Flexible spectrum usage for the future broadband mobile and fixed convergence

***Sun Lixin*[1], *Jiao Jian,*[2] *Li Yanbin*[3]**

[1] Huawei Building, No.3 Xinxi Road, Shangdi Information Industry Base,
Haidian District, Beijing 100085, China, Email: sunlixin@huawei.com

[2] As above, Email: jian.jiao@huawei.com
[3] As above, Email: ellen.liyanbin@huawei.com

Abstract

To meet the tremendous increase of user demands on the global market, it is necessary to find more available spectrum resources for the future broadband mobile and fixed convergence. However, not only would spectrum be limited and become more and more precious in the future, but the spectrum regulation-making process still have a long way to go. Therefore, the insufficiency of spectrum resources will remain and will not be completed changed in a short time. In this paper, we try to avoid the air interface becoming the bottleneck for the future broadband mobile and fixed convergence from the solutions of flexible spectrum usage and the sharing of spectrums of different radio services. For this purpose, we provide two solutions of flexible spectrum usage for the mobile broadband applications, from the operational and regulatory perspective. The first solution is to enable the deployment of advanced technologies such as multi-band, multi-carrier aggregation to enhance the spectrum efficiency and broadband experience. Heterogeneous networks can also significantly improve the capacity and materialize the networks convergence via the mobile platform. The second solution is the practical implementation of the possible candidate bands identified for IMT. In addition to the traditional methods adopted such as carrier aggregation, multi-band combination etc, the low power pico cell, indoor coverage, and CRS through spectrum sharing and dynamic allocation has been addressed. Finally we compare the two mainstream duplexing schemes used in flexible spectrum usage, Frequency Division Duplex (FDD) and Time Division Duplex (TDD). In light of the advantages of TDD in the flexible spectrum usage, as the paper summarized, we believe TDD is the convincible solution in the future broadband mobile and fixed convergence.

1. Introduction

Various market researches and the rapid industry development trend are clear indications of what lies ahead of us, the broadband mobile and fixed convergence. It is supposed that future mobile broadband consumers would request to have similar user experience in access to similar services or the use of applications in the mobile environment as they have today in wired office or home environments. It is necessary to provide equally high data-rate services and quality to the mobile broadband consumer. This will require more spectrum resources in the future. However it will be hard to acquire new additional spectrum for mobile broadband applications in short term.

On the one hand, spectrum is limited and will become more and more precious in the future. One of pressing matters which may be faced is the emerging shortage of spectrum for mobile broadband applications including spectrum identified for IMT. For example, Report ITU-R M.2078 [5] was developed on spectrum estimates for IMT before WRC-07. Even with significant improvements in spectral efficiency that may come from the technologies under development for the radio access technology, the predicted total spectrum requirement was calculated for both low and high user demand scenarios to be 1 280 MHz and 1 720 MHz at least. The bands in the Table 1 have been identified for IMT in the Radio Regulations [2] so far. This identification does not preclude the use of these bands by any application of the services to which they are allocated or identified and does not establish priority in the Radio Regulations [2]. It has to be noted that different regulatory provisions apply to each band. The regional deviations for each band are described in the different footnotes applying in each band, as shown in the Table 1. Administrations may deploy IMT systems in bands other than those identified in the RR, or administrations may deploy IMT systems only in some or parts of the bands identified for IMT in the RR. Even if it chooses to put aside the differences of regions and nations, merely from the quantitative viewpoint, this identification adds up to 1 177 MHz at most. Meanwhile some of the bands identified for IMT at WRC-07 cannot be used for mobile cellular systems in some regions or nations on a harmonized basis due to existing heavy use of other radio applications in those frequency bands and other reasons. In short the spectrum now identified for IMT in the Radio Regulations [2] does not meet the spectrum requirement in the amount estimated for IMT in the lower user demand scenario

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estimated in Report ITU-R M.2078, not even with those identified IMT bands unavailable in some regions or nations.

Table 1: The bands identified for IMT in the Radio Regulations [6] without the differences of regions and nations

Band (MHz)	Footnotes identifying the band for IMT
450-470	5.286AA
698-960	5.313A; 5.317A
1 710-2 025	5.384A, 5.388
2 110-2 200	5.388
2 300-2 400	5.384A
2 500-2 690	5.384A
3 400-3 600	5.430A, 5.432A, 5.432B, 5.433A

On the other hand, the spectrum regulation-making process still have a long way to go, longer than technology innovation, under the current circumstance, it is not realistic to ask for more of Broadband mobile frequency bands allocation, instead it is more important to strengthen sharing broadband applications with other radio services. Instead of only calculating the deficiency of resources, we need to try to find a solution through spectrum sharing with other services..

In sum, an important factor for a successful deployment of mobile broadband is to avoid the air interface to become the bottleneck for the future broadband mobile & fixed convergence and the future growth of mobile broadband. In this paper, we try to deal with this issue from the solutions of flexible spectrum usage for the future broadband mobile and fixed convergence.

2. The solutions of flexible spectrum usage

Compared to 2010 projected values, we forecast that the mobile broadband traffic will increase by 7 times in 2013, by 60 times in 2016 and by 500 times in 2019. Technology advances have led to much improved spectral efficiency, but demand is still far outpacing current supply. The first solution is to make good use of the following bands identified for IMT in the Radio Regulations [2] so far.

- Bring 2x60MHz (FDD) from the IMT-2000 2.1GHz Core Band;
- Bring the mobile broadband spectrum to 2x170MHz (FDD) when the 900MHz and 1800MHz refarming processes will be completed (110MHz to be shared with the remaining GSM services for a while);
- Bring the mobile broadband spectrum to 2x270MHz (FDD) when the 2.6GHz and 800MHz bands will be assigned (2x65MHz in <1GHz bands, remaining 2x205MHz in >1.8GHz bands);
- Additional 65MHz from 2.1GHz and 2.6GHz bands (TDD) will actually be used when products from mature ecosystems will be adopted by operators;
- New allocations in the TV band digital dividend (in addition to the currently considered 800MHz band).
- Future harmonized use of the 2.3 – 2.4 GHz band for mobile broadband applications: LTE TDD would be the proper candidate technology;
- Future harmonized use of the 3.4 – 3.6 GHz band (C band): such large amount of spectrum would allow the set-up of “capacity layers” for IMT-Advanced systems addressing localized high capacity requirements.

The methods included in this first solution are carrier aggregation and heterogeneous networks. First of all, greater flexibility with wideband deployments by employing wider bandwidth need to depend upon carrier aggregation across bands. carrier aggregation is being cited as a major technological enhancement that will be essential for IMT-Advanced, particularly the requirement for the support of larger bandwidths than those currently supported in LTE while at the same time maintaining backward compatibility with LTE. Carrier aggregation simply combines or aggregates multiple component carriers on the physical layer to provide the required bandwidth, users can enjoy higher throughputs and lower latency. The case of contiguous component carriers is illustrated in Figure 1.

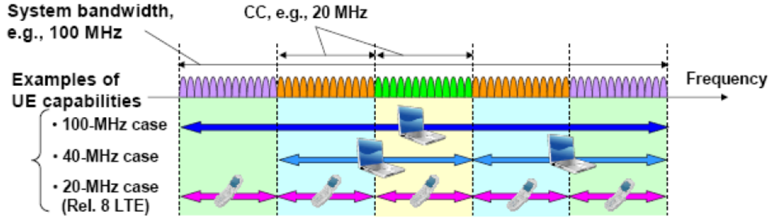

Figure 1: Carrier aggregation for LTE-Advanced systems illustrating flexible spectrum usage

In the next place, flexible and faster network deployment is achieved with the help of heterogeneous networks (HetNet). As reported in [8], improvements in spectral efficiency per link is approaching theoretical limits with 3G and LTE, therefore future technologies are considering improvements on the spectral efficiency per unit area. This means that users anywhere within a specific cell have to have a smooth and uniform experience and this can be achieved by implementing a new deployment strategy using heterogeneous networks which is different from traditional network topology. Heterogeneous networks will incorporate advances in wireless systems in which a single base station can achieve near optimal performance. Heterogeneous networks will combine a variety of low power nodes with distinct characteristics, deployed throughout a macro eNB cell layout and in a manner which guarantees an improvement in the spectral efficiency per unit area. These low power nodes will include micro, pico, remote radio head (RRH), relay and femto nodes, some of which are shown in Figure 2. Due to their lower transmit power and smaller physical size, these nodes can offer flexible acquisitions.

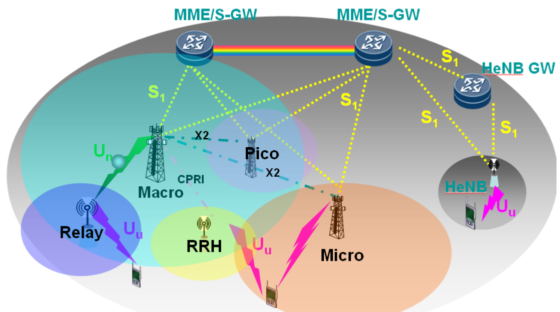

Figure 2: Deployment of Heterogeneous Network (Supplementary information can be found in [9])

The second solution is the new practical methods of the following possible candidate bands identified for IMT. We should consider spectrum requirements and possible additional spectrum allocations or share in the mobile service to support the future development of mobile broadband as follows.

- To access parts of the television spectrum ("white spaces" of the frequency band 470–790 MHz);
- New allocation or share in 1.5G: such large amount of spectrum would allow the set-up of “capacity layers” for mobile broadband applications addressing localized high capacity requirements.;
- New allocation or share in 2700 – 2900 MHz: The first has to do with sharing of some radar applications with mobile broadband applications within the 2 700-2 900 MHz band;
- New allocation or share in 3.8-4.2/4.5-4.8 GHz and higher frequency range: it is possible to share the C-band (3.8-4.2/4.5-4.8 GHz) between mobile broadband applications and the fixed satellite service (FSS)/some radar applications by the new practical methods.

Generally, temporally and/or geographically under-utilised frequency bands could be considered as unused spectrum. This kind of spectrum exists in many frequency bands, when the whole band or parts of it are under-utilised. Typical and well known applications which under-utilise the spectrum usage are, for example, television (TV) in the UHF band(470 - 806/862MHz), the fixed satellite service (FSS) in many bands such as the C-band (3.6 - 4.2 GHz) and many radar applications. Meanwhile one key element in spectrum use is the coexistence and sharing of the spectrum. Sharing/coexistence means that the radio systems share some of the resources (spectrum and/or time) in a certain geographical area in a way which makes it possible to operate both systems without causing harmful interference to each other in a regulatory manner. Therefore the goal of the methods included in this second solution should be flexible, efficient and interference free spectrum use in some previous unused spectrum. The second solution includes not only the methods mentioned above, such as carrier aggregation and heterogeneous networks, but aslo the predominant use of pico-cells and Cognitive Radio Systems (CRS).

To begin with, the predominant usage of pico-cells in some previous unused spectrum looks like an interesting scenario for the future mobile broadband. Spectrum sharing should be encouraged especially in areas with high capacity demands where it may not be easy for all operators to acquire the large amount of spectrum required: picocell indoor coverage generated a major part of mobile data traffic. Furthermore it is important to note that, while the macro base stations transmitting at high power levels of about 5W- 40W are deployed , the base stations used for picocell indoor coverage typically transmit at very low power levels ranging from 10mW-1W. As a result of the low transmit power of pico base stations coupled with unplanned deployment, the mobile broadband networks in which these base stations are located will not cause interference or otherwise influence the performance of other systems in some previous unused spectrum by minimising the interference.

Nowadays, CRS has been identified as one of the key technologies to support spectrum innovation and strong standardization and research efforts are on-going: ITU-R WP5A/WP5D/WP1B, ETSI Reconfigurable Radio Systems (RRS), IEEE Standards Coordinating Committee 41(SCC41)/802.22, SDR Forum and so on. The development of CR standards needs to be guided more by relevant regulations than by technical restraints. Although CRS has not been applied in industry due to a number of technical and regulatory challenges, academic research has shown that CRS is a potential solution to mitigate spectrum scarcity and improve spectrum usage efficiency.

The regulatory policies would affect the development of CRS, We need firstly focused on some specific scenario with some limited scope. The technological techniques outlined (use of CR, predominant use of pico-cells, etc) would be helpful in gaining more spectrums for Broadband sharing with other radio services.

3. The Advantages of TDD over FDD in Flexible Spectrum Usage

Frequency Division Duplex (FDD) and Time Division Duplex (TDD) are the two most prevalent duplexing schemes used in flexible Spectrum Usage for the future broadband mobile and fixed convergence. To compare these two duplexing schemes, the advantages of TDD can be summarized as follows:

- FDD is an scheme that was best suited for applications, such as voice, that generate symmetric traffic, while TDD is best suited for bursty, asymmetric traffic, such as Internet or other data centric services.
- TDD utilizes the spectrum more efficiently. FDD cannot be used in environments where the service provider does not have enough bandwidth to provide the required guardband between transmit and receive channels, especially when sharing with other radio services.
- TDD is more flexible than FDD in meeting the need to dynamically reconfigure the allocated upstream and downstream bandwidth in response to customer needs.

When reviewing the current spectrum allocation in the 2G/3G, most of TDD bands is unused or less widely utilized. In addition to seek for further candidate bands availability, to make full use of the existing unused or sparsely used TDD bands will relieve the burden of spectrum insufficiency to much extent, taking an example, the bands of 1900-1920MHz, 2010-2025MHz, 2570-2690MHz, and some other possible co-sharing bands.

In summary, TDD is a more desirable duplexing technology that allows system operators to gain greater flexibility of using of CR technology, predominant use of pico-cells. In other words, TDD is more suitable for flexible spectrum usage for the future broadband mobile and fixed convergence.

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