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4G: A USER-CENTRIC SYSTEM

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***Abstract*— The exponential growth of user demands and the limitations of *Third Generation of Mobile Communication Systems* (3G) have brought researchers to start reflecting on the *Fourth Generation* (4G). Many prophetic visions have appeared in literature presenting the future generation as the ultimate boundary of the wireless mobile communication without any limit in its potential, but practically not giving any designing rules and thus any definition of it. In this paper we hence propose a new framework — the user centric system — that, through a satellite hierarchical vision, presents the key features of 4G and points out the various level of interdependency among them. This leads to the identification of the designing rules and therefore to a more pragmatic definition of 4G.**

***Index Terms*— 4G, Heterogeneity, Integration, Personalisation, Reconfigurability, Services, User-centric, Wireless Communication.**

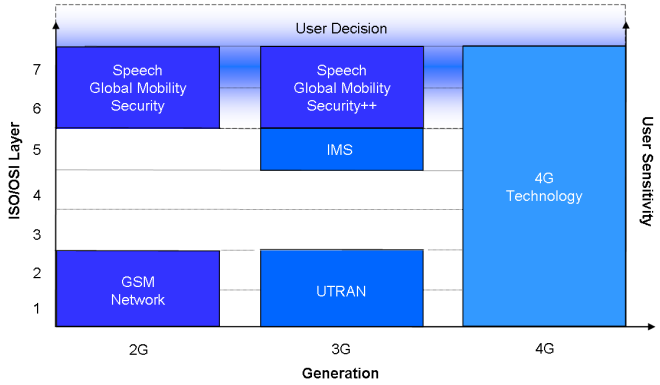

Fig. 1. Protocol Layers Innovation versus Wireless Generations

I. INTRODUCTION

The *Second Generation of Mobile Communication Systems* (2G) was a huge success story because of its revolutionary technology and the services brought to its customers. Besides high quality speech service, global mobility was a strong reason for buying 2G terminals. The *Third Generation* (3G) has been started in some parts of the world, but the success story of 2G is hard to be repeated [1]. One reason is that the evolution from 2G towards 3G has not brought any qualitatively new service for the customer, leaving the business model largely unchanged. The well known services plus some additional ones are provided, which may not be enough to encourage the customers to change their equipment (see Figure 1[1]). The lack of innovative services was encountered too late by the *3G Partnership Project* (3GPP). In the latest documents, an attempt was made to incorporate some advanced services into the 3GPP architecture such as the *Multimedia Broadcast and Multicast Service Center* (MBMS) in combination with the *IP Multimedia System* (IMS). However, these smaller corrections were made without the possibility to adjust the access technology properly [1].

The upcoming *Fourth Generation* (4G) is projected to solve still-remaining problems of the previous generation and to provide a convergence platform for a wide variety of new services, from high-quality voice to high-definition video, through high-data-rate wireless channels. Various visions of 4G have emerged recently among the telecommunication industries, the universities and the research institutes all over the world [2].

[1]Figure 1 depicts "user sensitivity", concept that is dealt later in Section II.

In Europe, the *European Commission* (EC) envisions that 4G will ensure seamless service provisioning across a multitude of wireless systems and networks, from private to public, from indoor to wide area, and provide an optimum delivery via the most appropriate (i.e., efficient) network available. From the service point of view, it foresees that 4G will be mainly focused on personalized services [3]. In Asia, the Japanese operator NTT DoCoMo has introduced the concept of MAGIC for defining 4G: Mobile multimedia; Anytime, anywhere, anyone; Global mobility support; Integrated wireless solution; and Customized personal service, which mostly focuses on public systems and treats 4G as the extension of 3G cellular service.

Even if 4G is named as the successor of previous wireless communication generations, it is not limited to cellular systems, therefore has not to be exclusively understood as a linear extension of 3G [1]. Figure 2 shows the shift in paradigm: while 2G was focused on full coverage for cellular systems offering only one technology and 3G provides its services only in dedicated areas and introduces the concept of vertical handover through the coupling with *Wireless Local Area Network* (WLAN) systems, 4G will be a convergence platform extended to all the network layers. Moreover, in order to boost the innovation and define and solve relevant technical problems, it has to be envisioned and understood the system level at a broader view, taking primarily into account the user. This approach can result in a beneficial method for identifying innovation topics at all the different protocol layers (see Figure 1). There is clearly a need for a methodological change in the design of the next wireless communication generation.

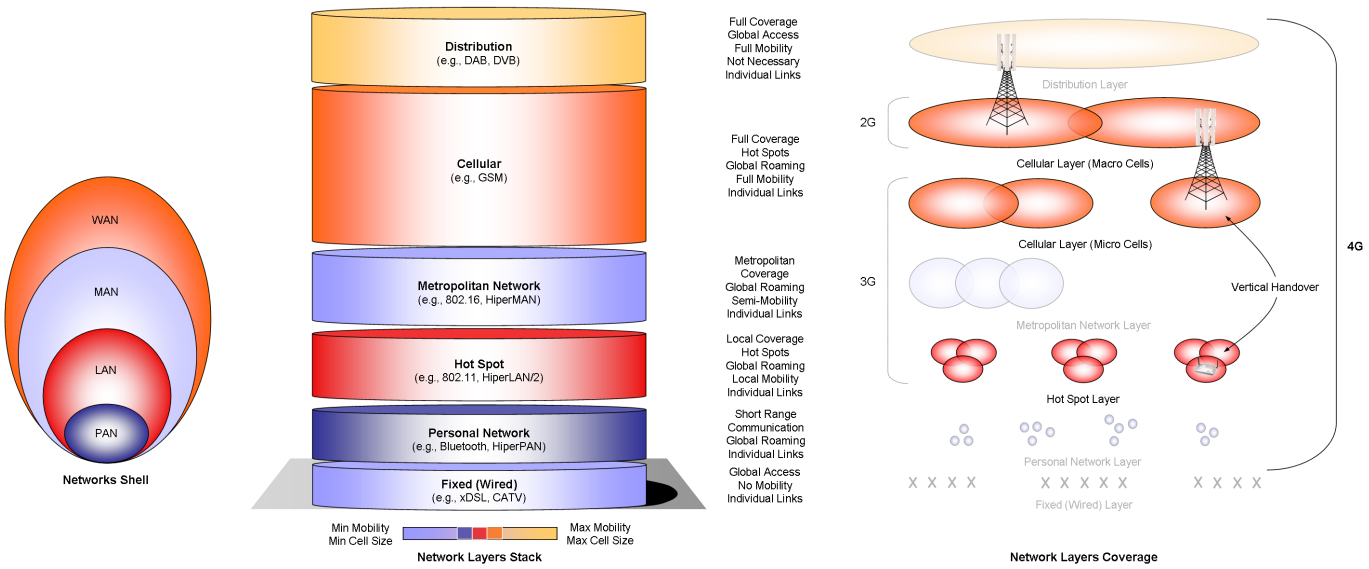

Fig. 2. Generational Evolution from 2G to 4G

The design should be more user-centric to avoid a potential "flop" of the system. Finally, it is also worth to highlight that the forthcoming technology should be as less dependent as possible from any geographical matter, addressing very different markets, such as Europe, Asia, and America.

In this paper we propose a new framework resulting from a methodology based on a top-down approach that concerns a user-centric vision of the wireless world. Starting from relevant user scenarios, we identify key features of 4G that are presented and interlinked in this new framework. Then, a mapping to technical features is performed, finally leading to a less prophetic and more pragmatic definition of 4G.

The rest of the paper is organized as follows: Section II describes the new framework. The concluding remarks are given in Section III.

II. THE USER-CENTRIC SYSTEM

In this section we list and describe all the key features and their relative technological development derived from relevant user scenarios. To do so, we propose a framework illustrated in Figure 3 and referred as the user-centric system, which may be the basis for the design of 4G.

Inspired by the Helios-centric Copernican theory, the user is located in the center of the system and the different key features defining 4G rotate around him on orbits with a distance dependent on a user-sensitivity scale. Therefore, the further the planet is from the center of the system the less the user is sensitive to it. The decrease of the user-sensitivity leads to a translation towards the techno-centric system in which the network heterogeneity has a much stronger impact than the user friendliness. Furthermore, this kind of representation shows also the interdependency between key features and their relative technological developments; in fact, as shown in Figure 3, some of the planets have their own satellites.

The user-centric system demonstrates that it is mandatory in the design of 4G to focus on the upper layers (max user-sensitivity) before improving or developing the lower ones. Without user friendliness, for example, the user cannot exploit his device and access to other features, such as user personalization.

A. Key Features of 4G

1) User Friendliness and User Personalization: In order to encourage the people to move towards the new technology, which is a process that usually takes a long time and a great effort from the operators' side, the combination of user friendliness and user personalization will be the winning concept. User friendliness exemplifies and minimizes the interaction between applications and user thanks to a well designed transparency that allows the man and the machine to naturally interact (e.g., the integration of new speech interfaces is a great step on to achieve this goal). For instance, a user reaching the place of a work appointment can get information in text, audio, or video format so that the travelling information can be displayed in the most user-friendly way. User personalization refers to the way the user can configure the operational mode of his device and pre-select the content of the services chosen according to his preferences. Since every new technology is designed having in mind as the principal aim to penetrate the mass market and to strongly impact the people's lifestyle, the new concepts introduced by 4G are based on the assumption that the user wants to have the feeling that he is unique and thus he has exclusive needs. Therefore, in order to embrace a larger spectrum of customers, it has to be provided a high level of personalization, so that either the user terminal will filter the huge amount of information delivered according to the user's flavors, or the operator will send only the information relevant to the user. This permits the users to receive targeted pop-up advertisements, for example.

The combination between user personalization and user friendliness gives definitely to the user the idea of an easy

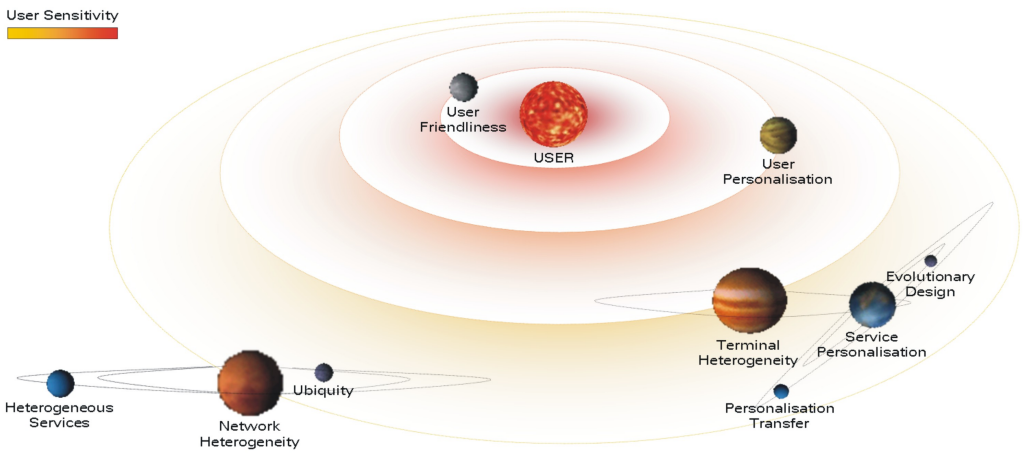

Fig. 3. The User-Centric System

management of the overall features of his device and the maximum exploitation of all the possible applications, conferring the right value to the user's expense.

2) Network and Terminal Heterogeneity: 4G in order to be a step ahead 3G must not only provide higher data rates but also some clear and evident advantage in people's everyday life. Therefore, the success of 4G will consist in the combination of network and terminal heterogeneity. Network heterogeneity (see Figure 4) guarantees ubiquitous connection and provision of common services (e.g., voice telephony, etc.) to the user, ensuring at least the same level of *Quality of Service* (QoS) when passing from one network's support to another one. Moreover, due to the simultaneous availability of different networks, heterogeneous services are also provided to the user. For instance, a user visiting one of the European capitals can listen to a guided tour and can purchase the entrance ticket for the museum as well. Terminal heterogeneity refers to to the support of different types of terminals in terms of display size, energy consumption, portability/weight, complexity, etc. (see Figure 5). In contrast with 4G, 3G is characterized by homogeneous terminals.

Since 4G will encompass various types of terminals that may have to provide common services independently of their capabilities, the tailoring of the content to the end-user device will be necessary to optimize the service presentation. Furthermore, as a result of the network heterogeneity, the upcoming new services will be accurately selected whether to be provisioned or not according to the capabilities of the terminal in use, in order to offer the best enjoyment to the user and to prevent a sensational flop of some service. This concept is referred to as service personalization (user personalisation works on top of it). It implicitly constrains the number of access technologies supportable by the user terminal. However, this limitation may be solved in the following two ways:

- By the development of devices with evolutionary design. A naive example can clarify this concept: in case the user has a watch-phone on which he would like to see a football match, just pressing a button on the watch's side a self-extracting monitor with a bigger screen can come out. Therefore, having the most adaptable device in terms of design can provide the user with the most complete application package, maximizing the number of services supported.
- By mean of a personalization transfer. An example can clarify this concept: in case the user has a watch-phone on which he would like to see a video, he does not need to possess larger screen devices as all the publicly available terminals can be borrowed by him for the displaying time. Therefore, the advantage for the customer is to buy a device on which he has the potential to get the right presentation format for each service, freeing it from its intrinsic restrictions. Furthermore, in a private environment the user can optimize the service presentation as he wishes exploiting the multiple terminals he has at disposal.

The several levels of dependency highlighted by the satellite hierarchical vision in the framework of the user-centric system definitely stress the fact that it is not feasible to design 4G starting from the access technology in order to satisfy the user's requirements.

B. The real technical step up — Integration of Heterogeneous Systems

The technical features of 4G may be summarized with the word integration — seamless integration of already existing and new networks, services, and terminals, in order to satisfy increasing user demands.

1) 4G Designing Rules: Regardless the actual technology, the forthcoming one will be able to allow the complete interoperability among heterogeneous networks and associated technologies, thus providing clear advantages in terms of:

- Coverage. The user will be connected "almost" anywhere thanks to a widespread coverage due to the exploitation of the various networks available, offering to the user the best QoS achievable (see Figure 2).
- Bandwidth. Sharing the resources among the various networks available will smooth the problem related to the spectrum limitations relative to 3G [2].
- Power consumption. The battery draining is a chronic problem of the wireless devices and the battery technol-

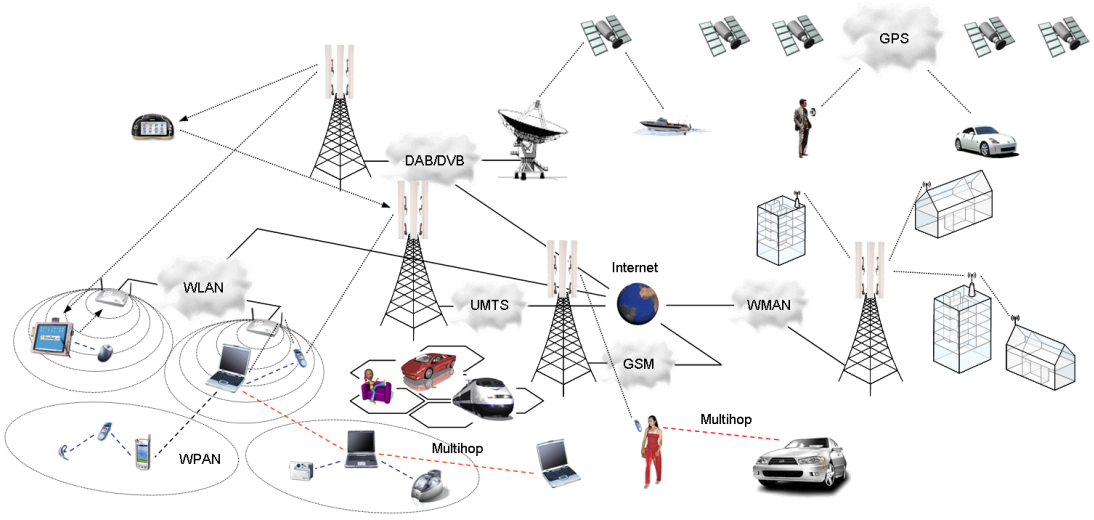

Fig. 4. Heterogeneous Networks

ogy is not progressing at appropriate pace. Furthermore, while 2G mobile phones were shipped out with one battery, in 3G most phones are already shipped out with two batteries. Therefore, if we follow this rule the power consumption will increase proportional to the more advanced services. 4G will hence break the 3G rule [1]:

$$P_{3G} \sim S_{3G} \quad (1)$$
$$P_{4G} \sim const \quad (2)$$

where P is the power and S is the service.

The incorporation in 4G of multi-hop ad hoc networks, for example, can permit to extend the coverage to many areas, increasing the spectrum efficiency of the system while minimizing the power consumption. It will be then a relief for the user terminal, which will also experience much longer stand by periods that will enable time demanding applications (e.g., movie on demand, etc.).

2) Provisioning of Heterogeneous Services: Services are heterogeneous in nature (e.g., different types of services, such as audio, video, pop ups, etc.), quality, and accessibility. In fact, at a certain time and place the quality and the accessibility of a service may not be the same due to the intrinsic heterogeneity of the network. For instance, a user in proximity of the shopping mall but out of the coverage of a WLAN can still receive pop-ups advertisements exploiting the multi-hop ad hoc network set up in his surrounding. Therefore, thanks to the dynamics of the network environment, which can change in number of users, terminals, topology, etc., 4G maximizes the probability to provide the user with the requested connectivity. Differently from the previous generations, the service provided in 4G will hence depend on time, place, terminal, and user:

$$S_{2G} \sim const \quad (3)$$
$$S_{3G} \sim f(place) \quad (4)$$
$$S_{4G} \sim f(time, place, terminal, user) \quad (5)$$

Indeed, also because of service and user personalisation, the service provisioning strictly depends on terminal and user respectively.

Apart from some ”soft” additional emerging service, such as fast Internet connection, pop-up advertisements, etc., there is still a lack of a really new one that will permit to start up new fruitful applications, making the user gain not yet marginal.

The real advantage in terms of services that 4G will bring is based on the integration of technologies designed to match the needs of different market segments. In particular, since 3G networks are not able to deliver multicast services efficiently or at a decent quality [4], the integration of *Digital Audio/Video Broadcasting* (DAB/DVB) in 4G will open the possibility of IP datacasting to mobile users, audio and video streaming in a much more efficient way than using the point-to-point switch network. Furthermore, also the integration of the *Global Positioning System* (GPS)/GALILEO in the user terminal will offer the essential feature of location-awareness, necessary to provide the user with the most comprehensive and extensive level of information, thus bringing the real revolution in terms of personalized services. These can provide not only location-based information, such as maps and direction to follow to reach a specific place, but also useful information relevant in time and space, such as pop-ups concerning offers in shops nearby. However, the GPS/GALILEO technology can only support outdoor localization of the user. Indoor localization requires the integration with short-range technologies, such as WLAN and *Wireless Personal Area Network* (WPAN). It is important to support, for instance, the guided tour in a museum in order to get information about the items exposed.

3) Multi-mode/Reconfigurable and Interworking Devices: As it is illustrated in Figure 5, 4G is characterized by the support of heterogeneous terminals ranging from pen-phone to car. However, since the mobile phone has been widely accepted and used for the past ten years (1.5 billion mobile phones are used worldwide, this more than three times the number of PCs), it is still expected to be in the next future ”on the edge of the wave” of the mass market.

Due to its size and weight that guarantees the satisfying

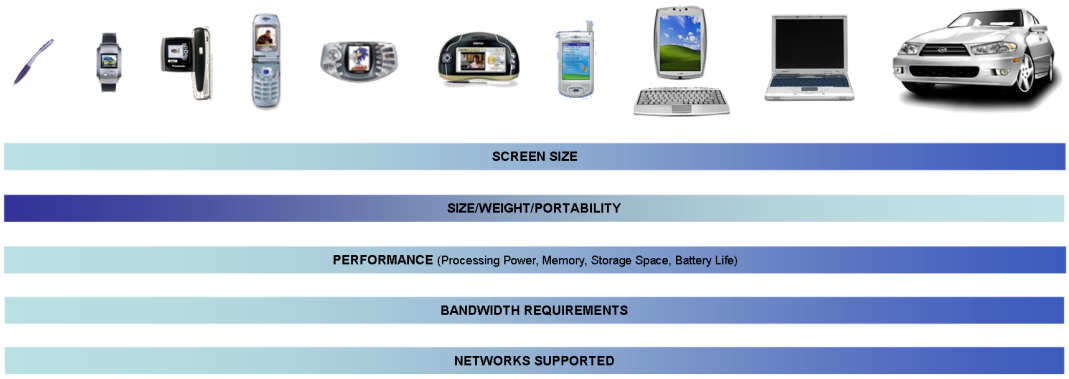

Fig. 5. Heterogeneous Terminals

portability, the wireless phone has still no competitor in the next future, while the penetration of other devices still occupies a restricted niche role in the market (e.g., a *Personal Digital Assistant* (PDA), a watch-phone and a pen-phone are still restricted to an elite of people more tech-confident). Moreover, due to the casual and informal feeling it gives, people will pay more attention to the pop up advertisements/news/events received on the mobile phone than on any other device.

Looking at the last innovations the actual tendency is to use a *General Packet Radio System* (GPRS) platform and provide the user with the most complete range of applications as possible, trying to include always new additional features (e.g., video camera). On the other hand, the new 3G mobile phones give essentially the possibility to support the mobile video communication. However, it is not really clear what is the real enhancement brought by 3G in our everyday life. The mobile video communication is not the ”killer application” as the quality of the video is still low and it is practically limited to a semi-static situation that implies a complete concentration of the user during the conversation (e.g., it is obviously not practical to watch a mobile phone while walking on the street), restricting the field of action and raising secondary problems, such as security issues (e.g., in the car for the driver himself).

Since 4G is based on the integration of heterogeneous networks, the future trend of wireless devices will move towards:

- Multi-mode/reconfigurable devices. The user terminal is able to access the core network by choosing one of the several access networks available and to initiate handoff between networks without the need for network modification or interworking devices. This leads to the integration of different access technologies in the same device (multi-modality) or to the use of *Software Defined Radio* (SDR) (reconfigurability) [5]. For example, the integration of Bluetooth in the user terminal will enable the personalization transfer, while the GPS/GALILEO technology will even allow the user to utilize his terminal as a navigator just by plugging it in the car, thus even lighten the number of needed devices. However, the reconfigurability of the user terminal is a key aspect that makes the future 4G technology as much adaptable as possible to the various worldwide markets.
- Exploitation of interworking devices. In order to reduce the hardware embedded in the user terminal and the software complexity, the use of interworking devices is exploited. For example, this is the case of a bridge/router performing the interworking between WMAN and WLAN: the WMAN is considered as the backbone and the WLAN as the distribution network; therefore, instead of integrating both technologies, the user terminal will only incorporate the WLAN card. The idea is hence to complicate the system with the advantage of a great relief for the user terminal.

III. CONCLUSION

In this paper, we have proposed a new framework — the user-centric system — that presents the key features of 4G: user friendliness and user personalization, network heterogeneity and terminal heterogeneity. Furthermore, its intrinsic satellite hierarchical structure shows the complex interdependencies among them, thus leading to the identification of the designing rules and consequently to a new pragmatic and not prophetic definition of 4G. Indeed, 4G will be a convergence platform providing clear advantages in terms of coverage, bandwidth, power consumption, variety of services ranging, from pop-up advertisements to location based services and IP datacasting ones. All these characteristics will be supported by multi-mode/reconfigurable devices and the implementation of interworking ones.

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