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Spectrum Issues in the post WRC'07 Era

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White Paper

Spectrum Issues in the post WRC'07 Era

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Spectrum Issues in the post WRC'07 Era

Abstract –

This white paper presents an overview of the outcome of the WRC (World Radiocommunication Conference) 2007 conference in the light of spectrum use for mobile systems. In the conference new spectrum bands were identified for mobile services, and especially for International Mobile Telecom (IMT) technologies. These results have implications on the future wireless system design and eventually on the services offered to the public, especially when reviewed in the light of predictions made about future spectrum requirements. Examples of implications include operation in non-contiguous bands, spectrum sharing and the availability of large enough spectrum bands. Future systems solutions are currently still very much worked upon in various research initiatives all over the world, we believe that this white paper provides valuable input to these initiatives.

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LIST OF ABBREVIATIONS:

3G	3rd Generation mobile services or systems
CEPT	Conference of European Post and Telecommunications
CR	Cognitive Radio
DAB	Digital Analogue Broadcasting
DMB	Digital Multimedia Broadcasting
DTV	Digital TV
DVB-T	Digital Video Broadcasting - Terrestrial
EIRP	Equivalent Isotropically Radiated Power
FCC	(US) Federal Communications Committee
FDD	Frequency Division Duplex
FS	Fixed Service
FSS	Fixed Satellite Services
HDD	Hybrid Division Duplex
GSMA	GSM Association
GSM	Global System for Mobile communications (an ETSI Standard)
IMT-2000	International Mobile Telecommunications - 2000 (an ITU term)
IST	Information Society Technologies
ITU	International Telecommunications Union
ITU-R	International Telecommunications Union - Radiocommunications Sector
JTG	Joint Task Group (within the ITU)
LTE	Long Term Evolution
MNO	Mobile Network Operator
PC	Personal Computer
PCS	Personal Communications Service
PDNR	Preliminary Draft New Recommendation (in the ITU)
RAT	Radio Access Technology
RRC	Regional Radio communications Conference
RLAN	Radio Local Area Network
SDR	Software Defined Radio
TDD	Time Division Duplex
TETRA	Terrestrial Trunked Radio (an ETSI Standard)
TV	Television
TVWS	TV White Spaces
TWIM	Terrestrial Wireless Interactive Multimedia (an ITU term)
UMTS	Universal Mobile Telecommunications System
UHF	Ultra High Frequency
UWB	Ultra Wide Band
WARC	World Administrative Radiocommunication Conference (of the ITU)
WINNER	Wireless World Initiative New Radio (an Integrated project in the EU FP6)
WLAN	Wireless Local Area Network
WP8F	Working Party 8F (a subgroup of Study Group 8 of the ITU-R)
WRC	World Radiocommunication Conference (of the ITU)
WWRF	Wireless World Research Forum

1 Introduction

From October 22 until 16 November 2007 the International Telecommunications Union's (ITU) World Radiocommunication Conference (WRC-07) convened in Geneva, Switzerland to discuss the updating of the Radio Regulations 2008 [2]. The Radio Regulations provide a worldwide framework for spectrum allocations, as well as certain technical details on how the band can be used [5].

This white paper presents an overview of the outcome of the conference in the light of spectrum use for mobile systems. In the conference new spectrum bands were identified for mobile services, and especially for International Mobile Telecom (IMT) technologies. These results have implications on the future wireless system design and eventually on the services offered to the public, especially when reviewed in the light of predictions made about future spectrum requirements [6]. Examples of implications include operation in non-contiguous bands, spectrum sharing and the availability of large enough spectrum bands. Future systems solutions are currently still very much worked upon in various research initiatives all over the world, we believe that this white paper provides valuable input to these initiatives.

The white paper is organised as follows; Chapter 2 presents an overview of the outcome of WRC for IMT. Chapter 3 discusses the impact of the outcome of WRC on the technologies and design of IMT systems. Chapter 4 addresses possibilities and challenges for mobile spectrum in the UHF band. Finally in Chapter 5 conclusions are drawn.

2 Summary of the outcome of WRC

2.1 Introduction

The first frequency bands for IMT-2000 were identified at the World Administrative Radio Conference in 1992, with additional bands identified at WRC-2000.

The need for a global vision for the further development of IMT-2000 and technologies beyond IMT-2000 was first recognized at WRC-03. The ITU was requested to study the technical and operational aspects of how these systems will evolve and report to WRC-07.

An agenda item (Agenda item 1.4) was created to "consider frequency-related matters for the future development of IMT-2000 and systems beyond IMT-2000 taking into account the results of ITU–R studies in accordance with Resolution 228 (Rev. WRC-03)" [1]. The World Radiocommunciation Conference, 2007 (WRC-07) was held from October 22 until November 16 2007 in Geneva.

Report ITU-R M.2074 says that there may be a need for new wireless access technologies to be developed around the year 2010 and be widely deployed around 2015 in some countries. ITU market and technology predictions show that further spectrum will be needed for IMT within the next decade; they are detailed in Report ITU-R M.2072. Based on these trends and predications Report ITU-R M.2078 calculates the spectrum bandwidth requirement for the year 2020 as 1 280 MHz.

2.2 Outcome Agenda item 1.4

Globally harmonized spectrum identified for use by International Mobile Telecommunications (IMT) represents an important driver in the worldwide development of IMT systems. At WRC-07 new bands were identified for use by IMT, the identifications differ from region to region and are not fully globally harmonized but there is a strong common factor. The identifications can be summarized at high level as follows [4].

- 450−470 MHz band
- 698−862 MHz band in Region 2 and nine countries of Region 3
- 790−862 MHz band in Regions 1 and 3
- 2.3−2.4 GHz band
- 3.4−3.6 GHz band (no global allocation, but accepted by many countries)
- In addition to the bands identified at WRC-07, the following bands are identified in the Radio Regulations for [IMT or IMT-2000]: 1 885-2 025 MHz and 2 110-2 200

MHz (WARC-92, No. 5.388), 806/862-960 MHz (WRC-2000, No. 5.317A), 1 710-1 885 MHz and 2 500-2 690 MHz (WRC-2000, No. 5.384A)

Note that Region 1 roughly entails Europe, Africa and the Middle East, Region 2 Americas, and Region 3 Asia excluding the Middle East and the Russian Federation. A more detailed description follows in the next section, full details about the outcome of the conference can be found in the final acts of WRC [3].

2.3 Detailed Frequency Identifications per Region

2.3.1 Region 1 (Europe, Africa and Arab countries)

- The band 790-862 MHz that was only allocated for broadcasting systems is now equally allocated Mobile Service and identified for IMT in Europe/Africa and Arab countries with equal rights (co-primary basis). This allocation will be effective from June, 17th 2015 [1] but is subject to neighbor countries agreement. Before this deadline, listed countries in a footnote, where part of the band 790-862 MHz is already effective, are authorized to implement IMT.

- Mobile Service, and by that IMT, can now also use the band 3 400- 3 600 MHz on a co-primary basis with other services sharing this band (Fixed Service (FS) and Fixed Satellite Services (FSS), under regulatory and technical conditions, in 83 countries in Region 1, including most of the European countries. This allocation is to enter into force from 17th of November 2010.

2.3.2 Region 2 (Americas)

- The region has now a Mobile allocation on a co-primary basis in the band 698-806 MHz (noting that 806-862 MHz was already co-primary for Mobile) except in Brazil where this band is secondary basis (operational restrictions compared with broadcasting services). This band is also identified for IMT.

- The band 3 400- 3 500 MHz is now allocated for Mobile on co-primary basis with FS and FSS but without IMT identification in a number of countries in Latin America. This allocation is subject to regulatory and technical restrictions.

[1] In Germany and some other EU countries this spectrum has already been auctioned and the spectrum will be available soon for broadband deployment in particular in rural areas.

2.3.3 Region 3 (Asia)

- The band 470-862 MHz was already allocated to the Mobile service on co-primary basis. The part 698-790 MHz is now identified for IMT in some countries but the part 790-862 MHz is identified for IMT in the whole Asia.

- The band 3 400-3 500 MHz is now allocated for Mobile on co-primary basis with FS and FSS and identified for IMT in several countries with regulatory and technical constraints. This allocation is to enter in force from 17th of November 2010.

- The band 3 500- 3 600 MHz that was already allocated to Mobile on co-primary basis is now identified for IMT under regulatory and technical constraints in several countries.

2.3.4 Worldwide

- The frequency bands 450-470 MHz and 2300-2400 MHz are now identified for IMT and globally harmonized. However, the use of this band is dependant on every administration.

2.4 Complementary information and agenda item 7.2 issues related to WRC-11 agenda

- The bands 470-862 MHz also have a Resolution 224 (WRC-07) related to the studies on the use of the band 470-862 MHz by mobile applications (including IMT) and broadcasting applications. It invites ITU-R to conduct sharing studies between the Mobile Service and other services in the band 790-862 MHz by 2011 (invites ITU-R 1 and 2).

- The WRC-11 agenda contains the following item that may have implications to IMT-Advanced, it's future research and deployment:

    - Agenda Item 1.17: "to consider results of sharing studies between the mobile service and other services in the band 790-862 MHz in Regions 1 and 3, in accordance with Resolution **749 (WRC-07)**, to ensure the adequate protection of services to which this frequency band is allocated, and take appropriate action;"

    - Agenda Item 1.19: "to consider regulatory measures and their relevance, in order to enable the introduction of software-defined radio and cognitive radio systems, based on the results of ITU-R studies, in accordance with Resolution 956 (WRC-07)"

3 Implications of WRC for Mobile Systems

The spectrum allocation outcome of WRC-07 has left some questions regarding how much of the requirement for the IMT-Advanced service can be satisfied, due to the relatively narrow contiguous band available for harmonization. This has raised questions [7] regarding what to do about the need to be able to utilize the limited spectrum available effectively and efficiently for the next generation communications.

3.1 Radio interface design

WRC-2007 identified additional frequency spectrum for mobile and wireless applications. However, these identifications are not accepted on global level. There are regional differences. Regional regulators bodies such as CEPT ECC PT1 in Europe and system specification bodies like 3GPP are currently investigating options how to use these bands. WRC 2007 identified the following frequency bands for further consideration [20]:

- 450 – 470 MHz
- 698 – 806 MHz 1)
- 2300 – 2400 MHz 2)
- 3400 – 3600 MHz 3)

The following remarks have to be taken into account for these bands:

1) The whole band 698 – 960 MHz is not identified on a global basis for IMT due to variation in the primary mobile service allocations and uses across the three ITU Regions. In particular 698 – 806 MHz in Region 2 and nine countries in Region 3, 790 – 862 MHz in Region 1 and other countries in Region 3.

2) This band is not available in Europe.

3) In some countries identified via footnotes in the ITU-R Radio Regulations. CEPT ECC PT1 will also address the band 3600-3800 MHz for IMT.

It is highly probable that substantial changes in the radio interface design may be required to deal with the WRC-07 outcome, where the likelihood of spectrum being allocated in non-contiguous manner, as witness through cases such as LTE and LTE Advanced, seems to be increasing and a need for spectrum sharing seems to be increasing as well. Currently many research initiatives are being undertaken in this field [8].

Regarding the first issue of non-contiguous spectrum being the main supply in the future, the question that needs to be answered is how the radio interface needs to be designed in order to deal with effectively utilizing the split spectrums. The radio interface design must enable protocols that may cover non-contiguous band allocations and it must also take into account signaling issues.

The second question that needs to be answered is what components and signaling mechanism there needs to be in order to enable spectrum sharing among different services.

3.2 Carrier bandwidths, technical implications

The bandwidth of carriers is becoming more important as the available spectrum gradually migrates toward the higher frequency bands. The apparent tradeoff of higher frequency bands is that usually more bandwidth is available at higher frequencies while the propagation characteristics are characterized as not good in terms of the range that a signal can travel. It becomes important to realize, however, that inferior propagation characteristics can actually work better in big cities where the number of users per square kilometer is overwhelming. In that case, the smaller cells can actually be an advantage in that the total number of people that can be accommodated increased due to the number of cells that can be created within a specific area.

Assuming that a wide range of frequency is available within a cell, the scheduling or allocation of frequency may be done intelligently by giving higher frequencies to users with high data rate demand, such as video, while lower frequency carriers are assigned to users with lower data rate demand but higher reliability demands such as voice and text messages.

And here also, the implication of the WRC-07 outcome, must be taken into account, especially the allocation of the non-contiguous band, at least for downlink.

3.3 Sharing between different Services

Sharing spectrum between different services is one of the main pillars of efficient spectrum utilization methods. Resolution 749 of WRC-07 [9], which deals with the use of the band 790-862 MHz by mobile applications and by other services, is an example of efforts being exerted for the purpose of finding ways to utilize the band with the most favorable propagation characteristic.

3.4 Infrastructure sharing in case of limited available spectrum

Sharing between different radio access technologies (RAT) may be the more feasible solution for the near future and heavy research is being exerted in this area. There may be several scenarios that need to be considered, but most cases fall into the following two cases: 1. co-primary scenario, 2. primary and secondary scenario.

Introduction of Cognitive Radio (CR) and Software Defined Radio (SDR) concepts , in accordance with Resolution 956 (WRC 07) on Regulatory measures and their relevance to enable the introduction of software-defined radio and cognitive radio systems.

One of the key issues that apply to either scenario is determining how reliable and efficient the sensing mechanism and signaling needs to be as well as the time required to sense existing users. In the co-primary scenario hidden-node problem needs to be investigated.

For the second scenario where primary and secondary systems are to share the same frequency channel, it is important for the secondary system to be capable of detecting primary systems that may be attempting to utilize the shared spectrum. The key technologies that need to be used in order to resolve such issues are spectrum sensing and geolocation.

An alternative to sensing is for a CR to have a database available of the frequencies that can be used at certain locations as well as the applicable rules (transmit power). To use the database, the CR needs to know its own location. Such a concept, also known as a geolocation database, could help to overcome most of the problems associated with standalone sensing.

There are five key issues to be addressed in developing a geolocation database:

- The information to be provided by the device to the database;
- The information returned from the database to the device. An intelligent database could return to the CR device not only the spectrum but also the transmit powers that could be used in each channel, decreasing complexity on the CR terminal side;
- The frequency of update of the database and hence the periodicity with which devices will need to update from the database;
- The modeling algorithms and device parameters to be used to fill the database;
- The maintenance of the database.

3.5 TDD / FDD Operation Mode

There are many issues that could be considered due to the new spectrum allocation trend where more and more spectrum are being assigned (including auctions) as unpaired and thus increasing the flexibility of users of the spectrum. What is apparent at this moment is that FDD mode has been is still in favor with most standards with legacy cellular background (e.g. LTE, LTE Advanced) while TDD mode is favored by emergent standards that have a data traditional background (e.g. WiMAX). Hybrid division duplex (HDD) had been proposed in the past [11] and the viability of the technology may be increasing due to the current trend in the spectrum allocation that allows for technological neutrality in assigning new and refarmed spectrum.

ECC Decision of 30 October 2009 on harmonised conditions for mobile/fixed communications networks (MFCN) operating in the band 790 - 862 MHz:

WRC-07 allocated on a primary basis the 790-862 MHz band to mobile services in Region 1 as from 17 June 2015, and in some CEPT countries it is possible to utilise this band for mobile services before 2015, in accordance with the provisions of the Radio Regulations.

All duplex methods TDD, FDD full duplex (FDD-FD) and FDD half duplex (FDD-HD) have been initially considered with the aim to define a solution to accommodate spectrum for operators who would wish to use different technologies, while paying due attention to coexistence issues and spectrum efficiency. Recognizing the advantage of a single harmonised frequency arrangement, the preferred frequency arrangement is based on FDD. TDD frequency arrangements and other approaches can be used on a national basis.

The harmonised frequency arrangement is 2 x 30 MHz with a duplex gap of 11 MHz, based on a block size of 5 MHz, paired and with reverse duplex direction, and a guard band of 1 MHz starting at 790 MHz. The FDD downlink starts at 791 MHz and FDD uplink starts at 832 MHz.

790-791	791-796	796-801	801-806	806-811	811-816	816-821	821-832	832-837	837-842	842-847	847-852	852-857	857-862
Guard band	Downlink						Duplex gap	Uplink					
1 MHz	30 MHz (6 blocks of 5 MHz)						11 MHz	30 MHz (6 blocks of 5 MHz)					

Figure 1. Preferred harmonised frequency arrangement [12]

3.6 Region Specific issues

The result of WRC-07 has shown that although spectrums for IMT-Advanced applications have been identified, only a fraction of the bands most sought out have been made available globally. Only 20MHz (450-470 MHz) of the UHF bandwidth has been identified and also 2300-2400MHz band has been identified for new IMT spectrum. The implication is that regional differences in allocation of spectrum will continue in order to satisfy the needs of spectrum for each location.

4 Spectrum for Mobile Services in the UHF band

4.1 Broadcasting (propagation path loss versus antenna gain)

The benefits of using a lower frequency band were developed in a former WWRF White Paper: "Considerations in the Choice of Suitable Spectrum for Mobile Communications" [13].

A higher the frequency results in a higher propagation loss. In a first approach the additional loss (ΔL) can be estimated as a function of the frequency difference (ΔF),

$\Delta L = 26 \log \Delta F$.

As an example comparing 700 MHz to 2.1 GHz means a difference of at least 13 dB.

This represents a huge amount if we compare the respective number of sites required for a given coverage in the two bands. In mobile, with an average base station antenna height of 30m, the path loss difference versus coverage distance Δd is given by:

$\Delta L = 35 \log \Delta d$.

Thus 13 dB gain means in theory a distance reduced by a factor of 2.3 and a number of sites divided by 5 when using UHF band compared to present 3G band.

Nevertheless this gain could be seriously reduced when we take into account the respective antenna gains on both sides:

Base station: On most cellular sites the size of antennas is limited due to environment constraints (which is not the case for high power broadcasting sites). In this example, for a given antenna size, the gain in UHF will be 5 dB lower than in 2 GHz band.

Terminal: Due to the large span of the UHF range (470 – 862 MHz) a tunable antenna is not possible if the entire band must be scanned. In consequence the gain for an integrated antenna is very poor, in the order of -7 dBi. This is to compare with a classical gain of 0 dBi in most GSM/3G handsets.

Presently this represents a strong disadvantage for a technology like DVB-H where no harmonized sub band was possible to achieve in UHF due to existing TV services.

A globally or regionally harmonized sub-band for mobile services also facilitates the handset design, with respect to the different filters that have to be implemented in order to mitigate interference from the adjacent broadcasting band, or from nearby handsets operating on two different band plans. Finally, harmonized band plans facilitates global roaming and the development of handsets that are affordable to the widest range of users (including users in developing countries with lower income).

In conclusion we can say that for future mobile services a harmonized sub band in UHF is strongly recommended.

4.2 Digital dividend, when available

4.2.1 The Challenge

The ITU World Radio communications Conference in October 2007 (WRC-07) was an opportunity for the telecom industry to have access, in a reasonable timescale, to part of the UHF spectrum which has been for decades attributed to broadcast TV services only.
In Europe for example, the band, at the moment, is fully used by these services, but the switch-off of analogue TV systems, around 2012 for most European countries, following the transition to full digital transmission of terrestrial television will allow the release of valuable spectrum called "digital dividend" for other uses.

The benefits for the telecom operators are important; the release of a portion of the UHF band for non-broadcasting services could be the key to provide wireless broadband to rural areas. The propagation characteristics of UHF could facilitate the deployment of networks reaching sparsely populated areas that are uneconomic to cover with networks operating at higher bands.

Without a common band agreed at European level, it is unlikely that the economies of scale will be sufficient to justify the deployment of mobile services on a spectrum plan unique to a specific country. Network equipment and terminals will simply be too expensive, if available at all. Co-ordination in this context means that similar quantities of contiguous spectrum is identified in broadly similar frequencies across all or at least most European markets, and that this spectrum is released in similar timeframes.

In 2006, during the ITU Regional Radio communications Conference (RRC-06), a general agreement in Europe was achieved on a new frequency plan for digital broadcast services in VHF and UHF taking into account the analog switch off transition period.

Unfortunately at that time no provision was taken for mobile services except mobile broadcast TV. For the partitioning of allotments between countries, the planning was based on existing DVB-T and T DAB standards and new mobile broadcast technologies like DVB-H or T DMB. In UHF, the whole spectrum was considered without any provision for future duplex mobile services.

Before WRC 07, some countries like UK had already identified a 112 MHz potential digital dividend, while some others like Germany were strongly considering using the whole UHF band for broadcast only services according to the RRC-06 agreement.

From a MNO perspective, the mobile allocation is a necessary, but not sufficient, step in order to open any options for a use of the digital dividend. Even with a mobile allocation of the band, European and national regulators could still decide that the best use of the spectrum is for broadcasting. However, without an allocation the possibilities of having a pan-European band will be slim since there would be no protection for mobile services

from interference, and vice versa, interference protection should be guaranteed to broadcasters.

In consequence at the beginning of WRC-07 a compromise between countries, broadcast and telecom communities seemed to be very difficult to reach, especially for Europe.

4.2.2 The status of the digital switchover in Europe

Due to the spectrum efficiency of Digital Television (DTV), some of the spectrum bands used for analog TV will be cleared and made available for other usage. Moreover, DTV spectrum allocation is such that there are a number of TV frequency bands which are left unused within a given geographical location so as to avoid causing interference to co-channel or adjacent channel DTV transmitters; that is to say, the spectrum bands are geographically interleaved. The cleared bands and the unused geographical interleaved spectrum bands provide an opportunity for deploying new wireless services. These opportunities create what is called the "Digital Dividend" in the literature [14] [15] [16] [17] [18] [19]. In other words, the digital dividend refers to the "leftover" frequencies resulting from the change of TV broadcasting from analog to digital.

The UK regulator, Ofcom, has led Europe in creating a digital dividend. As illustrated in Figure 2, the UK's digital dividend comprises:

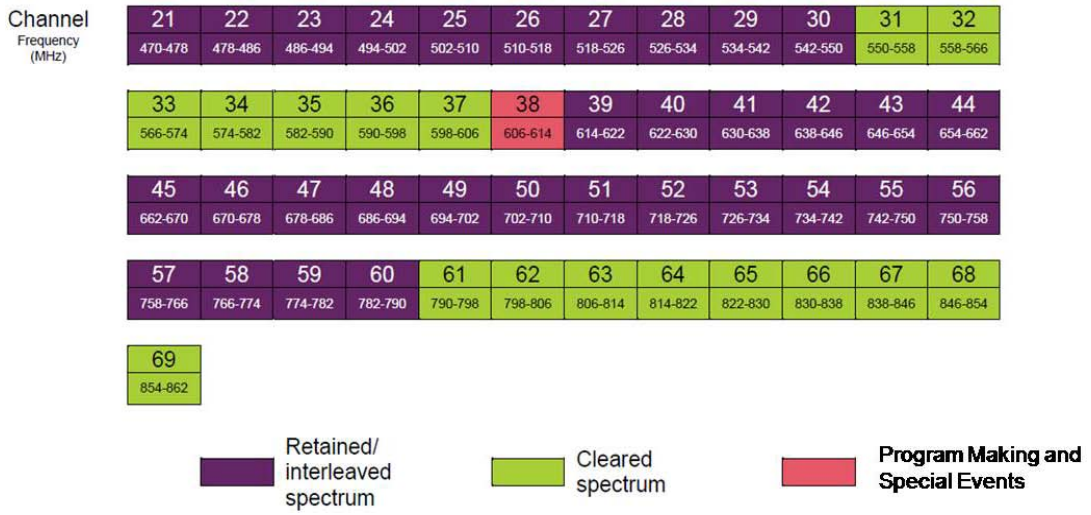

Figure 2. Spectrum allocation after the Digital switchover in the UK

- Cleared spectrum –128 MHz that will become available for new uses primarily as a result of digital switchover;
- Geographical interleaved spectrum (or Television White Spaces - TVWS) – the capacity available within the spectrum that will be retained for digital terrestrial TV after switchover. This is known as interleaved spectrum because not all this spectrum in any particular location will be used for digital terrestrial TV and so is available for other services on a shared (or interleaved) basis.

Following the UK's leadership, it is now clear that a growing number of other European countries will release a digital dividend, but within a slightly wider block of spectrum than the UK's, at 790-862 MHz (the so-called 800 MHz band). For example:

- In Sweden, a governmental decision taken in 2007 came into force on January 1, 2009;
- In Finland, the Government allocated the band 790-862 MHz to digital broadband mobile networks; the decision came into force on July 1, 2008;
- In France, the government announced the allocation of the 790-862MHz band to digital broadband mobile networks; with auctions/beauty contest announced for 2009.

As Finland, France and Sweden have already decided to release this wider block of spectrum of 72 MHz, a number of other countries are expected to do likewise. On the other hand, the European Commission is under consultation on how to harmonize the realization of the digital dividend over the whole of Europe so as to avoid fragmentation in terms of policies among member states [14] [15] [16] [17] [19]. As we have seen above, the Ofcom on its part is already aligning its digital dividend to the 72 MHz wider block so that devices can operate all over member states.

For the European Commission, the Digital Dividend (Cleared spectrum and geographical interleaved spectrum) constitutes a great opportunity to realize significant elements of the EU Lisbon strategy, e.g. providing significant improvements in mobile broadband, multimedia and Internet access.

4.2.3 UHF spectrum for future LTE development

The ability to take advantage of new spectrum allocations and the opportunity to potentially reform existing GSM spectrum are two key areas that will enable LTE deployments. Enhancing network capabilities presents new deployment opportunities, economies of scale and opens up markets that were previously inaccessible. The transition from analog to digital terrestrial television will release large amounts of spectrum potentially for mobile broadband deployments – the so-called Digital Dividend.

The oncoming spectrum auctions in the (700 MHz and 2.5-2.6 GHz bands) will have a direct influence on the LTE ecosystem and in which band LTE will be deployed.

Furthermore, the identification of new IMT mobile bands at WRC-07 (450-470 MHz, 2300-2400 MHz, 698-862 MHz and 3400-3600 MHz) will help fulfills the projected need for future bandwidth as well as facilitates global roaming. In fact, over the next several years the spectrum landscape will change significantly

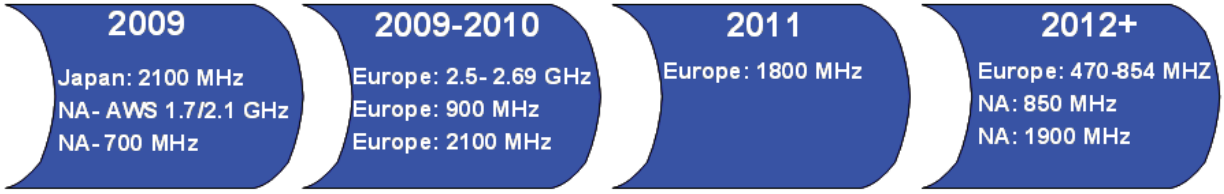

Figure 3. LTE development scenario.

A key characteristic of LTE technology is its suitability for deployment in scalable bandwidths ranging from 1.4 MHz to 20 MHz. What is more, it can operate in all 3GPP frequency bands in paired and unpaired spectrum allocations. In practical terms, the actual performance achievable with LTE depends on the bandwidth allocated for services, and not the choice of spectrum band itself. This gives operators considerable flexibility in their commercial and technical strategies. Deployed at higher frequencies, LTE is attractive for strategies focused on network capacity, whereas at lower frequencies it can provide ubiquitous cost-effective coverage.

LTE's flexibility to operate at a scalable bandwidth also allows operators to deploy LTE in their existing spectrum allocations. This could be achieved via re-farming, considered by many parties in the mobile telecommunications value chain as a cost-efficient option to address increasing traffic demands.

The characteristics of LTE as described below shows that this system can be deployed easily and with significant gains on the Digital Dividend bands:

- Increased downlink and uplink peak data rates;
- Scalable channel bandwidths of 1.4, 3, 5, 10, 15, and 20 MHz in both the uplink and the downlink;
- Spectral efficiency improvements for downlink and uplink;
- Sub-5 ms latency for small internet protocol (IP) packets;
- Performance optimized for low mobile speeds from 0 to 15 km/h, supported with high performance from 15 to 120 km/h; functional support from 120 to 350 km/h, under consideration for 350 to 500 km/h;
- Co-existence with legacy standards while evolving toward an all-IP network;
- Frequency spectrum choice and flexibility of deployment in GSM, CDMA, UMTS bands (450, 700, 850, 900, 1700, 1800, 1900, 2100, 2500MHz) means that global roaming will be possible;

The combination of LTE's increased spectral efficiency and flexibility, added capacity and simpler network architecture offers a very cost effective value proposition. Combined with

UHF bands and using advanced antenna systems, LTE networks will provide to the service providers a significant improvement on cost per bit delivered.

4.2.4 The Outcome for the Different Regions

At the start of the conference a 112 MHz contiguous band was requested for IMT services with a national coverage and protection against broadcast interference. This was obviously too much for the broadcast community which already, besides SD TV, had plans to deploy HD TV and mobile TV in the remaining spectrum.

The situation in the UHF band varying from country to country, a compromise was finally achieved leaving a necessary degree of flexibility in the band plan.

Region 1: (Europe, Middle East, Africa, Russia): 470-790 MHz band remains allocated only to broadcast and a 790-862 MHz band was allocated on a co-primary basis to the mobile service. This part of the digital dividend can be used by either broadcast or telecom services, leaving the possibilities to neighboring countries to discuss harmonization to minimize mutual constraints. WRC 07 decision is open in this regard but it is a strong indication to the telecom industry to start developing products in this band well before full effect of this dividend in 2015. However, mobile can be deployed before then, or below 790MHz, provided that a country gets the agreement of others that might be affected by interference.

The technical conditions (channelization, type of duplex, interference protection…) are discussed at CEPT level with a final report expected by mid 2009. The GSMA has commissioned a study to analyze the extent of the potential interference and the regulatory burden of gaining agreement from neighboring countries. At the time of writing a 2x30 MHz resource with some guard band provision for various duplex scenarios is under study.

Region 2: (North & South America): In some countries like US, part of UHF spectrum was already allocated to mobile services (PCS: 806-890 MHz). The US also had very advanced national plans for auctioning the band 698 – 806 MHz for mobile services. WRC-07 decided to allocate a possible additional spectrum 698-806 MHz to IMT in Region 2. Variations between countries will result as broadcasting is still possible in this band.

Region 3: (Asia, Pacific): The Asia Pacific countries mainly followed the decisions for Region 1. Many of these countries in Region 3 are using GSM in the 900 MHz / 1800 MHz bands and it was straightforward for them to align their digital dividend plans to the European ones. Nine Asia Pacific countries were more ambitious and allocated the band 698 – 790 MHz to the mobile service, in addition to 790 – 862 MHz. This leaves them the choice to either follow the US band plans or the European ones in future, depending on their main diplomatic and economic relations or simply the availability of suitable equipment. These nine countries are China, Korea, Japan, India, New Zealand, Bangladesh, Papua New Guinea, Philippines and Singapore.

5 Conclusions

This white paper presented the outcome of the World Radiocommunication Conference 2007(WRC.07). The identifications are different for different regions, at a high level the identifications can be summarized as follows:

- 450−470 MHz band
- 698−862 MHz band in Region 2 and nine countries of Region 3
- 790−862 MHz band in Regions 1 and 3
- 2.3−2.4 GHz band
- 3.4−3.6 GHz band (no global allocation, but accepted by many countries)

Full details about the outcome of the conference can be found in the Radio Regulations [2].

These identifications make new parts of spectrum available for wireless services, allowing mobile services to accommodate more traffic. The amount of identified spectrum however is not sufficient to accommodate all predicted spectrum usage scenarios by the ITU.

The identifications pose several challenges on the design of future wireless systems. These challenges include:

- Technologies for sharing the available spectrum: These could include techniques to share the spectrum on a 'static' basis where different technologies co-exist in the same part of the spectrum, e.g. this is the case in the 790-862 MHz band. They can also include techniques to share the spectrum in a more dynamic manner including dynamic sharing of the spectrum.
- Infrastructure sharing in case of limited available spectrum:
- Challenges in Radio interface design: Radio technology that is capable of handling new frequency bands, possibly non- contiguous, with varying propagation properties.
- Need for flexibility and scalability of carrier bandwidths, technical implications
- Both time division and frequency division multiplexing should be supported. Time division duplexing is gaining importance and well integrated approached are needed. Technology neutrality allowing the use of both techniques close to each other should carefully consider interference scenarios.

At WRC-07 for some regions part of the UHF band has been allocated to mobile services as well as to traditional broadcasting services. This results in new innovative ways of using the spectrum. The use of these bands varies from country to country, they can be allocated statically or dynamically. Recently in the USA dynamic sharing of channels not used by broadcasters (so called white spaces) has been allowed [12].

Future systems solutions are currently still very much worked upon in various research initiatives all over the world, we believe that this white paper provides valuable input to these initiatives.

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