Technology as a Need: Trends in the Evolving Information Society

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***Abstract*—In this paper, we take a broad view on the Information Society and on the Information and Communication Technologies which constitute its technical and, in a sense, social infrastructure. We discuss the fact that today the needs of human beings are strongly influenced by technology, which has become a need in itself. We propose an analysis of how the Industrial Society has left the scene in favor of the Information Society, based on two meta-trends identified as Personalization and Distribution. Using an original biological metaphor, we describe "The DNA of ICT Evolution", which uses the two meta-trends as filaments and ten trends as bases: ideal performance, ubiquity, flexibility, complexity, cognitivity, opportunism, cooperation, security, miniaturization, convergence. We then move on to a social analysis of the impact of the Information Society on nations and individuals, describing the Information Divide, composed by the Digital Divide and the Psychological Divide. We conclude the paper by arguing that a new skill will be needed by individuals to cope with all the above, which is the skill of disciplined creative thinking.**

***Index Terms*—Information Society, personal needs, ubiquity, flexibility, complexity, cognitivity, opportunism, cooperation, security, miniaturization, convergence**

I. Introduction: the Information Society

SOCIOLOGISTS tend to agree on the fact that the main element that characterizes the present post-industrial society is the pervasiveness of *Information*, in its many possible forms and with all the associated operations of acquisition, storage, processing, exchange, generation. For the first time in history, life is forged by an intangible and conceptual element, and as a consequence it is clear that transformations and evolutions become much faster than in the past.

Understanding the world becomes therefore more difficult and more ephemeral, as transients and regimes are confused into a seamless evolutionary path. In addition, the comprehension of even the most basic operations on Information requires a considerable acquaintance with technologies, which we broadly define as Information and Communication Technologies (ICT), to include as a minimum the Internet, wireless and mobile communications, and the underlying micro-/nano-electronic devices. The necessity of a technical alphabetization has clear consequences on separating generations, and in generating the paradox that the younger and less experienced appears to understand more of the world, albeit only in terms of its technological texture.

In the Information Society, the tertiary sector of *services* gains a central position, taking a full stand alongside with the traditional, and more "solid", primary and secondary sectors. Interestingly enough, ICT technologies have horizontal applications which also invest the primary and secondary sectors, such as for example the novel techniques for high precision agriculture, or the growing presence of ICT in manufacturing enterprises. In the Information Society, the tertiary sector has grown in centrality and criticality, to the point where a malfunction in the telecommunication infrastructure can paralyze an entire region.

To understand in depth this new form of society, it is required that we define the concept of Information more precisely. We elect to define *Information* as any conceptual entity that enables us to connect to the world and make sense of it. Three kinds of Information can be identified in general: *historical* information related to roots and origins, including the individual genome; *social* information derived from interactions with people and things, being part of a community; *professional* information consisting in the know-how exploited daily in one's working life. ICT technologies had their first impact on professional information, going back to the days when the Internet was game for a few, but then rapidly exploded into the realms of social and historical information, overcoming barriers and spreading a wave of homogeneity over the entire globe.

As a consequence of all the above, it can be concluded that access to Information is today a fundamental human necessity, which is required to satisfy basic personal needs. So the question arises as to what are the personal needs and how have they changed in accordance with this societal evolution. This paper attempts to address this issue in Section II, where we consider basic human necessities but with a technology oriented look, and we argue that technology itself becomes a need.

The attention is then moved onto technology, showing how it forges itself in relation with these new personal needs, giving life to new ICT trends. We argue that the two major forces that have driven the transformation from the Industrial to the Information Society are *personalization*, as opposed to standardization, and *distribution*, as opposed to the concentration of resources and intelligence typical of the Industrial Society. These are considered as meta-trends, which sustain ten specific trends, namely ideal performance, ubiquity, flexibility, complexity, cognitivity, opportunism, cooperation, security, miniaturization, and convergence. We dare proposing an original metaphor paralleling the biological DNA to the collection of the above meta-trends and trends in ICT. This can be found in Section III.

While the pervasiveness of technology in the Information society has definite and intrinsic positive aspects, it is also true that the impact on society, human relations, and even individual psychology is all but negligible. The fact is that there exists a new phenomenon which we identify as the *Information Divide*, which includes both the *digital divide*

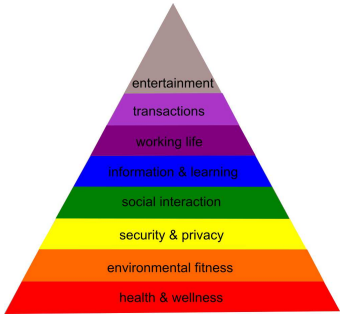

Fig. 1. A pyramid of personal needs with strong technological texture.

affecting all those who have no access to the Internet (or they access with insufficient bit-rate), as well as the *psychological divide*, related with the information overload which impacts upon all those who do have access. We dwell on these issues and their consequences in Section IV.

We conclude the paper by pointing to the one activity that we believe is instrumental in coping with the harsh consequences of the psychological divide: creative thinking, as the mechanism for becoming sources of information as opposed to mere sinks.

II. Technology as a Personal Need

While it may not be desirable nor in the intention of the technologists themselves, it is true that humans get immediately used to new devices and services, to the point where they become real *needs*. This has been recently testified by the phenomenal take up of cellular communications, whereby anyone who forgets his mobile phone, or whose battery runs out, suffers definite psychological distress. The mobile phone has become a part of our bodies, and having it with us is definitely a need.

In view of the above, we want to review what can be considered to be the basic needs in today's society, transformed under the light of technology. Starting from the individual is the preferred approach in order to avoid a brutal technology push. This is also undertaken in several policy programmes currently active in Europe, e.g. the Ambient Assisted Living (AAL) programme, which can be seen as the champion in focusing the attention on the human being [1].

Before we enter into the difficult realm of human necessities, we should underline the fact that we are not claiming the following discussion to be a psychological treatise on personal needs; rather, it is the interpretation of those needs in terms of their technological flavor. Re-interpreting in a more modern key the classical approach by Maslow [2], who modeled the personal necessities through a universally famous pyramid, user needs can be grouped into eight major categories as described in Fig.1.

Need 1 - Health

Health represents the most fundamental need of humans for truly satisfactory livelihood, without which any other asset loses its value. How can health be ensured through ICT technologies? This is the realm of e-health systems and technologies. The first application is to remotely assist patients, for example exploiting body area networks capable of monitoring vital parameters. E-health is the response to critical social challenges such as home care (or domiciliary care), i.e. healthcare or supportive care provided in the patient home by medical professionals, and independent living, i.e. providing assistance to disabled people. All of this is pursued at a significantly reduced social cost.

Once a complete e-health system will be in place, there is no doubt that it will be perceived as a crucial need, a necessity to have, and any malfunction will translate into serious problems. This will entail new levels of responsibility and accountability for ICT engineers.

Need 2 - Environmental fitness

Environmental fitness is a broad interpretation of the necessity for any human being to feel comfortable in the surrounding ambient. In our view, this includes two situations which have sufficiently distinct characteristics: fitting while in stationary conditions, and fitting in mobility, which opens the vast world of transportation. In terms of ICT technologies, these two dimensions can be respectively re-interpreted as the needs for *ambient awareness* and for *smart transportation and info-mobility*.

Ambient awareness integrates technology in two forms: hidden into the ambient itself (known as ambient intelligence, including all functions of domotics and sensor networks), or harnessed onto the person's body to "feel" the context (known as context awareness). An important part of context awareness is the ability to know the position with sufficient accuracy, which indoors may require precision in the order of centimeters, as well as the capability to capture automatically information from the ambient itself.

Smart transportation systems include traffic monitoring and route optimization on one side (exploiting navigation systems), and info-mobility services to the travelers on the other, which can also be delivered in a peer-to-peer mode by exploiting vehicle-to-vehicle communications. Automatic driving is yet a dream, but it could arguably solve one of the most dramatic problems in today's society, i.e. that of car accidents. Exploiting info-mobility systems, people can communicate, work, be entertained, and more generically reach the outside world while being on-the-move. Interestingly, ICT technologies can also reduce the need for mobility, by providing means for *virtual interactions*. This helps in exploiting resources efficiently and in favoring sustainability, in line with the *Green ICT smart energy* requirements [3], [4], [5].

All of the above depicts a situation whereby all the required technologies are absolutely necessary to feel fit in one's environment.

Need 3 - Security and Privacy

Security and privacy are primary needs of any person to feel protected during any aspect of life.

This necessity translates into the need for preserved secrecy on private data, which becomes a real social challenge in an era where communication of personal digital data is at the center

of many ICT applications, especially with the growing diffusion of Web-based Internet applications and social networks. Straightforwardly, in the ICT context this need translates into putting in place strategies for cybercrime prevention, avoidance of personal identity theft and dissemination of malware and spam; all these objectives can be reached via enhanced authentication mechanisms and digital identity management.

With the success of Internet and the ever increasing individual exposure over the net, the need for secure, certificated, authenticated transactions will become unavoidable.

Need 4 - Social Interaction

Social interaction is the natural need of humans to belong to some form of society, from a small scale (a family, a group) to a larger scale (a community, a Country), in response to the continuous search for support, discussion, comparison and opinion exchange with other persons.

This need takes a completely new connotation with the recent technology advances. In particular, it is worth mentioning here the tendency for *social networking*, so highly popular nowadays amongst younger generations, and the trend towards virtual interactions in cyber-realities where all aspects of life can be artificially re-constructed, through the creation of virtual identities or avatars (e.g. Second Life). The web is now used in a participating mode, as testified by the success of a number of applications such as Wikipedia, blogs, MySpace, Facebook, Twitter, YouTube, GoogleMaps, etcetera. In this framework, other foreseen technologies are *enhanced reality* (with brain electrochemical stimulation), and *augmented reality* (combination of real and digitally modified identities and environment).

Even if we believe that real interactions among human beings should not ever be replaced by their artificial counterparts, social networking, enhanced reality, and augmented reality are gaining widespread diffusion, which is likely to grow significantly in the medium-term.

Need 5 - Information and learning

Information and learning is the natural need for knowing, being up-to-date and informed anytime and anywhere.

This need has assumed a particularly compelling connotation in recent years with the rapid and capillary diffusion of the Internet, via the use of search engines and the introduction of the semantic web. In the digital era, the person is indeed more and more eager to reach rapidly and efficiently all contents in a precise moment, at home, at work, on the move. Besides the Internet, *e-learning* and *digital libraries* are other examples of ICT technological responses to this need, both contributing to satisfy the user thirst for receiving information and learning in remote areas.

Notably, these trends are first responses to the social challenge of inclusion, which contributes in avoiding person isolation from society through *e-inclusion* mechanisms. As broadband becomes a necessity of daily life (according to the "broadband for all" paradigm), the impact of information exclusion for citizens that do not have broadband access or who cannot afford it will be dramatic. Today's digital divide may become tomorrow's social-exclusion. This fundamental social problem will be discussed again in Section IV.

Need 6 - Working Life

Working life is the need for self-fulfillment and self-achievement realized through working activities, which enables to exploit talents and education, contributing fundamentally to self-esteem.

From the ICT technological point of view, this need is reflected in the recent *e-business* applications, which comprise for example home-based or mobile-based tele-working, broadband connection between different enterprise premises, remote training, supply chain management, electronic orders processing, customer service via Internet.

The nomadic use of ICT technologies will certainly challenge the meaning of 'being at work', and e-business will become the basis of the future working life paradigm.

Need 7 - Transactions

Transactions is the need of humans to be supplied with services and goods in order to satisfy material/immaterial desires.

This general need is reflected into ICT technologies through *e-commerce*, which consists of buying and selling products or services over electronic systems such as the Internet. E-commerce is growing considerably in business, private, and consumer contexts. Home banking, on-line shopping, electronic tickets are only some examples.

It is already a fact that e-commerce is a daily life tool for transactions, and it is almost a certainty that it will become more and more diffuse in the medium-term.

Also, *e-government* applications and services are gaining importance in everyday life of citizens to simplify burocracy, drastically reduce public administration costs and bridging the age divide by bringing public administration services directly into citizens' homes.

Need 8 - Entertainment

Entertanment is the need for amusement and hobbies, to aliment the innate human tendencies towards recreation.

ICT is strongly reflected in this need. In partial overlap with the social interaction need when applied to the personal sphere, the necessity for entertainment is one of the most typical goals of ICT, taking on various forms such as on-line gaming, portable consoles, three-dimensional television and cinema, mobile television, peer-to-peer downloads, MP3 players, and social networking.

We can state that the diffusion of these technologies will become more and more essential for individuals, providing new ways of experiencing entertainment, with quantum leaps with respect to traditional ways of being entertained.

III. Major trends in the Information Society

Taking on an original point of view, here the underlying and unifying major trends in the Information Society arena are presented. As already discussed in the previous Section,

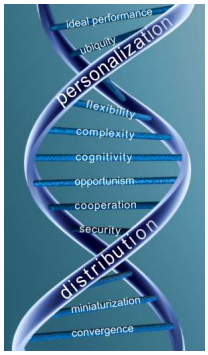

Fig. 2. The DNA of the Information Society evolution.

ICT applications provide several ways to satisfy personal needs. However, we want to go beyond a mere listing of ICT keywords, but rather point at extracting the major trends which lie within all the above mentioned technologies and their future evolutions.

We elect to say that the two main forces which are governing the Information Society revolution are *personalization* and *distribution*. Using a biological metaphor, we can think of personalization and distribution as the two strands, the two filaments, in a DNA structure, upon which and through which other trends are formed. This is what we call *the DNA of Information Society evolution*, represented pictorially in Fig.2. The two filaments generate and are linked by the bases, each one corresponding to a major Information Society trend. Therefore, in the following personalization and distribution will be identified as meta-trends, or "trends of trends".

As in the DNA structure, the two fundamental strands of personalization and distribution are actually running into opposite directions, i.e. they are the anti-parallel support of the Information Society DNA double helix. In fact, while personalization implies a local view, distribution naturally translates into a global reality. Therefore, Information Society is imposing on the world a complex organization, whereby the global truth is formed through belief propagation from individual nodes which intelligently work within their local boundaries.

A. The personalization meta-trend

The success of the industrial society was based on the mass production of goods at low cost, to be sold to a consumer market with homogenized tastes and desires. This paradigm today is completely reversed. The strategy is to go to the person, produce for the individual, satisfy specific needs, segment the market into small niches each tailored to a particular group of persons. This is all made possible by the fact that today it is feasible to produce at low cost with flexibility and modularity. This trend is clearly reflected in the world of communications. Since the advent of mobile telephony, also identified as personal communications, users do not call a location, but an individual. Users are now used to see the number that is calling, associated to a person in their phonebook, and can freely decide whether to take the call or not. Users can select a specific tariff structure, suited to their calling profile, and they may even have lower tariffs when they call specific groups of people. In terms of accessing the Internet, users can start from their preferred home page, can browse over portals shaped according to their own profile, can select their favored content from a huge offering, can even become content producers by uploading pictures and movie clips. The individual has become a source of information, and not only a sink to be filled with advertisement. Even when watching TV, users now have at their disposal a growing number of on-demand offerings, from which they can freely select. The individual is more important, enjoys more freedom, is much more active than it was in the past.

B. The distribution meta-trend

Another fundamental ingredient of the industrial society was the concentration of resources and intelligence into a few centers. This made interactions and investments more efficient, while also increasing the risk associated to losing a center, and caused large movements of people (the first of which was the move out of the country into cities). The structure of companies was based on rather rigid pyramids, with very specific work functions and descriptions, and linear work flow procedures. Again, also this paradigm is reversed in the information society. Today, there is a clear trend towards the distribution of resources. In the world of manufacturing, it is customary to have parts produced in geographically distant premises. This reduces costs and creates a global economy where effects propagate unboundedly. Intelligence is distributed and decisions are obtained through a network of interactions. This adds greatly to the responsibility of each person in the organization, and the work functions become ever more flexible. This also creates a need for continual education, for it is not possible to adapt to the fast dynamics of the current societal evolution if one considers that his/her training ended in school. Companies' structures evolve from pyramids into networks of intelligent nodes, and the structure may evolve on a per product basis. The more futuristic version is the virtual company, where different entities join into specific ventures which only have the lifetime of a product life cycle.

It can be stated, without the minimal shade of doubt, that all of this is resting upon Information Society technologies. The *network of people* relies on the telecommunication network, and, in the future, the same will happen for the *network of things*, also known as machine-to-machine (m2m) communications [6]. A distributed society and a distributed company need to find the necessary information anywhere they might reside. This is only possible thanks to the Internet and the associated search engines which allow to have nearly all the information in the world at one's fingertips, also in smart ways through exploitation of the Semantic Web (e.g. Bing) [7]. Intelligence and storage are pushed to the edges (think for example about cloud computing), which reduces the risk associated to the loss of any network node, but at the same time requires a new ethical code, as well as security in communications. Networks evolve from heavy infrastructures to lightweight ad-hoc self-organizing topologies, where the role of operators needs to be defined anew. Software itself becomes a distributed resource, now intended as a service and not as a product.

C. The ICT trends

The two meta-trends of personalization and distribution can be combined in various ways to form the trends of ICT technologies, which according to the DNA metaphor correspond to the bases, the sequence of which identifies the genetic code.

The following is our elected list of ten trends: Ideal performance, Ubiquity, Flexibility, Complexity, Cognitivity, Opportunism, Cooperation, Security, Miniaturization, Convergence. In the following we analyze them in detail.

1) The ideal performance trend: The search for the ultimate ideal performance is the major force behind the evolution of any technical or technological system. It appears to be in the nature of the human kind to strive for the extraction of the maximum possible output, the optimal exploitation of resources, with the largest possible efficiency. This requires knowledge of the ultimate performance boundaries. In the case of communications, the boundaries are the object of Information and Communication theories, which in many instances do indicate where these limits are. The trend is therefore towards achieving the performance limits set by Information Theory. How does this link to the two meta-trends? The optimization of performance requires perfect fit to the specific communication conditions (propagation channel, interference, transmission format, etcetera), which can be interpreted as matching the individual user needs and constraints. This is part of personalization. On the other hand, the limits set by Information Theory are not restricted to a single link, but can and should be extended to the more complex case of networks. In this case, achieving the optimal limits requires global optimization, to balance fairness and overall throughput, with distributed intelligence. This is evidently part of the distribution meta-trend.

2) The ubiquity trend: The trend towards ubiquitous communications, the overused "Anywhere, anytime" motto, has been the driver for the evolution of cellular communications since the 70's. Coverage is today extremely good in most urban areas, and surprisingly good in unexpected locations, even though obviously gaps remain in developing parts of the world. What is yet necessary is to sharply increase the geographic spectral efficiency (in bit/s/Hz/km^2), to provide ubiquitous broadband wireless access. Associated to ubiquity, we find mobility and pervasiveness. Mobility is the trend towards communication systems which can interconnect terminals moving at any speed, including all types of vehicles, trains, airplanes, ships. Pervasiveness is the trends towards finding connectivity all around us, in a truly wireless ambient. Even power supplies can become wireless, with free charging points distributed is strategic locations. This all adds to the trend towards "living without cables".

Smart cities [8] are a consequence of this trend, addressing ubiquitous connectivity within a city intended as an IT-district, towards the concept of *the Internet of Citizens*. This concept has many important social implications. Essentially, by living into a collaborative wireless ambient, the individual can benefit from optimized environmental fitness, which satisfies a basic human need. This is clearly a specification of the personalization meta-trend. At the same time, this personal fitness can be carried along in any location, becoming ubiquitous fitness, an evident derivation from the distribution meta-trend. Even though ubiquity and distribution may seem very similar concepts, we separate them by limiting the interpretation of ubiquity to the pervasiveness of wireless networks, and by attributing to distribution this and all other implications related to social aspects, work organization, global economy, etcetera.

3) The flexibility trend: Along with the search for Ideal Performance, this is also a major trend in the evolution of any technical system. All engineering systems start as rather simple and rigid, performing but a few functions, with limited scope for modifications in response to user needs. In the course of its development, the system acquires more and more functions, more and more options, which can be selected flexibly depending on instantaneous necessities. This is a very strong trend in wireless communications. Transmission systems, protocols, and terminals are being designed as reconfigurable entities, with capabilities that can be flexibly adapted to the conditions set by the propagation channels, the transmission buffers, the spectrum availability, the interference environment, the desired quality of service, etcetera. Dynamic spectrum assignment strategies are being devised and starting to find their way into regulatory policies. Digital electronics capabilities are exploited to design software radios and flexible radios. Even analog electronics is now being bent to the requirements of designing flexible Radio-Frequency (RF) front-ends, with reconfigurable filters over large bandwidths. It is an easy task to map the trend towards flexibility as a direct son of the personalization meta-trend. In fact, it is obvious that flexibility is only useful if it is used to accommodate individual conditions and needs. On the other hand, it may be harder to describe the connection with the distribution meta-trend. However, flexibility at system level requires knowledge of all local conditions, in order to find a global optimum satisfying the requirements of the entire user population. Therefore, we can say that global flexibility is related to the trends towards distribution of intelligence, where as a minimum each user must sense its own environment and feed back this information to peers or to base stations. Also, the trend towards flexible network topologies is clearly out-spinning from the distribution meta-trend.

4) The complexity trend: Technical systems always evolve towards increasing levels of complexity, as functionalities increase and performance improves. On the other hand, technological complexity can become a major hurdle in its usability. Therefore, while internal complexity increases monotonously, there is a contextual trend towards the simplification of the human-to-machine interface. Complexity and simplicity must live together in harmony. As complexity grows, we must face the danger of increasing energy consumption, which could make entire systems unsustainable. A clear trend towards the design of "green" technical systems is growing powerfully nowadays [3]: we could say that energy consumption is to complexity as energy saving is to simplicity. The long-term sustainability of human activities will be one of the paramount technological challenges of the 21st century. Since the data traffic in communication networks is exponentially increasing, energy-efficient communication techniques are needed for as-

suring that communication-related energy consumption is not exploding and that the pertinent carbon footprint is caped or even reduced [6]. In order to meet global and national goals for carbon-footprint reduction and to compensate for noticeably increasing energy expenditures, technological energy-saving measures are a mandatory ingredient of any emergent Information Society technology, be it in the short- or long-term, be it for evolutional or revolutionary technology.

Mapped onto the world of wireless communications, complexity is visible in systems, protocols, terminals, network equipment, essentially in every element. The need to simplify is stringent for user terminals, but also for network management. And we can say that "green" communications are emerging as a very hot area of research and development. The relationship between complexity and the personalization meta-trend is inherent in the fact that we do not accept standard and rigid solutions, but rather we always look for configurations which are adapted to individual needs. A personalized solution is always more complex than a standard item. The key enabler for the realization of complex systems is the fact that today we are able to produce personalized objects in a very cost effective manner. It is also true that, in many instances, personalization is perceived by the final user, but it is in reality a specific combination of a few standard objects. In view of the distribution meta-trend, it should be apparent that distributing intelligence, responsibilities, management functions, all translate into a more complex system. In this case, complexity also brings in the concept of emergence: the arising of novel and coherent structures, patterns and properties during the process of self-organization in complex distributed systems. Emergence can be weak when it can be reduced to its elemental parts, or strong when irreducible. Irreducible emergence can be thought of as an independent system, living a life of its own.

5) The cognitivity trend (including also self-organization and bio-inspiration): As complexity of systems grows larger, control becomes more and more difficult. At a first inspection, it would be desirable to be able to set rigid rules to which all system elements should abide. This has worked in the past and still does today. However, this can only be pushed to a limit, when exceptions to the rules become frequently necessary, but difficult to handle, and the overall efficiency is severely degraded. Also the system may become extremely large, and scalability of control becomes a major issue. Or, finally, flexibility demands may pose tremendous challenges to setting correct and efficient rules. In front of all of these difficulties, we are turning our observations to nature, where incredibly complex beings live apparently without any form of rigid control. This is the source for bio-inspired algorithms, techniques, and protocols. We see that life in nature is self-organized, and we can try to apply self-organization into devices, networks, and systems. And clearly, the most beautiful and powerful example of self-organized system is the human brain, with its capability of cognition. Therefore, the extreme finalization of this trend is to endow devices, networks and systems with cognitivity, i.e. the cognition capability. Hence the example of *cognitive radio*, where radio spectrum is not assigned a priori, but is cognitively selected based upon observations of the wireless environment. Seen through the light of the personalization meta-trend, we can see that we are actually turning our network nodes and devices into primitive forms of "persons", with a certain amount of artificial intelligence, that allows them to "think" and make decisions with a certain degree of autonomy. In the *Internet of Things*, the human element largely disappears, and the network is completely populated by artificial beings, or agents, which carry out functions to achieve specific objectives. The distribution meta-trend is related very closely to the concept of self-organization, where local realities and decisions contribute, through message passing, to the global behavior. This can be brought to the extreme where the overall objective functions, such as for example the estimation of a parameter, are elaborated only in a distributed manner, and the final result is not necessarily collected at a fusion center, but can itself be distributed into the network.

6) The opportunism trend: With increasing degrees of distributed intelligence, flexibility, and complexity, it becomes crucial to execute operations not at any generic time instant, but when and only when the conditions are optimal. In other words, it becomes necessary to catch the opportunity for performing a specified task in the most efficient manner, and with the largest associated benefit. Indeed, all systems are dynamically varying in several dimensions (as a minimum, time), which means that conditions will fluctuate and opportunities will be created. To use a dimension or another, depending on the underlying conditions, can be interpreted as a form of diversity. Therefore, opportunism is a way to exploit diversity, choosing from time to time the path which offers the minimum resistance to our action, and thus optimizing the use of resources. In a sense, opportunism can be seen as the opposite of the brute-force approach, where exploitation of resources is total and completely independent of the ensuing conditions. The beauty of this is the fact that, in a network (be it technical or social) the total amount of resources is limited, so if each one use the minimum necessary to achieve its own purposes, then the overall efficiency is maximized. In other words, the use of brute force from any single individual hurts the entire network. In wireless systems and networks, and particularly in the family of Beyond 3G cellular networks, opportunism has become a major flagship for resource assignment, scheduling, multiple access. Resources are given dynamically to those terminals which are at a particular instant enjoying the best channel conditions, which will allow to serve them with the minimum effort and maximal efficiency. In order to avoid that some terminals are always left out of the game, opportunism should always go along with fairness, implemented in one of its several possible embodiments. In this specific case, the personalization meta-trend materializes in the fact that we go after the opportunity which is occurring for a specific individual, knowing that it will only last for a limited window of time. On the other hand, we want to be fair to all users, and as such protocols and strategies are ready to consider also the needs of those for which opportunities do not seem to happen, at least not with sufficient frequency. In terms of the distribution meta-trend, we observe that opportunities may also be visible at a local level. This is because, to enable scalability, it is not conceivable that all information be collected in a

single decision making node. Therefore, decisions to seize specific opportunities should be taken locally, with feedback on instantaneous conditions transmitted only when and where necessary, possibly on short legs to minimize latency and thus maximize network reactivity. Hence, opportunism must go along with distribution.

7) The cooperation trend: Cooperation can be seen as the virtuous consequence of awareness. If an individual, or an entity, is isolated, it can only work for its own specific goals. On the other hand, even if the entity is not isolated, but is unaware of the needs, or even the sole presence, of other entities around it, it will behave exactly as it did in isolation, working undividedly towards the achievement of its objectives. Only when an entity becomes aware of the presence, requirements, and needs of other entities around it, then it can realize that working in isolation may not be the most efficient way. Even the objectives are modified, at least because one sees not only its own objectives but also those of others, thus creating the notion of global objectives. Awareness generates a change of perspective, which can lead to various forms of cooperation amongst the individuals. Cooperation requires trust, fairness, and regulation, in order to ensure that all individuals benefit from the process. Cooperation in wireless communications can, for example, take the form of relaying the information sent by another user, in order to help it reach the final destination. In this way, the cooperating node is spending part of its resources not to achieve its own objectives, but rather to help another node do so. In return, it will trust that the situation will reverse when its own opportunity comes along. It is clear then that cooperation and opportunism go together, as the mechanism for cooperation will adapt itself to the underlying conditions which will vary dynamically over time. Other interesting forms of cooperation can be envisaged for virtual beamforming, virtual MIMO, collaborative positioning, etcetera. Cooperation is an act between individuals, and as such it possesses intrinsically the character of the personalization meta-trend. The personalized network entity is aware of the other entities, cognitively decides that it is useful to cooperate, trusts the other entities, expects to receive mutual benefits and to achieve its own goals while contributing to the global goals. This comes very close to the description of the behavior of a person in a social network. On the other hand, the exploitation of cooperation means, once more, that the operations in the network do not belong to a single terminal and a single central control entity, but rather require the involvement of a multitude of actors, distributed of the area of service, whereby decisions and operation occur as the result of the overall interaction. This is clearly in line with the distribution meta-trend, and we can say that cooperation without distribution is impossible, and distribution without cooperation is less effective and not exploited to its fullest.

8) The security trend: We must also recognize that, in front of all the positive aspects brought in by the personalization and distribution meta-trends, there is also an associated increase in the risk of misuse of Information Society technologies. Centralized control may be bulky and in some cases unfair, but it can also serve as a guarantee for secure transactions, which can be protected more easily by various kinds of threats. On the other hand, when organizations become distributed, when decision making is the result of consensus, when resource management requires information from the edges, then it is clear that there are so many more possibilities for an alien to come in and disturb or deviate the process far from its intended objectives. And since there is a trend for personalization, any individual or any entity is up front with all of its features, which can be stolen or misused in many ways. Therefore, the meta-trends of personalization and distribution require that much attention is paid to ensure security, guarantee privacy, defy malicious attacks, propagate trust. This applies to society in general, and certainly it does also to wireless communications, which traditionally have been the weak side of network security. One special word for trust: it is not just a matter of making sure that content is encrypted, that access is conditional to authentication, that sensitive data is not exchanged (or at least not frequently). It is also a matter to make sure that the final user perceives that using Information Society technologies is secure. In other words, there must be trust in Information Society technologies, or else the uptake will always be below expectations, and the impact much more limited than the potential.

9) The miniaturization trend: In the evolution of technology, we always see a trend towards miniaturization, as the results of improvements in the processes and in the understanding of the underlying physics. This has held marvelously in the case of digital electronics, where the scale of integration of ICs (Integrated Circuits) has grown exponentially through the years. Digital ICs are horizontal enablers for the progress in wireless communications, not only from the technical point of view, but also from the economic side, given that the cost of ICs has also decreased steadily through the years. And the end is not in sight: with the rush for nanoscale devices, unprecedented improvements are yet on their way. Also, circuits built on organic materials promise to change forever the notion of ”hardware”, as we will be seeing and use devices in plastic and even softer materials. Nanotechnologies will produce entire nanosystems, which can be distributed as smart dust for a multitude of distributed sensing applications. Here comes the relationship with the distribution meta-trend. On the other hand, the trend towards miniaturization can also be seen in a more general way. In terms of cellular mobile networks, there is a clear trend towards the miniaturization of cells, which went from macro to micro, pico, and now femto-cells. The femto-cell is intended to be installed by and individual in a home or a small office, and as such we can see the connection with the personalization meta-trend. We can also see the miniaturization of networks, as for the case of the body area network, interconnecting different parts of the body for various applications for the benefit of the individual, such as e-health.

10) The convergence trend: Last but not least, convergence. It is placed at the end because in a way it connects all previous trends. In a general sense, convergence can be seen as that process according to which concepts which used to be separated come together to form new meaning. The process eliminates barriers and distinctions, and creates larger classes. Since we use classification as an instrument for clarification, it

is indeed true that convergence always causes a certain amount of confusion, as previous certainties are questioned and new approaches must come in. In economic terms, convergence is an earthquake that shakes market shares and inevitably increases both opportunities and threats. From the point of view of scientific research, convergence can be seen as the uprising of interdisciplinary research, where competences from different areas are merged. The major benefit is that different frames of mind coming together have the potential to produce breakthrough innovation. From the point of view of wireless communications, convergence plays a major role in at least two ways. First of all, the distinction between mobile and fixed telephony is vanishing, with operators offering bundles which include also Internet access and TV (the so-called quadruple play). Considering also the fact that IP (Internet Protocol) is rising as the common network protocol for all services, we can see clearly the incredible force of service convergence. Secondly, there is also convergence in the world of wireless terminals, which more and more become phones, computers, cameras, organizers, etcetera. Let's interpret the trend for convergence in view of the personalization meta-trend. No matter where the person is, we want to provide the same access conditions, the same service profile, as if the person was virtually at home. Convergence of networks and terminals can enable this concept. On the other hand, this can also be seen as the famous "anywhere, anytime" motto, i.e. the fact that we are always surrounded by a converged (albeit heterogeneous) network infrastructure, of which we don't want to know the details, as long as we can use it for our purposes. Therefore, convergence can be seen as an enabler for the distribution meta-trend, because without it we would not see a seamless wireless ambient but rather a jigsaw puzzle of technologies.

IV. Social impact: the Information Divide

The pervasiveness of technology in the Information Society presents undubitable benefits in terms of quality of life. However, there are also costs and negative consequences, which cannot and should not be neglected. The engineering point of view must here subside in favor of sociological considerations.

Let us imagine for an instant that the provocative assumption "all of the world's knowledge will be on the Internet by 2020" holds true. Although no one will ever be able to prove this, it is a fact that we are witnessing incredible growth in both the number of new web sites opened daily [9] and in Internet traffic (forecasts by Cisco estimate more than half zetta-byte of global traffic to be reached by 2012 [10]). It is also becoming a habit to verify facts and notions by matching what we know with the results of a web search. It is clear that, under the above assumption, the possibility to access the Internet becomes a major discriminator for individuals, groups, and even entire nations, creating a fundamental issue which we here identify as the *Information Divide*, intended as the separation between one entity's knowledge and the rest of all information. The information divide is not limited to a lack of technology infrastructures, because it can exist even with full access capabilities. Indeed, the information divide can take on two totally different, or dual, forms: the *digital divide* and the *psychological divide*.

The digital divide, i.e. the lack of proper telecommunication infrastructures, has critical impact both in professional and social terms, which can be unbearable for the younger generations. We can distinguish two kinds of digital divide: geographical and demographic. The geographical divide applies between continents and between specific countries within a continent. The geographical divide especially affects developing countries, where the benefits of the Information Society revolution are less clear, to the point where the gap with the developed countries tends to be exacerbated. Focused efforts and investments are needed to transform the divide into a digital opportunity [11]. The demographic divide refers to the clear difference in quality of service and coverage between urban areas and areas which are less densely populated, broadly defined as rural areas. The problem is one of economy of investment, and it cannot be expected that private entities take on all of the costs associated to giving full connectivity to rural areas. Again, institutional effort is required: bridging the digital divide requires large investments in telecommunications infrastructures, which can range from the cost-effective ADSL solutions to the super-high capacity optical fibers, from broadband cellular systems (which enable high penetration) to broadband satellite links (providing large coverage in remote areas).

The second type of divide is the much less explored *psychological divide*, which is related to the inability to handle information, due to either information overload or illiteracy in new technology matters. The psychological divide is related to age and education, as well as to the inability to handle huge amounts of information. The generational divide relates to the fact that younger generations are more used to technology with respect to older people. In fact, they are born with technology, and have a hard time imagining a world without it. It is a fact that having children in a household largely increases the demand for having Internet access. We are facing the paradox whereby young unexperienced people understand more of the technological world than older and wiser people, with an impact on familiar and social relationships. The educational divide derives by differences in the scholastic background. Several studies have confirmed that a small percentage of the people with lower secondary education access the Internet, while the percentage rapidly grows to saturation for people with higher and higher education. Finally, there exists a psychological problem in dealing with instantly available infinite information. While it is possible to download virtually unlimited amounts of data on any subject, it is undubitable that *knowledge without experience is not wisdom*. The progress towards the semantic web is a step towards pre-filtering of information in terms of its relevance, which should help considerably in reducing the information overload. But will this be sufficient? And from the professional point of view, what is the impact of the fact that the know-how will not be a major discriminator in the future?

V. Conclusions: A creative future

The Information Society is such that technology is pervasive and a true necessity for individuals, which depending on their condition are faced more or less fiercely by the Information Divide. We believe that the impact of the psychological divide may be dramatic on some individuals, who may be overwhelmed by the feeling that learning anything has much reduced relevance when all information is available at your fingertips, and they may reduce to living their life in a very passive mode. Entire lives could be spent simply enjoying online content.

Fortunately, there is a way out, which however requires a true paradigm shift in terms of the way we approach thinking and education. Throughout our history, we have always held at a prime the skill of *critical thinking*, i.e. the capacity to judge and criticize facts, ideas and happenings with respect to our knowledge. This is and will always remain a fundamental asset for any individual, in order to live a proper life. However, this will not be sufficient in the future evolution of the Information Society, because critical thinking does not generate new knowledge, rather it is a powerful filter that preserves our culture and our roots. We need to add the skill of *creative thinking*, intended as the capacity to generate new concepts and ideas in a disciplined and controlled manner.

Creativity is not yet a science, although there are many sciences that deal with creative thinking, such as the history of science, the philosophy of science, psychology, engineering, to name a few. But we are still missing a coherent view and a scholarly approach, which is necessary to turn creative thinking into an educational subject, taught in schools and universities as a fundamental and transversal skill. But we strongly believe that creativity will become a general subject and will grow to become the principal tool to allow humans to deal with the psychological divide imposed by the Information Society. Only when one becomes a source of new ideas then it is possible to come to terms with the information ocean.

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