, hence significantly different processing architectures.

One of this new paradigm is the molecular computers. It is particularly fit to process statistical computations. There are already a number of applications, such as the sequencing of the DNA and a further impulse may come from the growing interest on organic sensors.

These processors, however, are not competing with the classic areas of application for microprocessors.

A further paradigm is the one of quantum computers. Here, in spite of a few prototypes, we are still at a theoretical stage. The potential application sectors are interesting (cryptography, complex systems, finance, bio-environment) but it is not possible to make any forecast on the viability of this paradigm in practice. For sure it will not become available in this decade (even a breakthrough tomorrow will not be sufficient to have an industrial product available within the next five years).

Half way between today’s microprocessors and these new paradigms are the microprocessors having a dynamic wiring that can be configured dynamically as needed, such as those being studied at the CMU in Pittsburgh.

These aim at offering an increased flexibility in terms of functionality and hence can be better exploited by software since they would adapt to the task at hand.

This kind of processors may have an impact by the end of this decade and find interesting application in the cell phone area to better exploit software radio in an environment where low power consumption is of paramount importance.

Disruptions

Disruptions will happen and most of them is unexpected today. Looking at the technology trajectories and at the market, however, it is possible to make some guessing on possible disruptions that may happen in the next fifteen years. It is, obviously, a lot of time but it makes sense to have such a long horizon discussing what might happen at a global level, which is the one where disruptions occur. Several of them have been identified in the FISTERA project, and are summarised in Table 2. In this part one disruption, unlimited bandwidth in wireless access, will be presented in more details to serve as an example on the type of reasoning that led to their identification.

Table 2

Disruption	Technology Enabling Factors	Market Pull Factors	Impact on the Industry
Transformation of products into services	Embedding of communications capabilities into any product; competitive advantage derives from profiling, cheaper manufacturing	Products are becoming commodities; loss of differentiation capabilities, increased copycat possibilities	Enterprises become service companies; Shortening of product's life cycle, Strong increase of call centres; More global market, Restructuring of the value chain
The disappearance of the computer	Diminished processing cost; System on chip; Wearable computers; Increased connectivity and ubiquitous access	Need to increase volumes; Need to increase flexibility; Need to provide easier access to functions	Skill to exploit increased processing capabilities in any object; New level of competence required; New actors and competitors in the value chain
Ubiquitous seamless connectivity	Increased connection capabilities for any object as result of object capabilities and access points availability; Variety of infrastructures; WPAN; Software radio	Mature market drifting toward flat rate; Demand for transparency; Drive to decrease cost; Bundling communications into services and goods	Shift from connectivity to service; Bundling of services; Seamless service hopping; Crucial importance of profiling; Embedded connectivity demand; Increasing opportunity to offer new services
Changing traffic pattern	Huge amount of local storage; Sensors, tags; Digital Camera, Camcorder; Agent communications	Growth of peer to peer as content production is more and more dispersed and shared; Flat rate and always-on tariffs	Push towards the transition from ADSL to VDSL; Push towards optical access; Always on, ubiquitous wireless access and seamless connectivity across access points

Table 2 (continued)

Unlimited bandwidth See text for details	Advances in propagation studies; Terminals as network nodes; Cognitive radio; Software radio; Mesh Networks	Need for ubiquitous connectivity; Variety of local access operators; Great variety in traffic demand	Incumbent Mobile Operators; New Mobile Operators; Service and Product industry; Regulatory Framework
Disposable products	Diminishing cost of production “per item”; Increased flexibility and customisation; Long lasting batteries; on-site production; Short range embedded connectivity	Faster pace of evolution for fashion and design; Shift from products to services; Function oriented interface	Evolution in the value chain; Faster evolution life cycle; Evolution in customer care; Recycling as a problem: as part of production and as a service
Autonomous systems	Increased processing power in objects; Increased flexibility in terminals; Agent technologies; Ad hoc networks; Local world mirroring	Sensors and sensors networks; Overall increased complexity; Heterogeneous systems; Fast asynchronous evolution	Network Operators dilemma: A.S. as network users or as part of their offering; Virtual networks providers; Service providers; Engineering challenges
From content to packaging	Diminished cost of content production; Consumers’ based content production; Information as a “by product”; Multimedia and multimode; Profiling	Abundance of information; Need to get rid of information; Difficulty in controlling the ownership of content	Reshaping of the content industry shifting towards content bundled into services; Rise of the packaging industry; Ambiguity in the telecommunications industry biz to be resolved
The emergence of virtual infrastructures	Ubiquitous, seamless communications infrastructures leveraging on WiFi, UWB, Multimode terminals, WPAN; Wireless broadband; Increased local storage; Agents technology; Intelligent Ambient; Mixed Virtual Reality	Globalisation of business; increased circulation of people; Leveraging global investment	Telecom Operators see a growth of competition with a growing loss of the network ownership advantage; Emergence of Virtual Telecom Operators; Consumer Electronics opportunity; Computer industry used as underlying platform

One of the assumption on which the current wireless market is regulated and exploited is the limited availability of spectrum. Increasing the bearer frequency to have more spectrum available requires better and more costly electronics (and this has been done over the years from MHz to GHz) but, and this is the real problem, it is also weakening the transmission (adverse effect by weather condition, foliage…). Cramming more information within a given spectrum available creates interference. The Shannon theorem provides a figure for the maximum number of information a given spectrum within a given environment (signal power and noise/interference) can “carry”. This theorem, however, is only considering transmission over a single channel and does not say anything about using parallel channels and resolving the interference at the channels ends. New theoretical, and practical, progresses indicate that indeed it is possible to solve interference at the receiving terminal level providing that such a terminal can negotiate with at least n+1 terminals where n is the number of interfering channels. The practical obstacles in implementing such a terminal is both processing power and battery. The former will surely be solved within the next five years; the latter is still a question mark. By the end of the next decade, however, one might assume that swarms of terminals (such as the cell phones populating a metropolitan area) will be able to communicate with one another without a network and resolve interference thus providing for a basically unlimited capacity to carry information. The more users there are the more terminals you have and the greater capacity to carry information. The terminal will be “the network” and therefore the network will grow along with them. In such a situation the current rules, and regulations, will be moot. A completely different environment will be in place with significant impacts on many industries. Someone might see such a perspective as a doom bell for wireless operating company. Personally I do not think that this will be the case. First, there will be a significant time for these companies to get prepared; second, the value will have shifted from the pure connectivity to service and profiling. These companies are likely to have developed the best offering for their clients and any increase in network capacity will just be a “bonus” for them. In a way they may be left with the revenue stream without the network up keeping cost (not quite…but it gives the idea).

Impacts on the Telecommunication World

Terminals will play a much greater role in telecommunications evolution thanks to technology evolution providing more processing, storage and embedded communications. They will be offering new ways of capturing, presenting and sharing/communicating information. The terminal market for a while will be dominated by volume: only a few big companies can afford research and production cost by leveraging on huge volumes. A second phase will see terminals acting as hubs, with on one hand a local personal communication networks allowing mini terminals to communicate as a self organised swarm and on the other hand connecting with the most appropriate network for a given service in a completely seamless way (hidden to the user). In this phase a variety of industry will piggy back on the products offered by the big ones, as it is the case today in software with thousands of companies leveraging on Microsoft *de facto* standards. A third phase will see terminals taking up a growing role in the communication infrastructure. The definition of terminal fuzzes: sensors networks may be seen as terminals, some Telecom Operators may see them as infrastructures and will take an active role in their deployment.

As physical infrastructures take a backstage in the evolution scenario, soft infrastructures will take a centre stage. Several layers of data relations create information that will be customised as a service. In many cases information will not be a bunch of bytes located in a very specific place, rather a set of relations interpreted by a service (application) that as a matter of fact "creates" the information. Profiling will play a key role as well as raising difficult questions on privacy. Technologies like the one of autonomous negotiating agents may become crucial in this area. Profiling will find application to make use of RFID tags, labelling any object and service (soft tags), and will be a main actor in preventive and personalised medicine. Pervasive communications infrastructures extending to BAN (Body Area Networks) will be an essential part of the future scenario.

New Services and Paradigms Enabled

Disruptions like the ones presented have the potential to change the way people satisfy their needs. They do not change the needs, at least not in a few years. Basic needs tend to stay the same, people ate, eat and will keep eating. However we have moved from direct food harvest and preparation to getting it off the shelf. In perspective it may turn out that preparing food for eating will be more related to satisfying aesthetic needs than the need to make it edible. Pills may be sufficient for "feeding" but they may not be appealing for many years to come. Still, cooking technology made possible to standardize and quicken food preparation and now we've got hamburgers by the billions, the fast food era.

I would like to consider applications in a number of fields, more as examples than as real scenario for the future. Each of these examples should be transformed into a scenario and several approaches are possible. I will be discussing some of these issues in the last part of this contribution.

The home environment

Homes in the next ten years can become at the same time more personalised and more open.

Lot of information will be contained within our homes and tools to seamless use this information will become available. We will be able to store thousands of movies and television shows, but also all lessons we have been listening to when at school, training sessions at work and possibly several clips of meetings with clients…

Depending on what we are looking for and what we have available to display the information, applications will gladly oblige in delivering what we need when we need it.

Information sharing will become crucial. In the home we share the walls and appliances with our spouse, with the kids…possibly we do not want to share all information with all of them.

Information porting will be essential. As we depend more and more on information and all information is clustered in the home I will require to have part of it packed along with me as I go to the office or I am on the move. Access to information back home will also be an important service.

At the same time home will become more open. Wall sized screens can create artificial windows. In the kids' bedroom a screen can connect to grandpa living room, hundreds of kilometres away and let kids talk and play with their grannies.

Even if I am outside, I will be at home. Anyone ringing the doorbell can get to me. My home will route the doorbell to my cell phone. Through its screen I can see the person at the doorstep and talk to him. I can even let him deliver a package by opening the garage door from my cell phone and of course activate a transaction to pay for the delivery.

Homes can be clustered electronically to form communities; information can be shared across these communities, as well as applications and service. Babysitting and kindergarten can assume new shape.

Some appliances may be transformed from products into services by a market that is eager to keep a constant link on its clients. As an example, rather than paying to buy a washing machine we can have it in our home by paying for its delivery and installation and then paying for every laundry. The retailer will keep monitoring its washing machines providing for fixing whenever needed and informing us if he has to come to our place to change a part or replace the machine.

We can use the machine to inquire on how to remove a stain from a sweater and there may be shops suggesting us to buy a certain robe not because it is washable at home but because it comes with a special software that will make our washing machine to handle it correctly.

Healthcare

Healthcare is very up in the priority list for anyone of us. Sooner or later we are going to need it for us or our loved ones. It is very high in the cost budget for any country as well.

New technologies and infrastructures can significantly increase the quality of healthcare and decrease, at the same time, its cost.

The developments in sensors and in telecommunications access networks enable continuous monitoring of patients. Hospitals can really become without walls[3].

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[3] From the name of an Australian project, Hospital without wall, whose goal is to enable the cure of patient living in their home from medical personnel at the hospital.

A day in a hospital may cost 1 000 Euros and up. Setting up an ADSL connection with the required sensors to allow the monitoring of a home based patient from the hospital has about the same cost. We can swap one day at the hospital for a year of remote monitoring.

I believe governments should pay serious attention to this area. They can cut cost in health care by sending patients home sooner, without decreasing the quality of the medical care. At the same time they increase the quality of life of patients and their relatives and create a broadband platform that can be exploited for a variety of other uses. Once a patient finds his house ADSL enabled in order to be monitored by the hospital (and he can have it for free in the first year, since the cost of subscription can be paid out of the saving of the hospital) he is likely to use it for other services (and he may be required to pay something for it). Cutting cost and reinvesting in productive areas is the way to go.

Additionally, sensors in everyday objects are going to increase the self monitoring. Just brushing teeth every day provides sufficient data for a continuous check of several biological parameters. Proactive medicine may become much more common and effective.

In the longer term, in the next decade, we will start to see personalised medicine. The mapping of our proteins will let medical companies provide us with customised medicine, much more effective and with lower unwanted side effects.

Implanted chips can deliver medicines just right for us at the best time.

All these innovations will go a long way in increasing health care in developing countries and in making it viable. Doctors do not need to be there for most ailments.

Education

Education has not changed significantly in 2500 years. It became more widespread, we learn today in college what the best minds of 500 years ago had no chance of knowing.

However my bet is that education will change significantly in the next decades. The world is changing rapidly; a student needs to keep studying through the rest of his life[4]. Paradoxically, enterprises cannot afford retraining of their employees. The more an employee is crucial to the business, the less likely the employer is willing to "waste" part of his precious time for training. And the smaller the company the more this paradox holds true.

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[4] Recently the director of the American Treasury addressing a class of students said: be prepared to change job at least five time during your professional life and be aware that 3 of those jobs have not been invented yet.

Education should become part of the individual investment and it should become part of enterprise processes.

The individual will need education tools that can help him retrain constantly within the very limited amount of time available. Reading the daily newspaper can become an occasion for learning. Software agents can monitor what the needs are and what I am doing everyday. Based on that, windows may pop up at appropriate time to give me more information on specific topics so that I can learn a bit more every day. And we know that from a pedagogic point of view this is the best, most effective way to learn.

The enterprise can create and control a knowledge inventory and set strategic direction for its evolution. They can team, as a company, to education institutions and have them devising focused strategies to deliver training on the job. Based on what a person is doing, its expected area of work in the coming months and the evolution of knowledge, internal to the company and in its environment, every day actions can be made more efficient by prompting ideas, suggestions, guidance that are also training pills.

At country level education can be pursued as a strategic process and delivered leveraging on new technologies. Interactive television may be a good platform to deliver education. Private companies can deliver the entertainment, what people are looking for, but part of the interaction can be driven by education purposes.

Schools are, obviously, primary target for experimenting new ways of teaching. They should not teach internet, they should use internet, when appropriate, for teaching. New technologies may also improve learning capabilities to some kids that have some difficulties. Learning backpack, such as those in trial in some schools in the US, may keep the teacher with the pupils all day long so that they can learn at their own pace.

Tourism

Tourism is an interesting space for innovation. When people play the role of "tourist" they are more relaxed, usually willing to experiment, they have more time. At the same time, in some types of tourisms, they are willing to get more out of their experience and technology can help in doing just that.

From a business point of view, tourists are more willing to spend money, developing countries can attract wealth from abroad and be smart in mixing local attraction with tourist expectations.

Infrastructures created for tourists, and paid by them as they use the services, can offer a variety of services to locals, at a lower price.

Communications is crucial in improving the tourists' experience and enabling new services.

A tourist may come to a distant place and remain in touch with home and his friends. He can share his experience with them, on a day-by-day bases. Bloggers[5] like services can create a recording of the tourist experience. Access to this information can occur via dedicated terminals or just through a cell phone.

Tourism is a business area with many stakeholders. Hotels, artisans, guides, local municipality, transportation companies, content creators are just a few…

In the next decade we are likely to see virtual guides appearing as well as virtual shows and entertainment. Walt Disney, to name one, may set up thousands of virtual amusement parks all over the world. People going to, say, Budapest, may subscribe to a Disney virtual park in Budapest. That will provide them with plenty of top notch entertainment that leverages partly on local attractions and mostly on the capacity of Disney of turning that into an entertaining experience. The add-on is made available to the tourist by special, but progressively common, equipment, such as 3D display projecting directly on the glasses. Becoming part of the value chain is going to be essential to avoid being ripped off by those who have technological assets.

The production network

Although we will live in a world with hundreds of thousands of products and thousands of services, possibly customisable to single customers, with the greater variety we have already become accustomed to, the production processes will be based on few standardised blocks.

Innovative products will likely be produced using standardised processes and even innovative production processes will be based on few hundreds of basic components.

How could we imagine such a variety of end products (and services) stemming from relatively few production "bricks"? The key is in the flexibility of these production bricks.

Take the area of drug development. We are moving from a situation of very few products responding to a market of 6 billion people but developed in a variety of ways, basically one for every product, to a situation where we will have potentially million of products each one fitting specifically a single customer. The protein genetic mapping of the individual will be used to create customised drugs, basically on the spot.

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[5] Bloggers are now quite widespread in the US and they are also widely used in Europe. Basically it is like writing a diary and posting every thoughts on the internet in a special place shared by millions. For each thoughts (a blog) the author can decide with whom he wants to share. A specific person or a specific "kind" of person. During the Iraq war an Iraqi boy set up a blog that became a point of reference to understand what was going on there as seen by Iraqi people. www.blogger.com

Newspapers are likely to become more and more customised. In Venice we have activated a showcase with several historical characters interacting with visitors. At the end of the visit each visitor can print out her own guide to visit Venice according to the interest she has shown during the interaction.

Research will become more intense at the production level, and this is a significant change from the present phase where basically research is clustered in dedicated labs[6]. The flexibility of the production process and the competitive advantage deriving from customisation is the driver for this shift. Several are the enablers.

On the one hand technologies and systems to profile customer needs (and whims) will let companies to better understand their customers and on the other hand GRID related services will make it easier to retrieve applications made available by any company.

Pervasive infrastructures, both physical and logical[7], make possible this sharing.

As an example, companies sharing an environment, like those in the Adriatic basin, may find that exchanging information can be of mutual benefit.

By 2010 we can expect that language barrier will no longer exist. Text and voice can be translated automatically from one idiom into another. Semantic engines, already available for advanced applications, can help in making sense out of lumps of information.

Fishing industry on both side of the Adriatic shores can share information on fish schools, health and reproduction situation, processing resources, market request and behave accordingly. Only loose agreements may be required and each enterprise may work according to its own goals and practices. Still, the shared information may be beneficial to everyone, decreasing cost and improving effectiveness.

Multimodal transportation

End to end transportation, for goods and people, will become the focus of research and applications. We already see this happening in various countries for goods transportation. Package delivery by express courier has reached a tremendous level of sophistication. We can track a parcel almost in real time and swift it from place to place in very effective ways.

Transportation of people has not reached this sort of efficiency. There are many hurdles that are hastening it. Cars, for one, are seen, psychologically, as a ownership issue. There are technologies that would allow an easy sharing of cars; cars may become a public infrastructure and I can ask for one of them when I need it and pay for its use. If you look around you'll see many cars moving around but

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[6] We will still have dedicated labs; research at the production level will be an add-on, not a substitution. This may happen within ten years time, by the next decade.

[7] In many countries we have extensive and pervasive physical infrastructures and they will further evolve in terms of capabilities in the coming years. Developing countries will need to invest in these physical infrastructures.

many more standing still, parked for many hours. That is clearly a waste of resources, still no one of us is willing to give up his own car.

Personal transportation is not integrated in a seamless continuum. I use the car and then I spend most of the time looking for a parking lot. Once I found it I need to walk, often a long way, to get where I need to. It would be convenient if, when I board my car, I could key in the place I want to get to and receive the information on how to get there in the shortest possible time. First go to route x, exit at y park at lot z. Then get on the bus that will be right there when you reach the parking lot and go to M street. From there walk two blocks and there you are.

A centralized system, along with a number of local traffic management systems may do the trick.

Technically what I just described is feasible, and with reasonable expenditure. The problems are in the acceptance by the users.

In the coming years, however, many municipalities will reach a gridlock, too many cars on the road and some creative new approaches will be absolutely required. Enforcing public interest on private ones will be unavoidable. Managing cars as packet in a telecommunication network may be a solution. In order to do that individual cars will need to be tagged and monitored, the overall infrastructure resources controlled and allocated…

The lost of control from the private citizen may well result in a growing interest to consider cars as service, not as products and a complete new strategy of transportation may become possible. I do not expect, however, to see big changes in the next 10-15 years. Beyond…could be.

Getting there, making it happen here …and faster

The ideas presented need to be focused in each specific environment, both at country and more local level. One of the big advantages of the new technology is its flexibility and the possibility to have it applied where it matters most (or it is more productive).

The risk of wasting money remains high, as the one of lagging behind the evolution stream.

Localization is crucial: we have seen amazing penetration of new services in certain areas and surprising failures when those very same services have been tried out in different areas. I-mode in Japan, Kick boxing in Korea, SMS in Asia and Europe are examples that immediately come to mind but there are many others. Export them in other parts of the world and you get disappointing results.

Bigger (or more performing) is not necessarily better. MMS is not necessarily a success because it is extending SMS capabilities. And selling it at the same price of SMS to make it succeeds surely does not mean increasing revenues.

Hence the importance of creating scenarios that take into consideration the local situation.

Developing a Scenario

There are many inputs to take into account when developing a scenario. However the most important one is the understanding of needs and how these needs are being satisfied today.

Needs can be structured into layers, as shown by Maslow in its pyramid. Every country has a local layering of needs and a specific dimension for each of them. Developed countries have steeper pyramids, i.e. more population feels higher layer needs, developing countries have flatter pyramids, i.e. only a few perceive and have the money to satisfy upper layer needs.

Any strategy at country level has the basic goal of steeping the pyramid, which correspond to increase the well being of its citizen.

Layers are important in terms of position and of size. The higher the level the more can be charged for services and products satisfying those needs. The bigger the size of the layer, the bigger the size of the corresponding market and therefore the capacity to generate ROI.

In developing a scenario we should consider what are the reasons that may lead to a transition from the actual situation to the scenario being considered.

In this paper I am focusing on technology evolution and therefore I will consider this evolution as the enabling-triggering factor.

Technology evolution, or new technology can change the way we satisfy needs, very seldom it changes needs. It may make needs present in upper layer more economically viable to a larger market. In this sense technology helps in steeping the pyramid.

The first step in designing a scenario, after gathering the input parameters, is to plot actual processes and, side by side, the new processes enabled by the technology evolution. Each process is characterised by actors implementing it, benefiting from it, using the results. For each of these constituencies we should look at the value displacement caused by the new processes.

If this value, overall, is positive then we can move to the next step, understanding the cost of deploying the new process. If overall this cost is lower than the value perceived by the overall constituency within a certain timeframe then we can move to the next step, identifying business models, shareholders and stakeholders.

Business models are basically strategy of pricing and market evolution. They should find a way to generate a market response that is conducive of generating the desired ROI.

Shareholders are those constituency that can be convinced, involved, in the deployment of the new technology and all auxiliary measures to create the new processes. Shareholders bet their future on the new processes and are willing to invest the required money in their creation and deployment.

Stakeholders are those that are not willing to make any investment up front. However once the process is deployed they may be willing to be part of it and share their revenues with shareholders.

Stakeholders are the essential part in any business model based on indirect cash flow. An example can be advertisers. They are not willing to pay for the set up of a television network but once that is up and has a good market share they are willing to pay the network to broadcast their commercials.

Once we have got our scenario with a sound business model and its constituencies of shareholders and stakeholders we can move to the implementation phase. This requires the setting up of a deployment strategy. Usually it involves the identification of promising market niches where the scenario can be tried out with limited cost exposure and earlier revenues. Such niches should be characterised by the property of being expandable in a short time and they should work as aggregators.

For many ICT services and products one should aim at "mainstreaming", that is reaching a high penetration point within a certain market in a very little time. This is because in ICT services we can compound the perceived value by adding to the value of the service (product) the value of the network[8] resulting by those having that service (product).

Mainstreaming, thus, becomes an important characteristic in choosing the initial market niche.

Five Challenges

I mentioned, in the opening remarks, five challenges and it is time, at the conclusion of this contribution, to provide my two cents on how to tackle them.

Delocalised innovation, localised application

Innovation may happen and indeed it happens everywhere. "Per se" developing innovation does not necessarily bring a competitive advantage[9]. The reason is that in ICT a successful innovation is successful because of its market impact and in order to have a market impact it needs to be made available as widely as possible. How is it that countries having the highest number of patent production are also the most wealthy? It is a chicken and egg issue. If the environment is wealthy there is more money to dedicate to research which in turns brings new patents. A wealthy environment is surely more conducive to adopt innovative services and products and some of these[10] generate more effective production and distribution processes.

[8] If I am selling fax machine the value perceived by the client is the value of the product itself plus the value of the network formed by people having a fax machine.

[9] There are of course plenty of exceptions, such as in the biomedical area where the discovery of a new drug can bring a tremendous amount of money to a company.

[10] Although these innovations are a minority that is normally below the perception of the large public.

Developing countries should not consider themselves as inevitably cut off from innovation. Because of economy of scale and the need to make the market as broad as possible there is an interest to make innovation available in their environment as well. The issue is, of course, how to pay for it.

In most cases it is more effective to "buy" innovation rather than pursuing it through direct investment[11]. The strategy should focus on where to deploy innovation and to what effect. Innovation, particularly in developing countries, should be used to boost productivity and those parts of the distribution chain that connect with wealthy markets. The lower labour cost can be used, for a limited time frame, as a competitive advantage to attract production processes.

Education is crucial since highly skilled people are needed in today's sophisticated production processes and to handle interactions over the distribution chain.

A significant part of the distribution infrastructure can be used to link local universities to high education spots. Research carried out in wealthy countries can also make use of local resources and this further contribute to increase the level of education. The Grid can be used effectively to access tools available in other universities.

Whilst innovation in the production processes is basically independently of the local situation[12] innovation in the market is strongly influenced by local habits and culture. Hence companies need to adapt ideas and exploit the local situation.

Scenarios, as I have shown, can be a useful tool to gauge the market and make decision on how to attack it.

Localised applications may be exported to similar markets in other countries often far away geographically. Markets that may not be appealing to a developed country may be of interest to a developing one.

Making an impact across market segments

Focusing innovation deployment is a good strategy to minimise effort and get results. Hence it is the modus operandi of any enterprise. However at country level one should look at the overall impact of innovation. One should evaluate the effect of seeding innovation in a specific area by measuring its impact on other areas and calculating the overall value displacement.

As an example, telecommunications in Western Europe represent 6% of the GDP. By investing in telecommunications one is surely increasing its effectiveness

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[11] This is true also for companies. Many US companies grew in the past decade by acquiring innovation rather than investing in in-house developed technological innovation.

[12] Difference in labour cost should not lead to favour labour intensive processes that are usually resulting in lower and less controlled quality, nor should local regulation invite less strict safety discipline of production.

but the real question is how much that investment is increasing the effectiveness of the remaining 94% of European GDP.

This is the question that the European Community has kept asking during these decades of cooperative research programmes.

Additionally, restricting innovation to a certain area may foster discrimination and the widening of the gap between the haves and have-not.

Education is typically an area producing cross fertilization, hence it is a good one for government to invest on. E-government, forcing industries at any level to interact with institution in a new way, is another area that can foster cross sectors innovation.

ROI

The overall amount of money available within a closed system, such as a family, a township, a country, is fixed. Whatever is offered as a new product or service needs to divert money from existing products and services[13].

Innovation in the production and distribution leading to cost cutting frees money for other use. This is very important in the developed countries and it is also important for developing countries although the money made available may find different use.

Any scenario and related strategy should consider the displacement of money and foster those innovations that maximise it. Money can be an enabler and should be used as such.

As mentioned in the previous point, attention should be given to the global revenue over investment when designing a country wide strategy. It would be wrong to consider State led investment as a given. Stakeholders are obviously more important than shareholders in this kind of investment but the ROI is equally important. Taxation deriving from the bigger production and consumption, enabled by the State investment, should repay such an investment[14].

Foresighting

Foresighting is obviously useful but it has to be applied with some "caveats" and within a set of scenarios that are dynamically evolved and result in a continuous rearrangement of actions.

It is basically of no use the development of a snapshot to support a one-time strategy set up. Foresight needs to be the input for multiple scenarios generation[15]. One

[13] Shifting money from savings in the banks to the market is resulting from a slow change in culture and overall trust in the present country situation. A bad situation usually result in a contraction of money on the market, a very very bad situation may lead to a rush to acquire goods, momentarily. These effects, however, can be disregarded when considering the market potential for absorbing new offerings.

[14] Let me remind once more that I am focusing on ICT related innovation and investment.

[15] The European Community has launched a cooperative project, FISTERA, that has the objective of developing scenarios based on technology timelines and country based IC evolution program. See: http://fistera.jrc.es/

scenario may be chosen as the leading one, based on the strategy adopted but all of them[16] need to be kept handy and a continuous evaluation should take place to re-evaluate assumptions. This is seldom done. Scenarios are considered as starting point for decision taking and then they are abandoned and forgotten. As I have shown scenarios are based on technology timelines and market expectations. New technologies can arise and change significantly the assumptions. Any new technology should cause a re-evaluation of the scenarios. Monitoring of technology timelines and market reaction may lead to retuning of scenarios and to a change of strategy.

Scenarios may also have some milestones, go-no go checkpoint…all of them need to be monitored and acted upon.

Fore sighting activity and related groups need to be part of the implementation processes: this is the way to really benefit from scenario activity and to improve the predictive power of the foresight activity.

The Grand Plan and Micro Actors

It is unlikely that individuals and single enterprises would buy onto an idea, as appealing as it might be. Each one will act and behave according to his agenda and this, eventually, is good because everyone is most motivated when acting for his own good.

The country-wise evolution strategy needs be supported by a number of regulations, investment framework, incentives to steer the activity of the various actors towards the set goal.

Actors need to share information, resources, infrastructures but at the same time they want to act independently.

Technologies like the Grid may stimulate specific market segments to achieve this sharing.

References

FISTERA: http://fistera.ipts.es
A complete audio – visual presentation of technology trajectories and disruptions can be found at: http://fistera.jrc.es/pages/latest.htm
Technology Trajectories: http://fistera.telecomitalialab.com

[16] Actually, only the subset resulting from strategic decision taken.