Convergence of Networks: An Aerospace-Friendly Strategic Vision

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Abstract. The paper focuses on the revolutionary changes that could characterise the future of networks. Those changes involve many aspects in the conceivement and exploitation of networks: architecture, services, technologies and modeling. The convergence of wired and wireless technologies along with the integration of system components and the convergence of services (e.g. communications and navigation) are only some of the elements that shape the perpsected mosaic. Authors delineate this vision, highlighting the presence of the space and stratospheric components and the related services as building block of the future.

Keywords: Convergence, Integration, Communications, Satellite Navigation, Layerless

1 Introduction

The future of systems is *globalisation* and the future of networks is *convergence*. The full deployment of this challenging evolution brings through some cross-linked revolutionary changes in the conceivement and design of systems and services:

- Convergence (*C-approach*) of wired and wireless;
- Integration (*I-concept*) of components (terrestrial, stratospheric and space);
- Convergence of services (*S-convergence*) (e.g. Navigation and Communications, *NavCom*; Earth Observation and Communications, *ObsCom*, Earth Observation, Navigation and Communications, *NavObs Com*);
- Layereless design.

Those changes are taking place in a variegated technological scenario, where consolidated and emerging technologies need a continuous harmonization for the effective deployment of complex system architectures.

The diversity of technologies is due to many aspects, such as technical problems in different domains, ranging from the physical to the application layer, various market players and their interests, etc. A set of examples in the differences that can be found, for instance, in the wireless standards today are: coverage, data-rates, services, medium access control protocols, Quality of Service methods, network architecture, mobility solutions, security methods (authentication, key-management, encryption schemes).

At the terminal level, which is the first and closest experience of any user with technology, convergence can be seen as an invisible and seamless service provisioning, in the sense that apparently to the user, devices can easily interact with each other and offer services to the user according to his/her needs under given circumstances. An example, that is provided in Fig. 1, is the so called *flying screen* [1]. This concept involve the user need for a display service, which can be either the TV, laptop screen or the mobile phone.

The vision is that any content can be shown at any time and anywhere. However, according to present technology, it is not a simple matter to show pictures taken by the mobile phone camera on the TV. With the flying screen, pictures can be, instead, easily shown on either one of the available displays, without constraining the user to perform boring - and not always successful – technical setups and software installations for interacting with the service-providing device.

In the above frame, the present paper provides authors' vision on the four listed cross-linked revolutionary changes in system and service deployment – *C-approach, I-concept, S-convergence* and *layereless design* – moving from the activity of growing intensity that is being developed around each of the above topics.

The paper is organised as follows: in Section 2 the convergence of networks and technology, particularly in terms of wired-wireless convergence is faced; in Section 3 the integration of components for the deployment of integrated networks is dealt with: in Section 4 the focus in on service convergence; Section 5 is devoted to the visionary concept of layerless networks; finally in Section 6 conclusions and further perspectives are drawn.

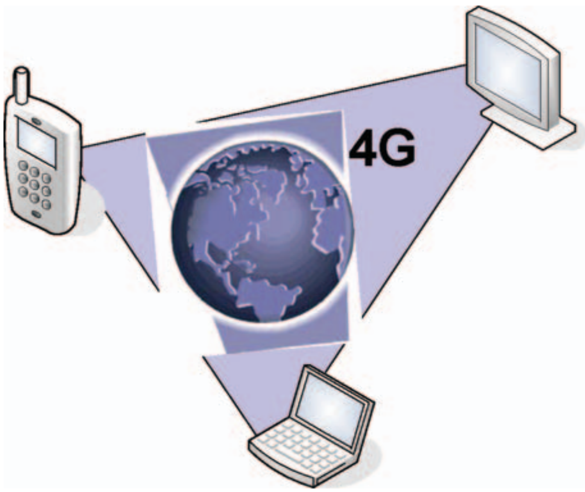

Fig. 1. The flying screen concept [1].

2 Convergence of Wired and Wireless

The convergence of wireless and wired technology (*C-approach*) – along with the *I-concept*, that will be dealt with in the following Section – brings to the conceivement of systems and applications without any polarisation in terms of technology and medium. In the development of a communications system, this approach would bring to the effective exploitation, in particular, of wireless or wired connections, in order to provide the optimal benefit to the user in terms of performance, variety of services, terminal technology and associated costs.

The *C-approach* has been the core, in 2004 and 2005, of closed-door Strategic Workshops on “Wire-(d)/-(less) Convergence towards 4G” and “Future Convergence of Wired and Wireless Network”, respectively, that gathered managers and experts from European, USA and Asian manufacturers and operators. The aim of the events was to highlights the issues deriving from the wired-wireless convergence and to shape a medium and long term vision for the communications world [2–6].

The *C-approach* frames in the eMobility European Technology Platform’s vision: in 2015 the wireless and wired communications networks will bring to reality “individual’s quality of life improvement by providing an environment for instant connectivity to relevant multi-sensory information and content” [7].

This vision calls for user-centricity coupled with a secure communications environment, where users will experience:

- convenience
- usability
- trust
- privacy

Users will be able to meet all their communications needs, as well as get timely access to their personal data anywhere, anytime, and by the means of any device and perceived with multiple senses. The vision necessitates the co-design of security technologies and the communications infrastructure.

The security features need to be designed from the end-to-end point of view, considering also the technologies to enable authentication of the biological user of the system, whereas currently the user equipment are authenticated and it is mostly assumed that the biological user is the authorised user of the equipment.

An effective implementation of the *C-approach* can be obatianed once the major open points in the wireless and wired components are solved. In particular, there are some technological challenges to be overcome in the wireless networks. Positioning technologies will be improved with the advent of the European GALILEO satellite navigation system [8]. Other positioning technologies could be coupled with satellite positioning to ensure continuous service regardless of location – also indoors. Integration of communications and positioning technologies is a future main application enabler. It is also important to take into account the possibility of extremely fast moving terminals taking advantage of the network services.

When designing the networks, user-centricity and application usability need to be considered from the beginning. Involving real users and case study analysis in the

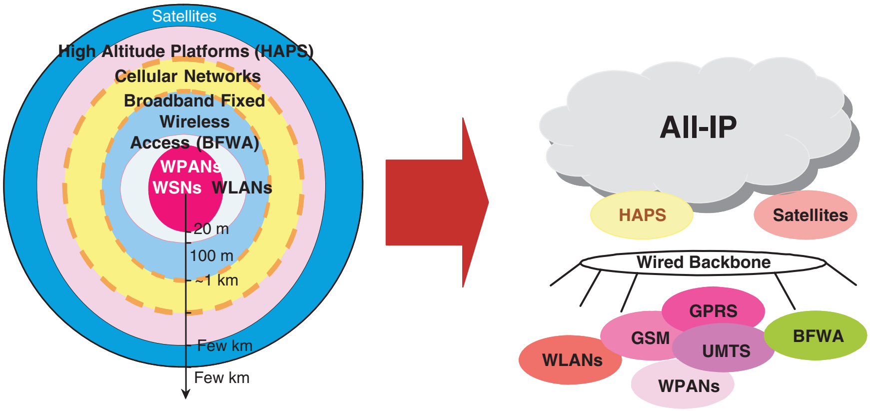

Fig. 2. Convergence in network technology [9].

development will enable to derive user requirements. The latter need to be converted into technical system requirements that, in turn, specify the system. In order to achieve a global roaming, large scale coordination and collaboration has to take place to align the future communications technologies views around the world.

The *full* network *convergence* will be achieved once the wireless transmission speeds and network latencies can be improved close to those in the wired networks. Then the wealth of the applications currently available in the fixed networks will be easily migrated to take advantage of the added convenience offered by the wireless networks.

In the deployment of the full convergence, a trend is being delineating at network level. Today a wide range of network technologies already exists on the market, some are IP based and others are not (e.g. Bluetooth, Zigbee). Some network are local, such as Wireles Local Area Networks (WLAN), Wireless Personal Area Networks (WPAN), while others are global, e.g. the Internet, satellite networks. From a user's point of view, a common technology is beneficial, since this basically enables communications between various devices, over short as well as long distances through whatever communication means that is available. The trend at network level is that an IP based solution will become the major technology for future network, as depicted in Fig. 2 [9].

Furthermore, a common platform as IP makes software development much easier, both for new network and application components, but also for services. This is a key issue that eventually will benefit the user, as a standardised interface will make interaction between applications much easier, and ultimately will make the convergence on terminal level happen.

3 Integration of Components

As the *C-approach*, the integration concept (*I-concept*) brings to the conceivement of systems and applications with the effective exploitation of satellite, terrestrial and stratospheric technologies to provide optimal performance (cost-to-benefit), without feeling constrained by any "lack-of-trust" in specific media or specific technologies.

The *I-approach* is the focus of various initiatives at local or international level. In particular, research activities have been undertaken in Italy since 1998, co-funded by the Italian Space Agency (ASI) and the Italian Ministry of University and Research (MIUR), addressing the integration of terrestrial, satellite and eventually stratospheric components to build advanced networks for mobile and fixed communications. Among the deployed programs it is worth mentioning: *DAVID* (*DAta and Video Interactive Distribution*) developed in 1998–2003 and funded by ASI, *CABIS* (*CDMA for Broadband mobile terrestrial-satellite Integrated Systems*), developed in 2000–2002, *SHINES* (*Satellite and HAP Integrated NEtworks and Services*), developed in 2002–2004, co-funded by MIUR and *WAVE* (*W-band Analysis and VErification*), 2004-on-going, funded by ASI [10–15].

Moving from the results achieved by the abovementioned activities, a new program, named *ICONA* (*I*ntegrated *CO*mmunications and *NA*vigation) and co-funded by the Italian MIUR, has been recently started in early 2006 [10].

A more detailed analysis if the *I-concept* brings to distinguish between *interoperability* and *pure integration*. In fact, interoperability implies proper interfaces at system and user terminal level, that integrate systems mostly conceived independently each other. The pure integration, instead, envisages that the components share common parts, according to an integrated-oriented design followed when initially conceiving the system. This approach obviously involve also the user terminal.

It is interesting to frame the *dual use* in the *I-concept*. Dual use brings to systems that from the beginning are conceived in an integrated mode, being able to meet the requirements of two very different class of users: military and civilian. If the sytem is composed of terrestrial, satellite and/or aerial components – according to the network centric vision – a multiple integration level is reached.

The I-concept translates into networks composed of existing or dedicated parts (*NoN*, Networks of Networks). An *I*ntegrated *Net*work (*I-Net*) is an *NoN* where all elements cooperate effectively in terms of:

- performance
- security
- seamless behavior to the user.

In an *I-Net*, terrestrial facilities are envisaged in terms of network nodes and connections; satellite and aerial components can be usefully considered to complement coverage, provide a back-up to the terrestrial section, provide additional services, strengthen the services mostly provided by the terrestrial facilities. On the other end, the satellite or the aerial component can be the main one, supported by a terrestrial section.

The aerospace component is structured in various layers: the HAP (High Altitude Platform) layer, where manned or unmanned stratospheric vehicles are located at about 20 km height, and the layers where satellites can be mainly located (low, medium, geostationary and highly elliptical orbits) [3,6,10].

The behaviour of an *I-Net* is related to that of its components and to the effectiveness of the integration. In terms of interoperability, the components can be meant as the various systems which work jointly. In the true integration, the components can be, for instance, identified in terms of height from the Earth (i.e.

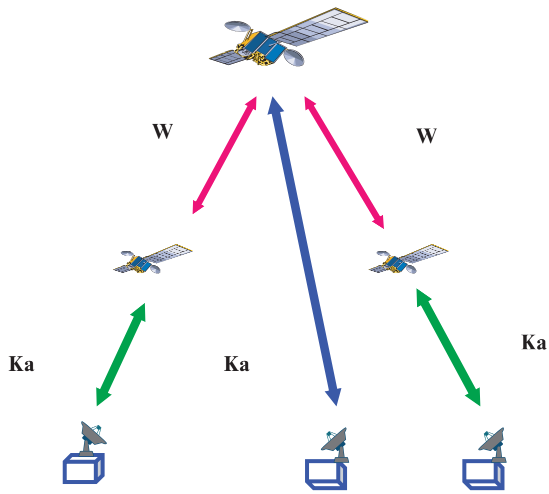

Fig. 3. An example of multi-orbit satellite *I-Net.*

terrestrial, aerial, space), service type (e.g. navigation, communications, Earth observation, data handling, etc), user type (e.g. military, civilian), technology (e.g. optical, radio, digital), access (e.g. wired, wireless), etc.

In both cases, the *I-Net* performance can be expressed in terms of *Quality of Integration* (*QoI*) as:

$$QoI = \left\{ \sum_j w_j P_j \right\} \eta_I \qquad (1)$$

where P_j is the performance of the j-th component that is shared in the integrated system; w_j is the weight of the j-th component performance; the sum is extended to all *I-Net* components; η_I is the *integration efficiency*, i.e. the capability of exploiting effectively the various components and their performance of interest in the integrated system.

Figures 3 and 4 provide examples of *I-Nets* that integrate satellites in different orbits and the stratospheric component with the terrestrial part. The user segment in Fig. 4 is both aerial and terrestrial. The Figures point out also that different frequency ranges can be exploited for the various links and, in particular, the use of the innovative W-band (75–110 GHz) is advised for most of them [13–15].

4 Convergence of Services

The convergence of services (*S-convergence*) offered by different systems or by different parts of the same system is becaming a key aim for the exploitation of system features, the improvement of market potential and the protection of nations at civil, military or dual level.

In particular the development of second generation of Global Navigation Satellite Systems (GNSS) is stimulating the effective convergence between navigation

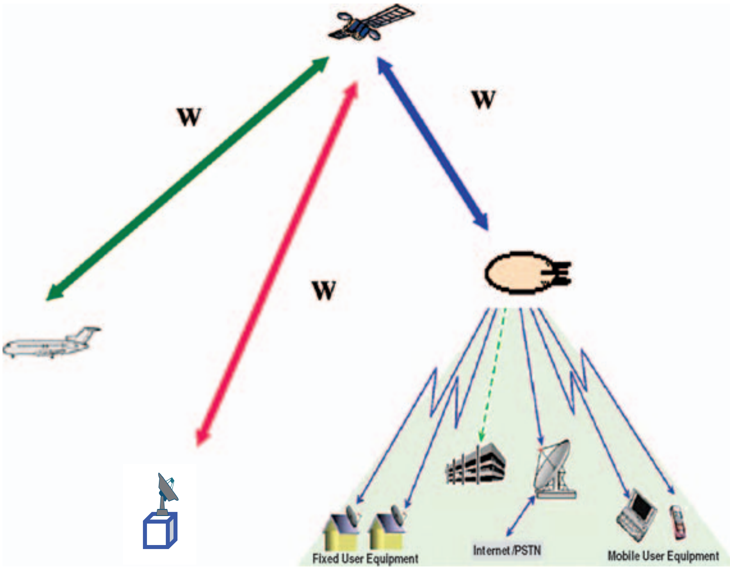

Fig. 4. An example of *I-Net* with satellite and stratospheric components.

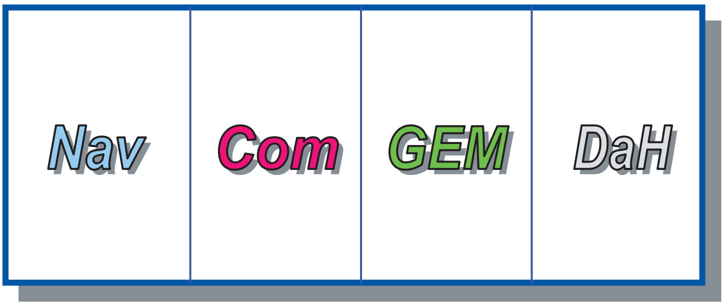

Fig. 5. An *S-convergence* package.

and communications services, bringing to a new class of *NavCom* (Navigation & Communication) users and services [6, 8, 10, 16–18].

The convergence is also being investigated and experimented among Earth observation, navigation and communications services for the effective deployment of the "Global System" concept. The Nav, Com and Global Earth Monitoring (GEM) component together with the supporting Data Handling (DaH) and user interface section could converge in global multiservice systems suitable to an impressive number of civilian, military and dual applications (Fig. 5).

The user is the core in the universe of service convergence: "personalisation", "personalized services" are the key-words for the user centric vision that is characterising the passage towards future systems.

This revolution has been started by the mobile communications world, in its transition from the present third generation systems (3G) to the next generation (4G). In authors' vision, 4G will be obtained by adding to B3G (i.e. beyond third generation), which is defined as the integration of existing systems to interwork with each other and with the new interface, the *personalisation*, which is the key issue in personal networks [19].

Even in today's market, the end user plays an important role, but in 4G the user will be the centre point and not the technology as it has been previously. In this sense, user centricity means applications and services will be developed with the end user as a person and not some anonymous entity that will have to use whatever the technology is capable of offering. This person centric approach means that applications and services will need to adapt to who the user is, to his/her needs and to current situations. From a users standpoint, some high level requirements can be set, for which the technology simply have to adapt to use a service or application anywhere at anytime; to do it in a cheap and efficient way; to not need a heavy technical parameter setup; to account for user's current situation and interests.

In fact, meeting all these requirements is not only a matter of ensuring a high coverage or high data rates but of taking into account *user profiles, user context* and *adaptation* towards service and applications that the user will be using.

Taking into account these matters enables the technology to adapt its behaviour by changing system parameters, bringing to a context aware service discovery The envisioned personalisation will have a potential impact on our society and the way we communicate, as it will assists our everyday of interacting with our work, family, friends and so on. It is also this concept that acts as a trigger to develop a new network paradigm such as Personal Network.

5 The Layerless Approach

Another aspect of the future mosaic concerns the network structure. The trend today in wireless communication is to utilise information from various layers in the protocol stack to adapt and optimise the behavior of the protocol to the given circumstances. This is typically referred to as cross layer optimisation and is prune to continuously research. In fact, many information found in the lower layer, such as the physical and medium access control layers may be beneficial also for the networking and application layer and viceversa.

Looking at the way the information is used, i.e. in particular the vertical movement of information, blurs the picture of how the typical networking model (OSI) represents today's network.

The OSI model refers to clean and well defined interfaces between the different layers, where none of the layers needs to care of the communication either below nor above the layer itself. This is not the case when discussing cross layer optimisation, since the natural phenomena – such as fading, interference, device mobility – that are influencing the bit and frame error rates, ultimately put limits on the user's experience of bandwidth and delay.

Different techniques can be used to remedy this, but in most cases usage of information above and below one specific layer is useful to adapt to circumstances.

Getting all information necessary up and down in the various layers of a protocol stack necessarily introduces a more complex interface structure which, in turn, may even delete the benefits of structuring the control software in layers.

Instead, one could define a *layerless communication model*, based on a well defined communication platform, i.e. IP. In such a model, all information are available to all control mechanisms that are potentially involved in the optimisation process when doing wireless communication. The main benefit from taking such a drastic direction in designing software, is simply to keep the interfaces very simple.

Needless to say that security, as well as the privacy of the user, have to be maintained as key objects in this vision. Security solutions should be all tailored for securing the information exchanged between user devices and access points. Under all circumstances, security will need to be an integrated part of any network solution in order to meet the user's requirement of end to end security.

6 Conclusions

The paper has depicted a challenging picture of the future, where the user is the center and all components (terrestrial, satellite, stratospheric), technologies (wired, wireless) and services (communications, navigation, Earth observation, etc) will participate to the deployment of global system where "convergence" and "integration" are the implementation guidelines.

Some of the major expected achievements within the coming years is the convergence, layerless communication, a sensing and reacting communication environment as well as security and privacy.

Convergence toward an all-IP based world wide platform is one of the key issues, but to reach that goal a long range of challenges must be solved whereas standardisation for interoperability and ensuring sufficient user capacity on a global scale are examples on some of the most important ones.

Cross layer optimisation is a key issue in wireless communication, but the introduction of this concept requires a lot of information exchange in the traditionally layered software architecture. Hence future technology may introduce a concept where the layered structure is not visible as in today's technology.

Building intelligent software, which can sense and react on the user's environment and contextual situation, is also a key point wherein many technical challenges are still to be solved in order to achieve an operational system.

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