Assessment of the benefits of introducing a HSDPA carrier at 900MHz

Conference Paper *in* SSRN Electronic Journal · January 2011

DOI: 10.1109/GLOCOMW.2010.5700441 · Source: IEEE Xplore

J. Pérez
Universidad Politécnica de Madrid
48 PUBLICATIONS **171** CITATIONS

Catalina Ovando
Universidad Popular Autónoma del Estado de Puebla (UPAEP)
19 PUBLICATIONS **20** CITATIONS

Submitted for publication at 6th IEEE Broadband Wireless Access Workshop collocated with IEEE GLOBECOM 2010

Assessment of the benefits of introducing a HSDPA carrier at 900MHz

Antolín Moral, Arturo Vergara, Jorge Pérez and Catalina Ovando
Grupo de Tecnologías de la Información y las Comunicaciones (GTIC)
Universidad Politécnica de Madrid (UPM)
Madrid, Spain
E-mail: {amoral; avergara; jperez; covando}@gtic.ssr.upm.es

Abstract—**The roll-out of UMTS/HSPA networks in 900MHz band offers the possibility to bring 3G and mobile broadband services to new areas with less base station sites and to improve the indoor coverage in the existing UMTS coverage areas. This paper presents the benefits in term of savings on site numbers and on network-related costs provided by the roll-out of a mixed-frequency UMTS network (networks with carriers operating at 900 and 2100MHz) instead of a single UMTS2100 network. These results are presented for dense urban, urban, suburban and rural areas and for three demand scenarios. Despite the higher reductions on site number are achieved for the lower demand scenarios, savings higher than 30% are found even in the higher demand scenarios. Regarding the costs savings, the higher savings are obtained in the green field roll-out scenario. Lower cost savings are achieved in the brown field scenario but the introduction of a UMTS900 layer results in a more cost efficient solution than the maintenance of the single frequency UMTS2100 network.**

Index Terms- mixed-frequency network planning, refarming, technoeconomic modelling, UMTS900

I. INTRODUCTION

The roll-out of UMTS networks at 900MHz band combines the benefits of providing 3G and mobile broadband services with better signal propagation at lower carrier frequency. These benefits have already been assessed in several papers. Thus, according to [1], a reduction of 60% in the number of base stations could be achieved by deploying a UMTS900 instead of a UMTS2100 network. This result has been confirmed by Elisa in a commercial network for suburban and rural areas and leads to reductions in the network-related costs (capital expenses, CAPEX, and operational expenses, OPEX) of 50% to 70% [2]. Elisa also shows that most of GSM900 sites can be reused for UMTS900 to achieve extra cost savings. These costs reductions justify the role that mobile networks in lower frequencies, such as dividend digital and 900MHz bands, could play to ensure full broadband population coverage (e.g. as appointed in [3]).

Despite the fact that the roll-out of UMTS900 is considered for rural and uncovered areas initially, its extension to urban areas is also frequently mentioned. In fact, according to UMTS Forum ([4], page 7) “the best approach on an operator’s long term strategy is to deploy a uniform UMTS900 layer for coverage purposes and deploy a UMTS2100 layer for capacity enhancement on specific regions (mainly urban)”. This strategy has already been implemented by Optus (UMTS900) and Telstra (UMTS850) in Australia.

In addition to coverage advantages, the roll-out of HSDPA in 900MHz also offers capacity gains, especially whenever the system is limited by noise rather than by interference (e.g. in deep indoor situations or in rural areas environments) as shown in [5]. It also improves the indoor data rates by more than 50% compared to UMTS2100 (see [1] or [6]).

This paper presents the benefits in term of savings on site numbers and in network-related costs provided by the roll-out of a mixed-frequency UMTS network (a network with carriers operating at 900 and 2100MHz band) instead of a single UMTS2100 network. A ten year period study from 2010 to 2020 has been considered and results for four geographic areas and for three demand scenarios are presented. Two models are used to simulate both kinds of UMTS networks. The first one is based on analytical techniques and let determine the density of UMTS sites for the different traffic demand in the case of single-frequency UMTS networks. The second one uses a set of heuristics to estimate the site density for the mixed-frequency networks taking as an input the site densities obtained for the single-frequency UMTS networks. In addition to the reductions on site numbers, the network-related costs savings are also assessed and two roll-out scenarios are analyzed: a green field and a brown field scenario. Despite this article is focus on UMTS900, the learnings can also be applied to UMTS850 networks.

This paper is organized as followed. Section II presents the main characteristics of the technical models and the savings on site numbers achieved for different network configurations. Section III describes briefly the UMTS cost model and Section V presents the assumptions and results for the green field and the brown field roll-out scenarios. Section V eventually concludes the paper.

II. UMTS NETWORK DIMENSIONING

The analysis is based on the use of UMTS technology (data access services based on Release 5 HSDPA in the downlink and on Release 99 in the uplink) and on macro cell radio networks. Four different geographic areas have been considered: dense urban, urban, suburban and rural areas.

The first author would like to thank the Ministry of Education for its support through its FPU Research Fellowship Program

A. Geographic areas and forecasted traffic demand

Four different geographic areas have been considered with the following population density per km^2: 25.000 (dense urban), 10.000 (urban), 1.000 (suburban) and 450 (rural). A slightly increasing overall service penetration starting from 113% in the first year and a market share equal to one third have been considered.

The traffic demand assumptions are based on average volume downloaded per mobile user per day and a range of plausible scenarios have been used to capture the uncertainty associated with the forecasting of future traffics according to [7]. The traffic demands assumed in this paper increase from current levels (about 0.4MB/user/day in 2008) to reach 1MB, 10MB or 30MB per user and day for the low, base and high demand scenario in 2015. After 2015 and until 2020, the traffic levels are kept flat because any traffic forecasting could not be considered reliable. The data usage during the busy hour is assumed to be 10% of the total and the uplink data volume 20% of the downlink volume.

B. Analytical model for single-frequency UMTS networks

The model used in this paper to estimate the density of UMTS sites operating on a single frequency required to attend the forecasted traffic demands has been developed for the national regulatory authority of United Kingdom, Ofcom and was used in the cost-benefit analysis associated to their proposals regarding the liberalization of the 900 and 1800MHz band [7]. Consequently, all the details of the model could be found in Annex 13 of [7].

Next, the procedure followed to calculate the site density is described briefly. First, the mobile user densities and the traffic levels for the different demand scenarios are translated into their corresponding active user densities in the busy hour (to say, user transmitting simultaneously in the busy hour). To provide these traffic demands, the model distinguishes two main regions: up to a certain maximum active user density, the cells are coverage limited and the cell-area is a constant value obtained from a link budget analysis; for higher active user densities, the cells become capacity constrained so the cell-area increases linearly with the active user density.

In the coverage limited scenario, the cell range is calculated by the application of the SE21-Hata propagation model for a maximum allowable path loss (MAPL). This MAPL is the minimum of the MAPL obtained for the uplink, downlink and the pilot channel signal. The MAPL in the uplink and in the pilot channel signal are calculated following the procedure described in [8] and are based on a link budget analysis combined with the calculation of the noise rise of the system. In the case of the downlink, the signal-to-interference-plus-noise ratio (SINR) on the HS-DSCH channel for the desired cell-edge user throughput (the HSDPA network could be dimensioned to satisfy different cell-edge user throughput) is determined via relationships given in figure 7.5 p. 130 of [9]. The reference curves are the results of link level simulations and are valid for user speeds of 3 km/h and for channels being subject to flat (not frequency selective) Rayleigh fading. Therefore, mainly indoor users are considered in the analysis. The network is planned for 80% loading level in the downlink and 75% in the uplink (50% in the case of rural areas).

In the capacity limited scenario, the maximum number of users is found from the user throughput (a dimensioning parameter calculated from the desired cell-edge user throughput and considering a 6dB margin for the average to maximum path loss), the maximum sector throughput and a multi-user diversity gain via an iterative approach described in page 127 of [7].

Finally, the user density limit that determine when the cells become capacity constrained is found by dividing the number of active users, which was found in the capacity limited analysis, by the cell-area, which was calculated in the coverage limited scenario. Consequently, this user density limit depend on the cell capacity, the number of carrier per sectors, the operating frequency (900 and 2100MHz bands are supported) and the geographic area as it will be shown later. Three sectored sites are considered in all cases.

In addition to HSDPA dedicated channels, shared channels are also supported. In this latter case, five codes available for HSDPA and a power distribution of 50%, 25% and 25% for high speed data channel (HSDC), Release 99 data channel (DCH) and pilot and common channels respectively have been assumed.

C. Mixed-frequency planning model

Given that today's UMTS networks are deployed at 2100MHz, realizing any savings on the site number as a consequence of the use of 900MHz band would require a network with service provided using a combination of frequency bands (900 and 2100MHz). Under this kind of network, the carriers at different frequency bands provide different coverage areas while still delivering equivalent services everywhere. The use of these mixed-frequency networks will allow capacity constraints to be relieved by higher-frequency spectrum, freeing the lower frequency to provide coverage for more challenging traffic, the traffic generated by farther or deeper indoor users, and are possible thanks to the inter-frequency hard handovers supported by this technology (fully supported by 3GPP standards from release 6 onwards as specified in TS 25.331). Consequently, the number of sites required under this frequency-mixed network will then be lower than the ones required under a single-frequency network with an equivalent quantity of spectrum.

The concept of deploying a uniform UMTS900 layer for coverage purposes and a UMTS2100 layer for capacity enhancement to reduce the overall number of sites and the network costs have been mentioned, as an example, by GSMA [10] or by UMTS Forum [4]. Consequently, in practice mobile operators are likely to deploy a combination of the several different bands they possess, in particular, carriers at 900MHz and 2100MHz bands.

As previously mentioned, the model used in this paper to estimate the site densities required for these mixed-frequency networks is based on the one provided by the national regulatory authority of United Kingdom, Ofcom, in [7]. The model takes as an input the cell size for both the low frequency network with one and two carriers and the high frequency band network with 2 carriers, and provides the cell size for the mixed-frequency network with one carrier at the low frequency and two carriers at the high frequency band. The model, fully described in [7], use a set of heuristics mainly based in the behavior previously mentioned: the higher-frequency spectrum carry the traffic generated close to the base station, freeing the lower frequency to provide coverage for more challenging traffic.

D. Results

The general behavior of the models described above is illustrated in Fig.1 and in Fig. 2.

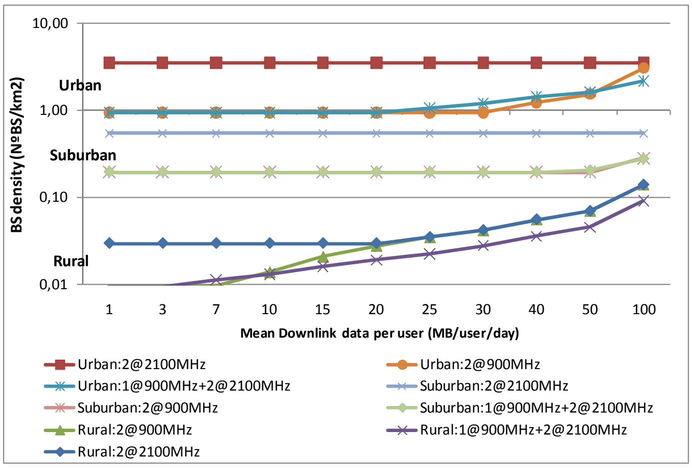

Figure 1. Site density for different demand levels for UMTS networks with different numbers of carriers and frequencies

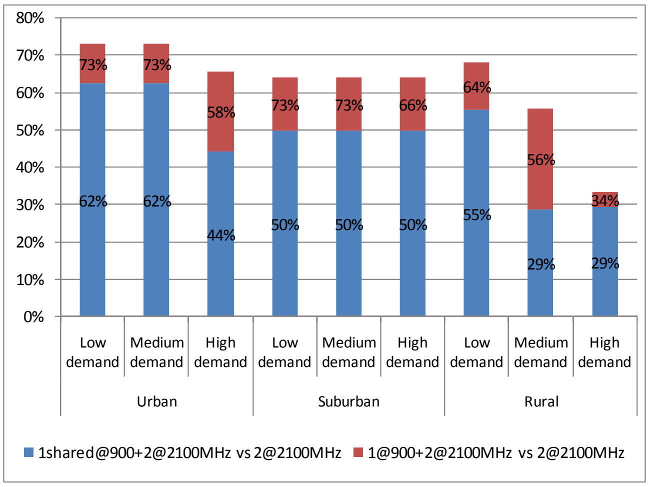

Figure 2. Savings on the site number provides by the introduction of a shared or a dedicated HSDPA carrier at 900MHz in an UMTS2100 network

Fig. 1 shows the number of sites required to deliver a given service (144kbps/1.2Mbps UL/DL data services) versus the average volume of data downloaded by each user for three UMTS networks. Each UMTS network has a different number of carriers and frequencies (the notation used is “X@Y MHz” where X is the number of carriers and Y the frequency band). The coverage limited and the capacity limited regions could be clearly identified. Given that similar capacity per site (capacity gains at 900MHz as shown in [5] have not been implemented in our models) and coverage level have been considered for each network, the UMTS2100 network with many more sites can support higher levels of demand before becoming capacity constrained. Consequently, the 2@900MHz network becomes capacity constrained at lower traffic level than the 2@2100MHz network. The same reasoning could be applied to explain the differences among rural, suburban and urban areas.

As it can be observed, the introduction of a carrier at 900MHz in the UMTS2100 network reduces the site density for the coverage limited traffic levels. In fact, this mixed-frequency network (1@900MHz+2@2100MHz) requires almost the same number of sites than the 2@900MHz network for these lower levels of demand as being the cell range determined by the 900MHz layer. However, when the network becomes capacity constrained, the higher spectrum resources available for the mixed-frequency network (three carriers versus just two in the 2@900MHz or 2@2100MHz networks) leads to a lower cell density compared with both single-frequency networks (see this effect in the rural areas case).

Fig. 2 shows the saving achieved for the different scenario demand considered in Section II.A. As it can be observed, the savings achieved in the lower level of demand (coverage-limited networks) are in line with the ones mentioned by other sources such as [1], [2] or [6]. However, these savings decrease as the traffic demands increase. Moreover, the case of using a shared instead of a dedicated carrier at 900MHz is also included showing how the lower traffic carrying capacity of this shared carrier leads to higher cell density and consequently, to lower saving compared with the case of the dedicated carrier.

Finally, the impact of the introduction of subsequent improvements of HSDPA, known as HSPA+, or other technologies, such as LTE or femtocells, in the site number savings provides by the introduction of a carrier at 900MHz in an UMTS2100 network can be assessed based on the behavior of the analytical model. As the use of HSPA+ will increase the overall sector throughput, it will also increase the demand levels from the ones the networks become capacity constrained. Therefore, more coverage limited networks could be expected what could leads to higher site number savings between networks using different frequency bands. The same effect could be expected from the introduction of LTE or femtocells but in this case as a consequence of the reduction in the traffic level to be carried in the UMTS macrocell network (a share of the traffic demand will be delivered by the other technologies).

III. NETWORK-RELATED COSTS MODEL

The savings on site numbers provided by the introduction of a carrier at 900MHz are translated into cost savings in the corresponding UMTS networks. In order to assess the extent of these cost savings, an UMTS costs model have been developed. This model is based on a techno-economic modelling approach as the one used in [11]. The network element characteristics and investment and operating unit costs are based on the ones used in the long-run incremental cost (LRIC) model of Arcep [12]. Only the network-related costs, and particularly those associated with the radio access network (sites, backhaul and RNC), are considered in this paper. The rest of networks elements are excluded because they are almost independent of the operating frequency used in the RAN being almost exclusively determined by the number of users and traffic levels attended by the network. After estimating the evolution of the costs, a discounted cash flow model is applied to account for both investment and running costs considering a commercial discount rate of 11.5%.

IV. MODELLING THE BUSINESS CASE

The cost savings that a mobile operator could obtain in the roll-out of an UMTS network by the introduction of an additional carrier at 900MHz instead of using only the 2100MHz band are assessed in this Section for two different business case: a green field and a brown field scenario. These savings are presented for the four geographic areas and the three demand scenarios considered in Section II.A.

In this section, a mobile operator with 2x15MHz at 2100MHz and gaining access to 2x5MHz at 900MHz for the roll-out of UMTS is considered. Thus, the cost savings associated with the roll-out of an UMTS900 instead of an UMTS2100 network is presented considering the following network characteristics: in the case of the UMTS2100 network, two dedicated HSDPA carriers are used being the third one reserved to provide Release 99 voice and data services; in the case of the UMTS900 network, a mixed-frequency network is considered with a shared HSDPA carrier at 900MHz and two dedicated HSDPA carriers at 2100MHz. In this latter case, part of the capacity of the carrier at 900MHz and the third carrier at 2100MHz are reserved for the provision of Release 99 services. In all cases, the number of carriers mentioned earlier is referred to number of carriers per sector and three sectored sites are considered. The network is dimensioned to provide 144kbps/1.2Mbps UL/DL data services.

A. Green field scenario

In this case, an area without 3G coverage is considered and the costs savings provide by the roll-out of a UMTS900 instead of a UMTS2100 network are presented. These savings are showed in Fig. 3 for two different cases: 1) the operator has a GSM900 network deployed and these sites could be re-used for the roll-out of the UMTS network (85% of GSM sites are suitable to be shared) and 2) the operator does not have a GSM900 network.

As it could be expected, the reductions in the site-related costs are close to the reductions in site numbers presented in Fig. 2 in the shared carrier case. On the other hands, the backhaul-related costs are more dependent on the traffic levels so the savings regarding these costs are lower and decreasing with the increase on the traffic levels. As a consequence, the resulting overall RAN costs savings are between the savings obtained from sites and backhaul-related costs and show a decreasing trend as the traffic demand increases. This reduction is consequence of the lower savings on site numbers got in the higher demand scenario as the networks become more capacity constrained and of the increasing share of the backhaul costs over the overall RAN costs).

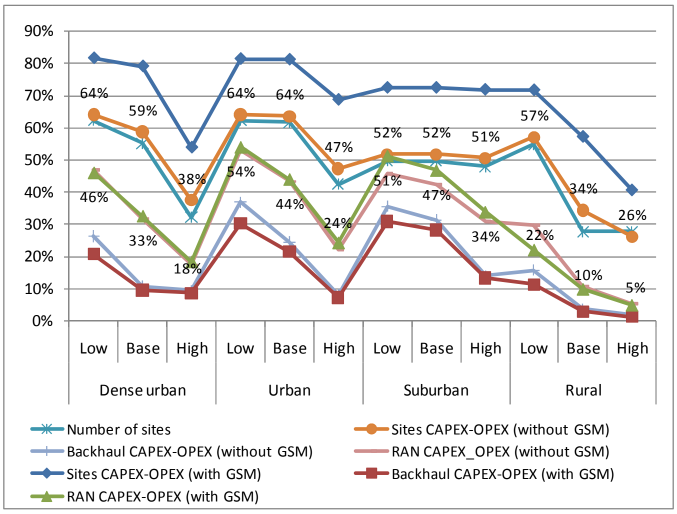

Figure 3. Cost savings for the roll-out of a UMTS900 instead of a UMTS2100 in the greenfield scenario

Finally, the site-related cost savings are higher in the case of sharing the UMTS sites with the already deployed GSM sites and these savings are even higher than the savings obtained on site numbers. The reason is that the higher number of sites of the UMTS2100 network, higher that the total available GSM900 sites, makes necessary the roll-out of new sites what increases the site-related costs with regard to the roll-out of UMTS900 networks whose lower number of UMTS sites could be co-ubicated in existing GSM sites.

B. Brown field scenario

In this second case, an area that has been already covered by the progressive roll-out of a UMTS2100 is considered. The network roll-out started in 2005 and was completed in 2008 being dimensioned to provide 144/386kbps UL/DL services. As in the previous case, a GSM900 network is available. The costs savings provided by the introduction of a shared carrier at 900MHz on this already deployed UMTS2100 network are presented against keeping the UMTS2100 network. The costs are estimated for the period 2010-2020 and the roll-out of the UMTS900 starts in 2011. The downlink cell-edge user throughput is increased progressively from 384 until 1.2Mbps in 2012.

As described in subsection II.C, the introduction of the UMTS900 layer for coverage enhancements lets the mobile operator to reduce the number of total sites and thus, the network-related costs. However, the need to ensure the continuity of the 3G services provision makes the mobile operator delay the decommission of additional UMTS2100 sites until two conditions are satisfied: 1) a sufficient diffusion of 3G user terminals supporting the 900MHz band has been achieved and 2) the area attended by the UMTS2100 sites have already been covered by the UMTS900 network.

To obtained the penetration of the UMTS900 terminals, the forecasted diffusion of the UMTS900 handsets provides by Elisa [13] have been considered but have been moved forward two years to take into account that UMTS900 handsets already represented 40% of total 3G handset shipments in July 2009 (according to Qualcomm [14]). Therefore, 80% of total 3G terminals are UMTS900 capable in 2011 achieving 100% of penetration in 2013. Finally and considering that the roll-out of the UMTS900 network starts at 2011 and takes two years, the decommissioned of the additional UMTS2100-only sites could start in 2012 finishing after three years (2012-2014).

The cost savings associated with the introduction of the carrier at 900MHz are presented in Fig. 4.

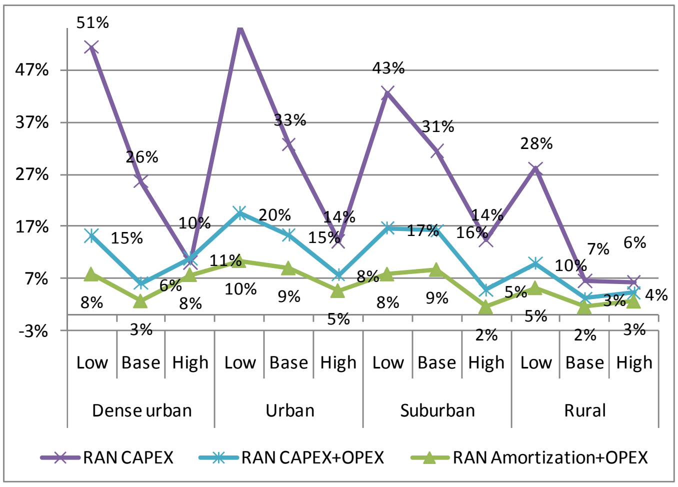

Figure 4. Cost savings for the roll-out of a UMTS900 instead of a UMTS2100 in the brownfield scenario

Comparatively with the green field scenario, the savings are lower due to two factors. Firstly, as a consequence of the need to roll-out/maintain UMTS2100-only sites during the transition period to ensure the continuity of the service provision for the UMTS2100 user terminals. Secondly, because of the need to amortize the investment made in the UMTS2100 sites before the study period and that have to be paid entirely despite being decommissioned before finishing their lifetime periods. and because of the fact that most of the network roll-out happens before the study period and its investment have to

V. CONCLUSION

This paper has presented the benefits in term of savings on site numbers and on network-related costs provided by the roll-out of a mixed-frequency UMTS network instead of a single UMTS2100 network. Despite being aware that the numerical results obtained with the models used in this paper are naturally subject to the assumptions and modeling applied, some conclusions could be drawn regarding the benefits of the introduction of a HSDPA carrier at 900MHz.

As it could be expected, the higher reductions are achieved for the lower demand scenarios where the networks are coverage limited and the more favorable propagation at the lower frequency are fully exploited. Despite these savings decrease as the demand increases, savings on site numbers higher than 30% are found even in the higher demand scenarios.

Regarding the costs savings, the higher savings are obtained in the greenfield scenario what justify that the roll-out of UMTS900 had been considered initially for rural areas without 3G coverage. The brownfield scenario shows costs savings lower than the greenfield scenario but demonstrates that the introduction of a UMTS900 layer in current UMTS2100 network is a solution more cost efficient than the maintenance of the single frequency UMTS2100 network. Moreover, higher savings could be achieved in many likely situations (such as dimensioning the network to provide higher cell-edge user throughput or deeper indoor coverage, using a dedicated instead of a shared HSDPA carrier at 900MHz or introducing new technologies such as HSPA+, femtocells or LTE) and other benefits, such as higher indoor data rates and capacity gains as shown in [6], contribute to justify the extension of the UMTS900 layer to already covered areas.

REFERENCES

[1] Holma, H.; Ahonpaa, T.; Prieur, E.; , "UMTS900 Co-Existence with GSM900," Vehicular Technology Conference, 2007. VTC2007-Spring. IEEE 65th , vol., no., pp.778-782, 22-25 April 2007

[2] GSA, UMTS 900 Operator Case Study - Elisa Finland. Information paper. September, 2008. Available: http://www.gsacom.com/gsm_3g/info_papers.php4

[3] Radio Spectrum Policy Group (RSPG), RSPG Working Group on Wireless Broadband –Final Position Paper. 14 May 2009. Available: http://rspg.groups.eu.int/_documents/documents/meeting/rspg18/rspg09_260_progressreport_wgwirelessbroadband.pdf

[4] UMTS Forum, UMTS/HSPA broadband services in the 900 MHz band: Strategy and Deployment. UMTS Forum White Paper. 2009. Available: http://www.umts-forum.org/component/option,com_docman/task,cat_view/gid,327/Itemid,214/

[5] Khaji, N.; Elayoubi, S.E.; Marache, F.; , "HSDPA Capacity Gain in the 900 MHz Band," Vehicular Technology Conference, 2009. VTC Spring 2009. IEEE 69th , vol., no., pp.1-5, 26-29 April 2009

[6] Nokia Siemens Networks: WCDMAFrequency Refarming:A Leap Forward Towards Ubiquitous Mobile Broadband Coverage. Nokia Siemens Networks White Paper.

[7] OFCOM, Application of spectrum liberalization and trading to the mobile sector. A further consultation. Consultation document. February, 2009. Available: www.ofcom.org.uk/consult/condocs/spectrumlib

[8] H. Holma, A. Toskala: “WCDMA for UMTS: Radio Access for Third Generation Mobile Communications”. John Wiley & Sons, 2004.

[9] H. Holma, A. Toskala, “HSDPA/HSUPA for UMTS”. John Wiley& Sons, 2006.

[10] Ovum, Market Study for UMTS900. A report for GSMA. February, 2007

[11] Hoikkanen, A.; , "Economics of 3G Long-Term Evolution: the Business Case for the Mobile Operator," Wireless and Optical Communications Networks, 2007. WOCN '07. IFIP International Conference on , vol., no., pp.1-5, 2-4 July 2007

[12] Analysys Mason, Network model for ARCEP mobile LRIC model. October, 2008.

[13] Elisa: Developing A Fully Inclusive Mobile Broadband Strategy: Bringing Mobile Broadband To Remote And Rural Areas. Presentation in the Mobile Broadband World Conference, London, 23.9.2009

[14] Qualcomm: BIS Consultation on a Direction to Ofcom to Implement the Wireless Radio Spectrum Modernisation Programme: Qualcomm response. February, 2010.

[15] Holma, H.; Ahonpaa, T.; Prieur, E.; , "UMTS900 Co-Existence with GSM900," Vehicular Technology Conference, 2007. VTC2007-Spring. IEEE 65th , vol., no., pp.778-782, 22-25 April 2007.