Cooperative Services for 4G

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***Abstract*— The progress in communication systems has fostered the need for a pragmatic methodology, centered on a user-centric approach, that leads to a novel vision of the *Fourth Generation of Mobile Communication Systems* (4G) and the definition of its key features and technological development. Along with this view, 4G will be a convergence platform that will provide clear advantages in terms of bandwidth, coverage, power consumption and spectrum usage, thus also offering a variety of new heterogeneous services (from pop-up advertisements to location-based and interactive or on-demand ones – so called IP datacasting). Though the core is still cellular, the network architecture will be predominantly extended to short-range communication systems, where the users may cooperate in a completely distributed or cellular-controlled fashion. In this paper, we propose new services derived from this vision of 4G and we give an insight of their potential social impact.**

***Index Terms*— 4G, Convergence, Cooperation, Heterogeneity, Power consumption, Services, Short-range communication, Spectrum efficiency, Unlicensed, User-centric, Wireless communication.**

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 users. Besides high quality speech, global mobility was a strong and convincing reason for users to buy 2G terminals. The *Third Generation* (3G) has been launched in several parts of the world, but the success story of 2G is hard to be repeated. One reason for this assertion is that the evolution from 2G towards 3G has not brought any substantial 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. The lack of innovative and appealing services was encountered too late by the *3G Partnership Project* (3GPP). In the latest standards, 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 improvements were made without the possibility to adjust the access technology properly.

Following the paradigm of generational changes, it was originally expected that the *Fourth Generation* (4G) would follow sequentially after 3G and emerge between 2010 and 2015 as an ultra-high speed broadband wireless network [1]. In Asia, for example, the Japanese operator NTT DoCoMo introduced the concept of MAGIC for defining 4G [2], which mainly concentrates on public systems and envisions 4G as the extension of 3G cellular service (the latter is in general the main trend also in China and South Korea [3]). This view is hence referred to as the *linear 4G vision* and, in essence, it focuses on a future 4G network that will be deployed several years after 3G has become commercially available on a large scale and will provide very high data rates (exceeding 100 Mbit/s). Furthermore, it assumes that the network will generally have a cellular structure, which basically means that it will be built on the fundamental architecture of the preceding generations of mobile technologies.

However, the future is not limited to cellular systems and thus 4G has not to be exclusively understood as a linear extension of 3G, even though it is named as the successor of the previous wireless communication generations. The *European Commission* (EC), for example, 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 [4]. This view is referred to as the *concurrent 4G vision* and emphasizes the heterogeneity and integration of networks and new service infrastructures, rather than increased bandwidth 'per se'.

Basically, 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 rule and thus any definition of it. Recently, a first attempt has been done in [5] and [6], where a pragmatic methodology, centered on a user-centric approach, leads to a novel vision of 4G and the definition of its key features and technological development. Along with this view, 4G will be a *convergence* platform that will provide clear advantages in terms of bandwidth, coverage, power consumption and spectrum usage, thus also offering a variety of new heterogeneous services (from pop-up advertisements to location-based and interactive or on-demand ones – so called IP datacasting). *Though the core is still cellular, the network architecture will be predominantly extended to short-range communication systems, where the users may cooperate in a completely distributed or cellular-controlled fashion.* Indeed, the concept of node cooperation introduces a new form of diversity that results in an increased reliability of the communication, leading both to the extension of the coverage and the minimization of the power consumption. In fact, mobiles are less susceptible to the channel variations and shadowing effects and can transmit at lower power levels in order to achieve a certain throughput, thus increasing their battery life. Furthermore, cooperative transmission strategies increase the end-to-end capacity and hence the spectral efficiency of the system.

In this paper, we propose new services derived from this vision of 4G and we give an insight of their potential social impact.

The rest of the paper is structured as follows: Section II describe the new proposed services, whereas Section III discusses their social impact. Finally, the concluding remarks are given in Section IV.

II. Novel Cooperative Services

This section gives a high level insight of the proposed services. Several technical dimensions such as cooperative diversity and quality of service will be discussed.

A. Cooperative service support by customer diversity

As shown in Figure 1, we assume a certain number of *Wireless Stations* (WSs) in the range of the same *Base Station* (BS), served by the same multicast service flow. In case only one terminal out of the group has received the overall information, we propose to perform the needed retransmissions locally.

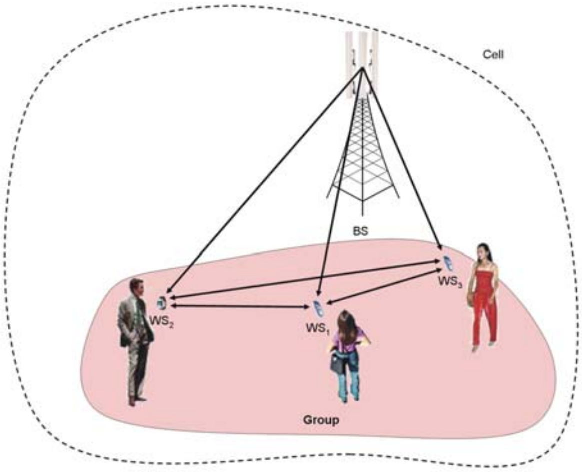

Fig. 1. Cooperative video service support by customer diversity.

The terminals in the same multicast group are in physical proximity, such that they can communicate with each other using high-speed wireless links. Due to the multi-user diversity, there is a high probability that at least one of them will receive the downlink multicast packet correctly; that terminal may hence become leader – *Cluster Head* (CH)[1] – and take the responsibility, if needed, to retransmit the data packet locally by using links with high data rate. In addition, it should also acknowledge the reception of the downlink packet towards the BS.

Contrarily to ad-hoc networks where the scope is to achieve a better routing and the retransmissions are performed at the IP layer, the novelty of the proposed service is to provide a more efficient retransmission scheme and an increased *Quality of Service* (QoS) to the users in the same group through an action at the *Data Link Control* (DLC) or *Physical* (PHY) layer. An explicative example of local retransmissions is shown in Figure 2 and Figure 3.

[1]Note that in this paper we do not take into consideration any specific algorithm for the clusters' formation, but we suppose that they have already been formed.

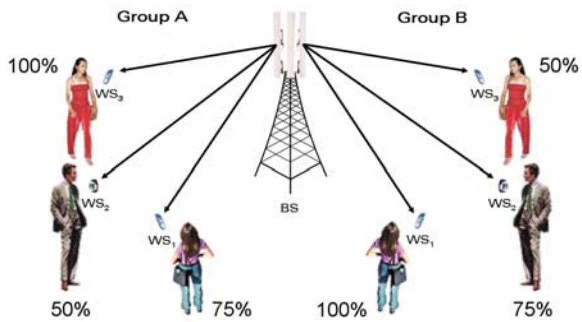

Fig. 2. Example of percentage of data correctly received by each user within different groups.

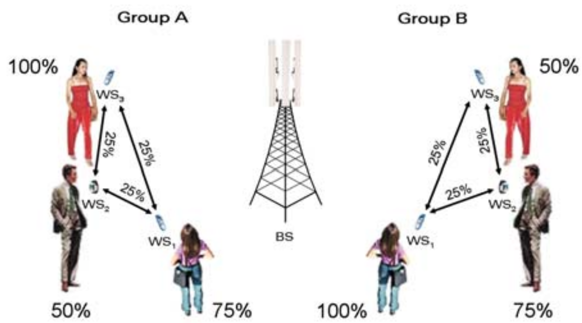

Fig. 3. Example of 'triangular' retransmissions.

Local retransmissions within the same short-range group have the following advantages:

- Retransmitted packets from neighboring terminals will be transmitted at a lower power level than it would be done by the BS, thus leading to a lower interference for parallel ongoing communications.
- Retransmissions can be performed by exploiting the unlicensed band, thus providing the service at a lower price.
- The BS can reserve some licensed band for the retransmissions in each group. As an example, in Figure 4 a common spectrum is used by the BS to convey multicast services to the terminals in both groups. If a retransmission for Packet 1 is requested in Group A while a retransmission for Packet 2 is requested in Group B, different retransmissions can be performed at the same time. In case of retransmissions performed by the BS, instead, the same amount of spectrum would have been used for twice much time.

Note that the retransmissions performed by the BS may be not totally avoided as all the group members may have not received the overall information. Thereby, the number of retransmissions performed by the BS depends on the number of users belonging to the same group:

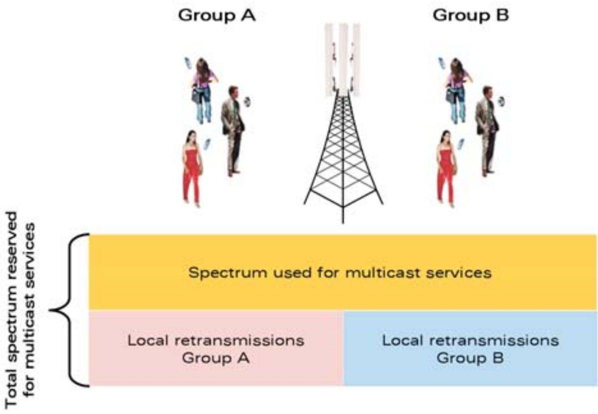

Fig. 4. Example of splitting the spectrum for common service support and local retransmissions for two different groups.

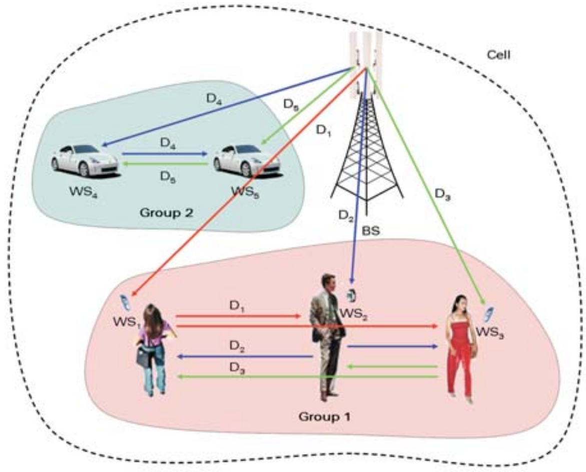

Fig. 5. Increasing video quality due to customer accumulation.

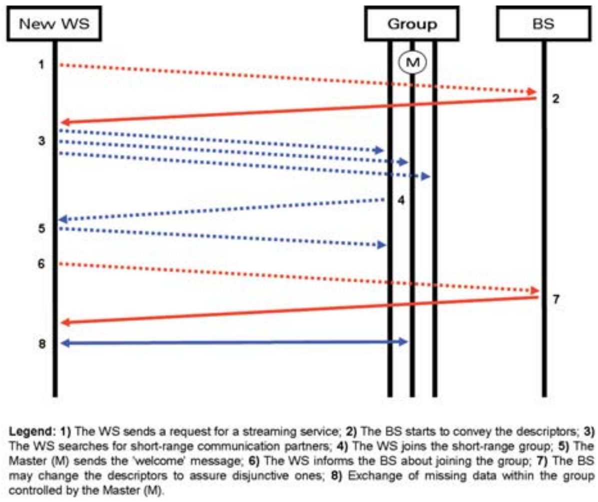

Fig. 6. Message sequence chart for a new user joining the group.

$$R = f(\frac{1}{GS}) \tag{1}$$

where *R* and *GS* are respectively the amount of retransmissions and the group size. Therefore, as a consequence of Equation 1, the proposed service infrastructure allows an adaptive regulation of the redundancy in dependency of the group size.

B. Increasing the quality of service due to customer accumulation

As shown in Figure 5, we assume a finite number of terminals in the range of the same BS served by the same video flow – as an example, we suppose a video streaming encoded by using the *Multiple Description Coding* (MDC). In order to increase the quality of the video, we propose that the BS transmits disjunctive descriptors to the different members of the group. Therefore, even if the higher data rate cannot be processed by one terminal alone over the cellular air interface, different terminals will receive different descriptors and repeat/forward them over the short-range air interface, thus having more bandwidth available. As a consequence, the increasing QoS will be dependant on the number of users belonging to the same group:

$$QoS = f(GS) \tag{2}$$

where *GS* is the group size.

The proposed service infrastructure hence induces the users to form cooperative groups in order to achieve the common benefit of an enhanced quality of service. Figure 6 shows the message sequence chart for a new user joining the group.

Although we referred to a video streaming the same framework may be applied to any other type of service.

III. The Social Dimension of the Proposed Cooperative Services

This section gives an insight on the potential social impact of the proposed services. The latter are mainly based upon three fundamental phenomena of social order:

1) *Group building.* Social groups on different levels (such as teenage groups, organized groups of football players, loosely organized groups of neighbours, which are relative stable over the time, or loosely organized and only for a short time stable internet groups) are the intermediaries in societies. Groups differ concerning what they have in common: spatial proximity (neighbours), interests (internet groups, business groups), age (teenage groups) and so forth. They are more or less durable over the time and more or less organized. Although the service provision is performed at the technical level, on the social level new groups might be established to lower the costs and offer a better quality of the services.
2) *Network.* The proposed cooperative services make intelligent use of a decentralized network of terminals. As Manuel Castells outlined [9], fuzzy, spontaneous networks become more and more important. In the proposed services, instead of acting strictly hierarchically, the necessary but limited hierarchy is evolving out of the given situation. The decision concerning the *master-*

terminal is drawn on the background of technical means and conditions seamless to the users. Customers will use this service according to the resulting performance and if they trust in the capability of the network of terminals to define a master-terminal that will be really able to coordinate. This type of network could be coined *situational hierarchy* and indicates the increasing relevance of new types of time-limited and functional networks.

3) *Cooperation/sharing.* The cooperation in question could be clarified by taken into account how it works in the society. Cooperation is usually defined as a coordinated effort to reach mutual goals. The different reasons at the base of this coordination are: traditions and habits, emotions (like compassion) or instrumental rational considerations (like efficiency, utility) or more normative rational considerations (what one ought to do according a given social or moral norm). It depends very much upon the context and the behavioral setting as well as upon the motivation in the background and thus in the stability of the cooperation. Although the common sense makes us believe that the best motivation for cooperation is a personal good outcome or result, the concept of the self-interested actor that tries to maximize his own interests and profits is not always valid. In the cooperative use of the mobile phone, for example, the rational interest of lowering costs and receiving a better quality of the services lies clearly in the realm of maximizing the profit. Nevertheless, also to become member of a group and to share not only material but symbolic resources (e.g., joint values, prestige, friendship, etc.), could be a strong motivation for utilizing the proposed services. Indeed, we can imagine groups that would like to make clever use of them in order to watch videos or share other files that are usually more expensive. Therefore, ad-hoc communities based on agreements about what to watch together are then possible to set up. These services hence increase the cooperative behaviour and empowers the consumer to make clever use of them. In general, the possibility for customers to deal in a creative manner with the technical possibilities is of great importance for the services' acceptance. In a way, the user terminal is not any more a bare medium to transfer information, but a social medium that helps to build groups and friendships.

Some researchers and mobile phone enthusiasts put high hopes in the possibilities of enhancing the cooperative behaviour and the resource sharing by mean of technological settings like ad-hoc networking. Howard Rheingold, who introduced in the beginning of the 90s the *virtual community*, reflects in his latest book [10] about the cooperational forces that mobile phones – *smart mobs*, as he calls them – provide for modern societies. Beyond some more utopian visions about wearable computers in clothes and a world of things that offers information about itself (the chocolate bar telling you its amount of calories aloud), Rheingold outlines the possibilities for modern societies to enhance social integration and solidarity with technological means.

Social integration, or more specific, some trust in the operators is necessary for the proposed cooperative services. The customer should be informed about the technical possibilities and services that enhance the use of his device. Transparency of the technology that is not directly visible on the level of the user interface is not only important to give customers the chance for creating their own use pattern and for active group building, but also for ensuring the value of security and trust. Data security is a sensitive feature in all networks within the fields of communications technology. Operators have to ensure that no unwanted data transfer arises with the proposed services.

IV. Conclusions

In this paper, we have proposed new services related to a novel 4G vision. According to the sociological point of view, each of them will enhance the use of the mobile phone and open the opportunities for creative social actions, such as cooperative groups. The critical discussion of relevant social issues concerning the different services is part of the development of socially robust knowledge and has the function to strengthen the proposals. The allegedly soft dimensions of culture and society had proved to be hard facts in the case of 3G and the WAP service. The pragmatic approach defined in [6], which leads to the new vision of 4G indicates hopefully a more successful way of technology development.

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