

Economic study of the benefits from use of 1452- 1492 MHz for a supplemental mobile downlink for enhanced multimedia and broadband services

A report for Ericsson and Qualcomm

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Executive summary

The CEPT¹ is considering the best future harmonised use of the spectrum in the 1452 to 1492 MHz band. The European Parliament voted in the first reading on the Radio Spectrum Policy Programme (RSPP) for the harmonisation of this band for wireless broadband services². The band is variously called the 1.4 GHz/1.5 GHz/L band in Europe. In this study we refer to it as the 1.4 GHz band.

The band is currently allocated for use by digital audio broadcasting (DAB) services in most European countries – part of the band is allocated to terrestrial networks and part is allocated to satellite networks³. None of these services have developed in the band.⁴ Rather in all countries in Europe the satellite part of the band is unused and this is also the case in the terrestrial component in most countries^{5 6}.

CEPT has set up a Project Team, FM PT 50, to assess which future use(s) of the 1.4 GHz band would be the most beneficial for Europe⁷. Ericsson and Qualcomm asked Plum to carry out an independent assessment of the net benefits from using the 1.4 GHz band for a supplemental downlink (SDL) for the delivery of enhanced mobile multimedia and broadband services.

What is a supplemental downlink (SDL)?

A supplemental downlink uses unpaired spectrum to enhance the downlink capability of mobile broadband networks by enabling significantly faster downloads and supporting a much greater number of users with mobile or portable wireless devices. This approach has not been used up until now in mobile networks because it required new technology (sometimes termed carrier aggregation technology). Supplemental downlink and carrier aggregation are now enabled in the HSPA+ and LTE-Advanced standards⁸.

The technology allows the bonding of the usual downlink with a *supplemental* downlink channel(s), in a different band, into a single wider downlink channel as shown in Figure 1⁹. This provides an efficient way of using spectrum because consumption of rich content and other data heavy applications is asymmetric. There is much more traffic on the downlink than on the uplink over mobile broadband networks.

¹ European Conference of Postal and Telecommunications Administration (CEPT).

² European Parliament amendment to the RSPP reads “*The Commission is invited to take action, in cooperation with Member States, at the appropriate levels to achieve further harmonisation and a more efficient use of the 1.5 GHz band (1452-1492 MHz) [...] for wireless broadband services.*”

³ 1452-1479.5 MHz for terrestrial networks - Under the Maastricht 2002 Special Agreement as revised in Constanta 2007 (MA02revC007) the arrangement contains technical characteristics for T-DAB and multimedia systems to operate in the 1.4 GHz Band. 1479.5-1492 MHz for satellite networks – see ECC Decision of 17 October 2003 on the designation of the frequency band 1479.5 -1492 MHz for use by Satellite Audio Broadcasting systems, ECC/DEC(03)02.

⁴ http://rspg.groups.eu.int/consultations/consultation_futradio/rspg10_349_annex.pdf; There was an attempt to rollout DAB services at L band in Switzerland but this was found to be too expensive and so Band III is used.

⁵ There are some legacy systems in operation in few countries (e.g. fixed links/telemetry, defence systems, ground and wall probing radar, radio astronomy and aeronautical telemetry).

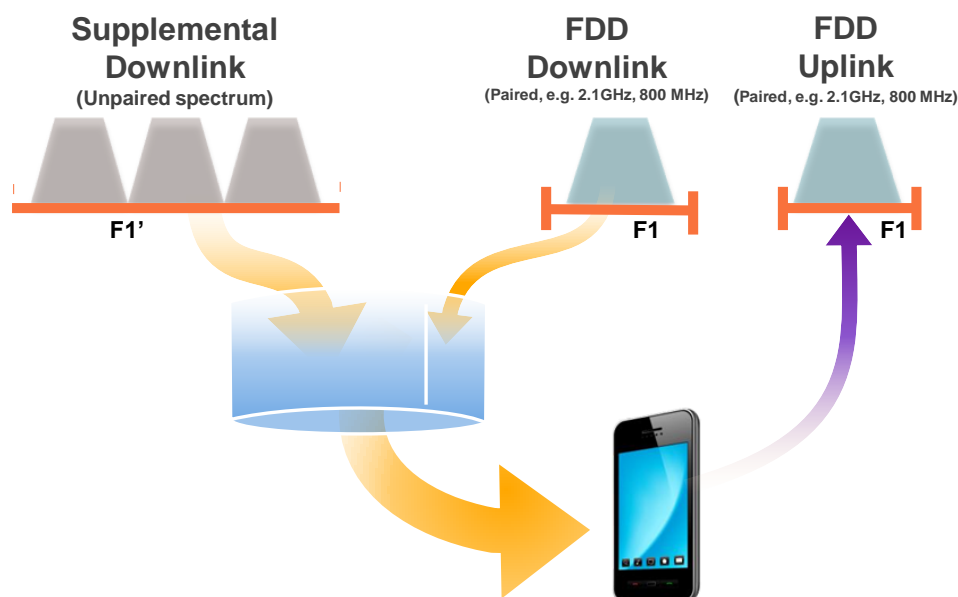
⁶ The use by country is given in http://rspg.groups.eu.int/consultations/consultation_futradio/rspg10_349_annex.pdf and by the World DAB Forum in the latest http://www.worlddab.org/rsc_brochure/hires/12/rsc_brochure_20100910.pdf

⁷ ECC FM(11)131 Annex 05, www.ero.dk.

⁸ Carrier aggregation across bands is supported in HSPA+ R9 (and beyond) and LTE R10 (and beyond) standards, but each specific bands combination has to be defined in 3GPP.

⁹ Example of HSPA+ R10 with a 3 + 1 inter-band downlink carrier combination.

Figure 1: A supplemental downlink.



Source: Qualcomm, HSPA+ enhancements in Release 9 (and beyond)

A supplemental downlink is not just a theoretical possibility. AT&T plans to use a supplemental downlink in its LTE network, aggregating 700 MHz unpaired spectrum¹⁰ with other paired spectrum on which it will deploy LTE (outside of the 700 MHz band).¹¹ AT&T expects to be able to deploy handsets and equipment using a supplemental downlink as early as 2014.¹²

What is enhanced mobile multimedia?

Enhanced mobile multimedia is different than mobile TV. It includes unicast and multicast/broadcast delivery for most mobile data. Typical early applications include streamed audio and video, real-time broadcasts of big sporting or popular cultural events, video based news, IP radio, video based specialist magazines and clips or long form content (movies, programs, etc.). There is considerable overlap between mobile multimedia and mobile broadband. Allot¹³ estimates that 63% of mobile broadband traffic was multimedia in 2010. According to Cisco¹⁴ this proportion was even higher at 81%. Moreover, these proportions are rising.

Demand for enhanced mobile multimedia services is expected to grow rapidly in future. This is reflected in mobile traffic forecasts (see Figure 2). Furthermore, the introduction of a supplemental downlink could stimulate innovative business models for mobile broadband and multimedia services, which could further stimulate demand. Some examples are given in Section 4 of this report.

¹⁰ Spectrum that it seeks to acquire from Qualcomm in the 700 MHz band, subject to regulatory approval.

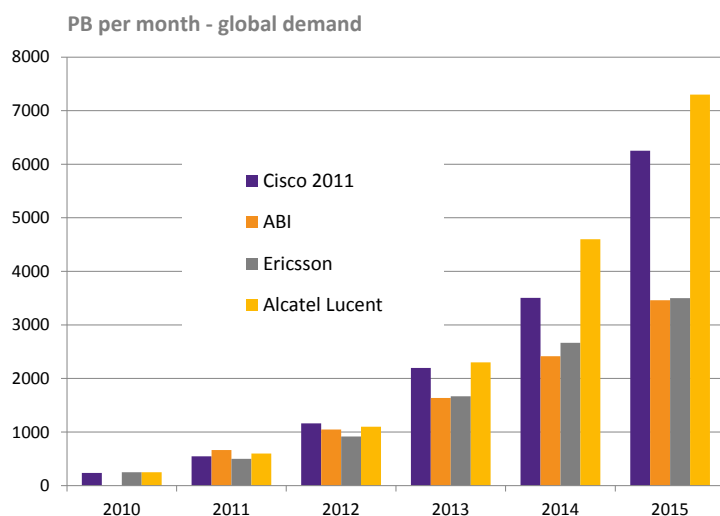
¹¹ <http://www.att.com/gen/press-room?pid=18854&cdvn=news&newsarticleid=31447&mapcode=financial|wireless>

¹² Declaration of Kristin Rinne, AT&T to the FCC 12 January 2011.

¹³ *Global mobile broadband traffic report, H2 2010*, Allot, 2011.

¹⁴ *Global Mobile Data Traffic Forecast update, 2010-2015*, Cisco, February 2011.

Figure 2: Mobile traffic forecasts to 2015.



The case for a supplemental downlink at 1.4 GHz

In principle, there is a substantial case for harmonising the 1.4 GHz for supplemental downlink. It:

- Provides much needed downlink capacity given the asymmetric nature of mobile broadband and mobile multimedia traffic. Downlink to uplink ratios range from 4: 1 to 8: 1¹⁵ and are expected to increase in future with the rapid proliferation of smartphones and tablets.
- Enables considerably higher user data rates and supports a greater number of users, all of which will substantially enhance the user experience.
- Equipment for use of the band could be available by 2014 and the spectrum is readily available in Europe and in numerous countries outside Europe (see Figure 3), providing the basis for realising significant economies of scale, which should drive down equipment costs.
- Following the current release of 800 MHz and 2.6 GHz, there are unlikely to be other new bands available on a European basis for mobile broadband and enhanced multimedia services before 2018 or later (see Figure 4). In addition, the frequencies at 1.4 GHz are lower than other bands that could become available before 2020 (e.g. 3.5 GHz) and so have more desirable propagation characteristics (indoor penetration and rural coverage).

¹⁵ See Section 3.1.

Figure 3: Map showing potential availability of 1.4 GHz band for SDL on a global basis.

1.4 GHz band availability worldwide

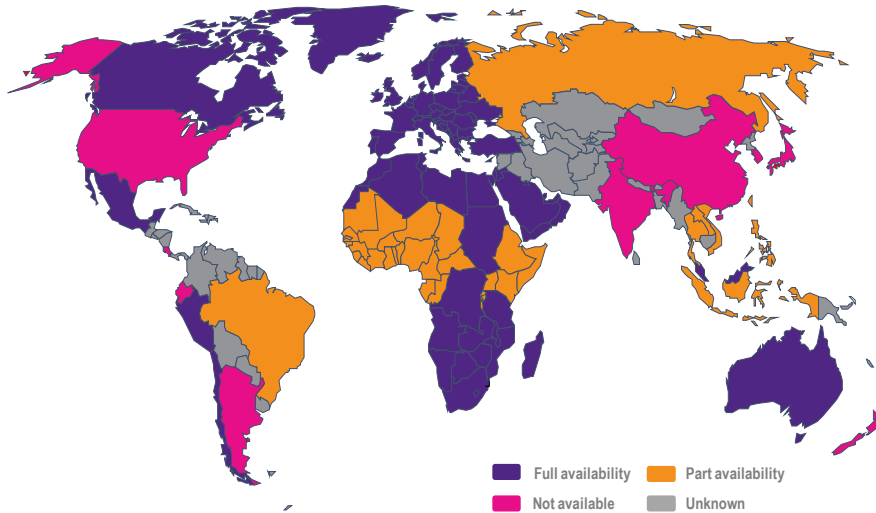
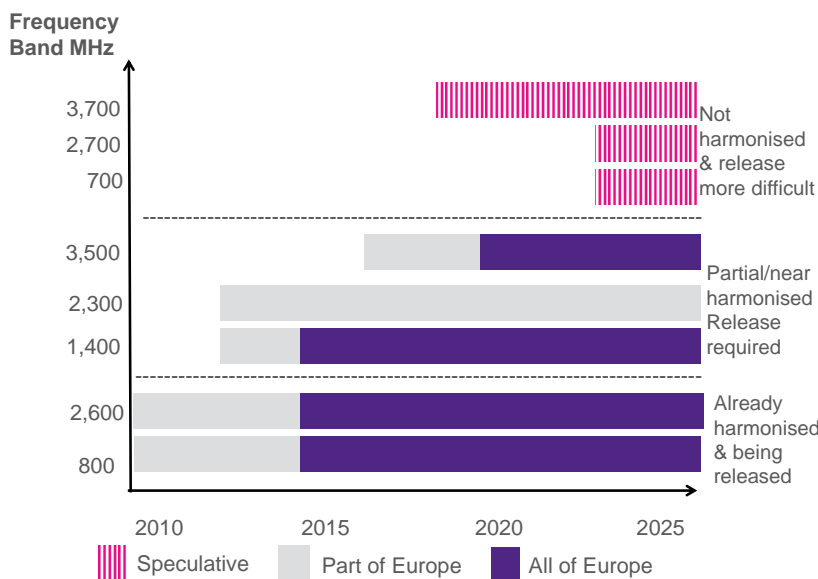


Figure 4: Possible timings of spectrum bands released for mobile services.



Source Plum analysis

What are the benefits of a supplemental downlink at 1.4 GHz?

We have quantified two principal benefits of an SDL at 1.4 GHz:

- The avoided costs from using the SDL to meet rising demand for mobile broadband rather than investing in additional base stations. This benefit is shared between producers and consumers, with the bulk of the benefit going to consumers in a competitive market;

- The net benefits to consumers that arise from implementing an SDL at 1.4 GHz including faster download speeds in urban and suburban areas, support for a greater number of users and better in-building coverage¹⁶.

Our estimates show that **the harmonisation and use of 1.4 GHz for a supplemental downlink for enhanced mobile multimedia and broadband services could generate economic benefits worth as much as €54 billion for Europe**¹⁷.

These estimates may be on the conservative side given that we have modelled only the impacts of a low projection of demand for mobile data. Modelling the impacts of a high demand projection would produce higher values for the benefits.

There are three additional major benefits from the use of an SDL at 1.4 GHz. The 1.4 GHz band:

- Supports delivery of the Digital Agenda target to provide 30 Mbps access to 100% of the EU by 2020. This is an extremely challenging target for the market to deliver. Wireless has a key role in providing high speed broadband to remote and rural customers. The 1.4 GHz band can play an important role in providing very high speed broadband access required before 2020 to meet Digital Agenda targets and reduce the requirement for public subsidies.
- Increases competition in the mobile broadband and content markets. Limited availability of spectrum below 1GHz means that in many countries, operators will have little¹⁸ or possibly even no low frequency spectrum to provide mobile broadband services. The availability of additional spectrum at 1.4 GHz for an SDL will enable players to compete more aggressively in the supply of high speed mobile broadband and multimedia content. Increased competition is likely to result in lower prices for consumers. It is also likely to result in more mobile broadband capacity to experiment new business models.
- Gives European suppliers an early opportunity in the development of innovative mobile multimedia services and new mobile broadband business models utilising an SDL. There is considerable scope for the adoption of 1.4 GHz for an SDL outside Europe such as in the Middle East and Africa, Australia, Canada and Mexico. Implementation of the standard in Europe will open up new business opportunities in international markets¹⁹, particularly for service and content providers with successful business models.

What regulatory changes are required?

The deployment of an SDL at 1.4 GHz for enhanced mobile multimedia and broadband services is compatible with Maastricht Agreement²⁰. But it will require work by CEPT to develop the least restrictive technical conditions for the band, in line with the EU regulatory approach to technology

¹⁶ The in-building coverage and propagation characteristics is similar to the anchor frequency that SDL is bonded with (e.g. 800 MHz, 900 MHz).

¹⁷ This the net present value of the economic benefits for the European Economic Area i.e. the EU plus Iceland, Liechtenstein and Norway.

¹⁸ Auctions rules of 800 MHz in many European countries impose spectrum caps that limit the maximum spectrum holdings per operator to 2x10 MHz or 2x15 MHz of 800 MHz spectrum.

¹⁹ Including in the US where supplemental downlink is planned to be deployed.

²⁰ FM(11)062 Annex 18

neutrality²¹. These conditions are required by 3GPP as an input to its standardisation work to support a supplemental downlink at 1.4 GHz. It is also important for the success of an SDL at 1.4 GHz that these technical conditions are harmonised and potentially applicable to a large geographic area/population in Europe so that economies of scale in consumer devices and infrastructure equipment production can be realised. This approach is compatible with the deployment of terrestrial DAB should there be national demand for such a service.

²¹ These will address the frequency range, harmonised channelling arrangement and technical requirements both in-band and in adjacent bands for use of the 1.4 GHz band for an SDL.

1 Introduction

1.1 Reason for this study

The CEPT²² is considering the best future use of the spectrum in the 1452 to 1492 MHz band. The European Parliament voted in the first reading on the Radio Spectrum Policy Programme for the harmonisation of this band for wireless broadband services²³. The band is variously called the 1.4 GHz/1.5 GHz/L-band in Europe. In this study we refer to it as the 1.4 GHz band.

The band is currently allocated for use by digital audio broadcasting (DAB) services in most European countries – part of the band is for terrestrial networks and part is for satellite networks²⁴. None of these services have developed in the band²⁵. Rather in all countries the satellite part of the band is unused and this is also the case in the terrestrial component in most countries^{26,27}.

CEPT has set up a Project Team, FM PT 50, to assess which future use(s) of the 1.4 GHz band would be the most beneficial for Europe²⁸. Ericsson and Qualcomm asked Plum to carry out an independent assessment of the net benefits from using the 1.4 GHz band for a supplemental downlink for the delivery of enhanced mobile multimedia and broadband services.

1.2 What is a supplemental downlink?

A network implementing a supplemental downlink uses a wider channel for the downlink than for the uplink, by aggregating the usual downlink with a *supplemental* downlink channel(s). Using a wider downlink channel enables faster download speeds for mobile or portable wireless devices and support for a greater number of users (see Figure 1-1). This approach has not been implemented up until now in mobile networks because it required new technology (sometimes termed carrier aggregation technology). Supplemental downlink and carrier aggregation are now enabled in the HSPA+ and LTE-Advanced standards²⁹.

²² European Conference of Postal and Telecommunications Administration (CEPT).

²³ European Parliament amendment to the RSPD reads “*The Commission is invited to take action, in cooperation with Member States, at the appropriate levels to achieve further harmonisation and a more efficient use of the 1.5 GHz band (1452-1492 MHz) [...] for wireless broadband services.*”

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²⁵ http://rspg.groups.eu.int/consultations/consultation_futradio/rspg10_349_annex.pdf; There was an attempt to rollout DAB services at L band in Switzerland but this was found to be too expensive and so Band III is used.

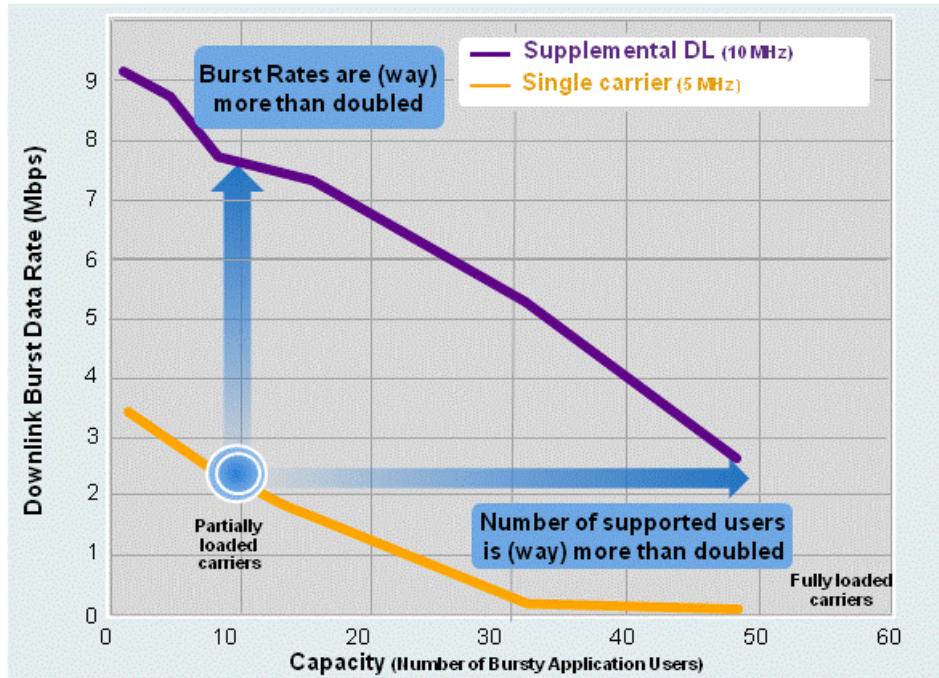
²⁶ The use by country is given in http://rspg.groups.eu.int/consultations/consultation_futradio/rspg10_349_annex.pdf and by the World DAB Forum in the latest http://www.worlddab.org/rsc_brochure/hires/12/rsc_brochure_20100910.pdf

²⁷ There are some legacy systems in operation (e.g. fixed links/telemetry, defence systems, ground and wall probing radar, radio astronomy and aeronautical telemetry).

²⁸ ECC FM(11)131 Annex 05, www.ero.dk

²⁹ Aggregation across bands is supported in HSPA+ R9 (and beyond) and LTE R10 (and beyond) standards, but each specific bands combination has to be defined in 3GPP.

Figure 1-1: Results of simulation of performance of a HSPA+R9 supplemental downlink (SDL) network for bursty applications.

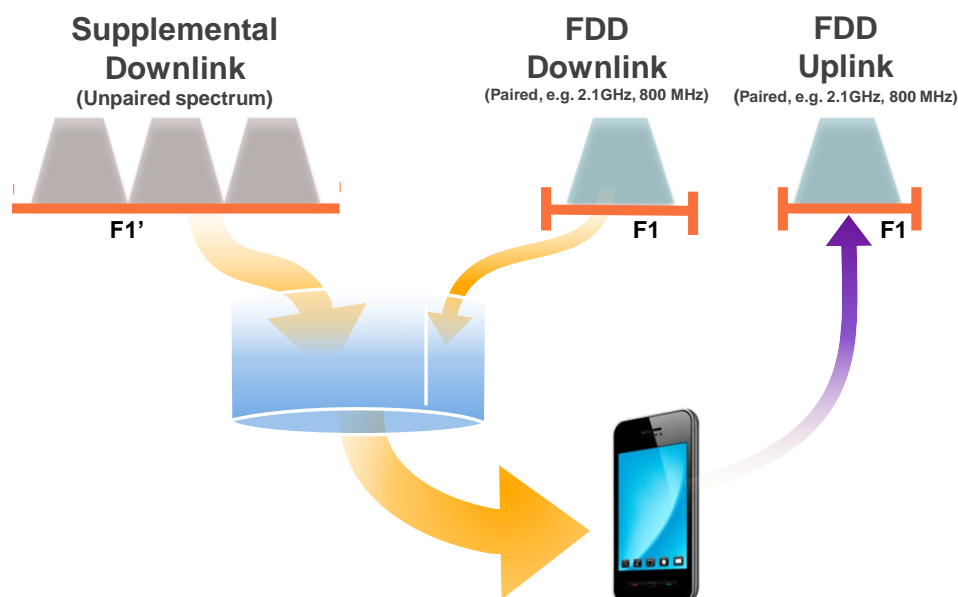


Source: Qualcomm

The technology allows the bonding of spectrum in different bands into a single wider downlink channel as shown in Figure 1-2³⁰. This provides an efficient way of using spectrum because consumption of video and other data heavy applications over mobile broadband networks is asymmetric – there is much more traffic on the downlink as opposed to the uplink.

³⁰ Example of HSPA+ R10 with a 3 + 1 inter-band downlink carrier combination.

Figure 1-2: A typical supplemental downlink configuration.



Source: Qualcomm, HSPA+ enhancements in Release 9 (and beyond)

A supplemental downlink is not just a theoretical possibility. AT&T plans to use a supplemental downlink in its LTE network, aggregating 700 MHz unpaired spectrum³¹ with other paired spectrum on which it will deploy LTE (outside of the 700 MHz band)³². The relevant standards work is under way in 3GPP in order to develop the detailed specifications for the technology that will be required by handset and other equipment manufacturers. AT&T expects to be able to deploy handsets and equipment using a supplemental downlink as early as 2014³³.

1.3 The options to be evaluated

Impact assessments involve³⁴ the evaluation of the incremental impacts (i.e. incremental costs and benefits) of the proposed policy change (i.e. use 1.4 GHz for a supplemental downlink versus a “no change” base case). Impacts need to be considered over a reasonable future time scale – say 10 to 15 years in future – as the policy choices will have long lasting effects.

³¹ Spectrum that it seeks to acquire from Qualcomm in the 700 MHz band, subject to regulatory approval.

³² <http://www.att.com/gen/press-room?pid=18854&cdvn=news&newsarticleid=31447&mapcode=financial|wireless>

³³ Declaration of Kristin Rinne, AT&T to the FCC, 12 January 2011.

³⁴ ECC Report 125: Guidelines for the implementation of impact assessment in relation to spectrum matters, Liege, September 2008; Internal ECC Report (09)042 Annex 13: Management of Impact Assessments in the ECC Structure, January 2009; European Commission. January 2009. Impact assessment guidelines. http://ec.europa.eu/governance/impact/commission_guidelines/docs/iag_2009_en.pdf

The “no change” base case

The base case is continued allocation of the band in European countries to DAB, both terrestrial and satellite, under the current set of regulatory measures³⁵.

There is no current use of the band for DAB³⁶ and in most countries in Europe the band is sitting idle. In some countries it is used by a number of legacy services, namely fixed links/telemetry, defence systems, ground and wall probing radar, radio astronomy and aeronautical telemetry³⁷.

The impact assessment needs to make an assumption about the likelihood of DAB services being deployed over the next 10-15 years. The probability of this happening is low. All current DAB deployments in Europe use Band III (174-230 MHz) frequencies, which have better propagation characteristics than the 1.4 GHz band. Even in Band III there are issues concerning the coverage and commercial viability of DAB services, particularly for local area delivery³⁸. In addition standalone mobile TV broadcasting has not been a commercial success in Europe, even at frequencies with better propagation characteristics than 1.4 GHz (i.e. at VHF or UHF).

This limited demand, together with the fact that the proposed alternative does not preclude the base case from occurring (see below), simplifies the impact assessment. We can assume that the net benefits from the base case are zero and simply assess the costs and benefits of the supplemental downlink option.

The supplemental mobile downlink option

The alternative of a supplemental downlink for enhanced mobile multimedia and broadband services involves some regulatory changes. This deployment is compatible with Maastricht Agreement³⁹ but will require work by CEPT to develop the least restrictive technical conditions for the band, in line with the EU regulatory framework approach of technology neutrality⁴⁰. These are required by 3GPP as an input to its standardisation work to support a supplemental downlink. This approach is compatible with the deployment of terrestrial DAB should there be national demand for such a service.

Whatever the technical conditions adopted, it is important for the success of an SDL that they are harmonised and potentially applicable to a large geographic area/population in Europe so that economies of scale in consumer devices and infrastructure equipment production can be realised.

³⁵ The Maastricht Agreement as revised in Constanta in 2007 allows the deployment of mobile multimedia technologies in addition to T-DAB in 1452-1479.5 MHz. However the allocation of the 1.4 GHz band at national level in most European countries has remained for T-DAB in addition to S-DAB in 1479.5-1492 MHz.

³⁶ http://rspg.groups.eu.int/consultations/consultation_futradio/rspg10_349_annex.pdf; There was an attempt to rollout DAB services at L band in Switzerland but this was found to be too expensive and so Band III is used.

³⁷ The use by country is given in http://rspg.groups.eu.int/consultations/consultation_futradio/rspg10_349_annex.pdf and by the World DAB Forum in the latest http://www.worlddab.org/rsc_brochure/hires/12/rsc_brochure_20100910.pdf

³⁸ Some countries are looking into the use of narrowband digital technologies such as DRM+ for local services. It has also been suggested that DVB-T2 might be used for digital TV and radio at Band III.

http://rspg.groups.eu.int/consultations/consultation_futradio/rspg10_349_report_future_radio_broadcasting.pdf

³⁹ FM(11)062 Annex 18.

⁴⁰ These will address the frequency range, harmonised channelling arrangement and technical requirements both in-band and in adjacent bands on use of the 1.4 GHz band for an SDL.

1.4 Structure of the report

The remaining sections of this report address:

- The nature of and demand for enhanced mobile multimedia over mobile broadband (Section 2 and Appendix A).
- The case for an SDL using the 1.4 GHz band, including the timescales for implementation and the relative merits of the 1.4 GHz band as compared with other possible bands (Section 3 and Appendix B).
- The business models that could be enabled by an SDL (Section 4).
- The potential benefits from an SDL at 1.4 GHz (Section 5 and Appendices C-E).

2 Demand for enhanced mobile multimedia

2.1 What is enhanced mobile multimedia?

The first generation of mobile multimedia, namely broadcast mobile TV, has failed commercially in Europe and the US. Four years ago there was strong interest in broadcast mobile TV. Many operators launched trials and devices were developed to receive mobile TV. That interest has now evaporated given the limited demand. Industry and consumers have shifted to a second generation of enhanced mobile multimedia services.

This failure of market demand prompts us to ask whether enhanced mobile multimedia, based on unicast and/or multicast of multimedia over the cellular networks, will succeed or not. In making this assessment, we need to recognise that broadcast mobile TV and enhanced mobile multimedia are very different.

Broadcast mobile TV is characterised by:

- A separate broadcast network typically operating at UHF or VHF (Band III)⁴¹.
- 4 to 15 channels of TV broadcast over this network to mobile devices.
- A limited range of handsets capable of receiving service through a separate receiver and standalone technology in the terminal.
- Very limited opportunity for the user to interact with the linear video content broadcast over the mobile TV network.

By contrast **enhanced mobile multimedia**:

- Includes unicast and multicast/broadcast delivery of rich data (text, audio, video, interactive content) delivered to mobile devices (e.g. smartphones, tablets, laptops, games stations, etc) from mobile networks⁴².
- Is a set of applications which can run on all 3G and 4G enabled devices using existing mobile networks.
- Can use the full range of frequencies assigned for 3G and 4G mobile use so as to deliver video services and other multimedia content to end users.

Current implementations use unicast mode so that:

- The user can select precisely the content he or she wants to consume on the move.
- The application can be as interactive as a service provider wants it to be.

Typical early applications include streamed audio and video for archive and catch up TV, real-time audio and video broadcasts of big sporting and popular cultural events, video based news, and video based specialist magazines.

In circumstances where several end-users in a cell want to watch the same real-time event⁴³ mobile multimedia will, in the future, be able to use multicast/broadcast mode⁴⁴, assuming mobile operators

⁴¹ And proposed for 1.4 GHz band

⁴² The network base station transmitting to the mobile and wireless devices.

decide to implement this facility when they upgrade their networks to LTE Release 9/10. This feature should be available from 2013 and will provide lower costs and higher quality of service than unicast for efficient delivery of video based services to an audience of two or more people in a single cell. It will also have the capacity to deliver service to large groups of people in a particular location e.g. a sports stadium or concert venue.

2.2 Demand for enhanced mobile multimedia

There are a number of arguments which, when taken together, suggest that demand for enhanced mobile multimedia is already significant and will grow strongly over the next decade.

First, there is a strong trend towards personalisation and immediate use of the video-based content - which lies at the core of most multimedia applications. A significant proportion of the population, and especially young people, now watch video over their computers, tablets and smartphones rather than just via a television set⁴⁵. In particular there is substantial demand for catch-up TV and video on demand. Much of this demand is currently satisfied by services offered over fixed broadband. But the next logical step is to use mobile broadband services to meet any need for personalised and immediate video on the move.

Secondly, a high proportion of mobile broadband is already enhanced mobile multimedia⁴⁶. Allot⁴⁷ estimates that 63% of mobile broadband traffic was multimedia in 2010. According to Cisco⁴⁸ this proportion was even higher at 81%.

Thirdly, demand for mobile broadband is expected to grow strongly over the next 10 years with enhanced mobile multimedia driving the growth. Figure 2-1 shows the findings from four published sources, while Appendix A provides more detailed analysis. In Europe, mobile broadband traffic carried over mobile networks is forecasted to grow between 14 and 29 fold over the period 2010 to 2015.

European mobile revenue was approximately €165 billion in 2008⁴⁹. Mobile data revenues are likely to form an increasingly significant proportion of mobile revenue. Nomura forecasts European mobile dongle and smartphone data revenue to grow from around €4 billion in 2007 to €15 billion by 2012⁵⁰. If this growth rate were to continue, the mobile data market would amount to approximately €70 billion by 2020.

⁴³ Such as major sporting and cultural events and when events of global or national significance occur such as the final of the World Cup or major news stories.

⁴⁴ Based on the eMBMS standard.

⁴⁵ Ofcom. 2010. Communications Market Report.

http://stakeholders.ofcom.org.uk/binaries/research/cmr/753567/CMR_2010_FINAL.pdf

⁴⁶ We include video and web browsing and exclude file sharing, VoIP and instant messaging.

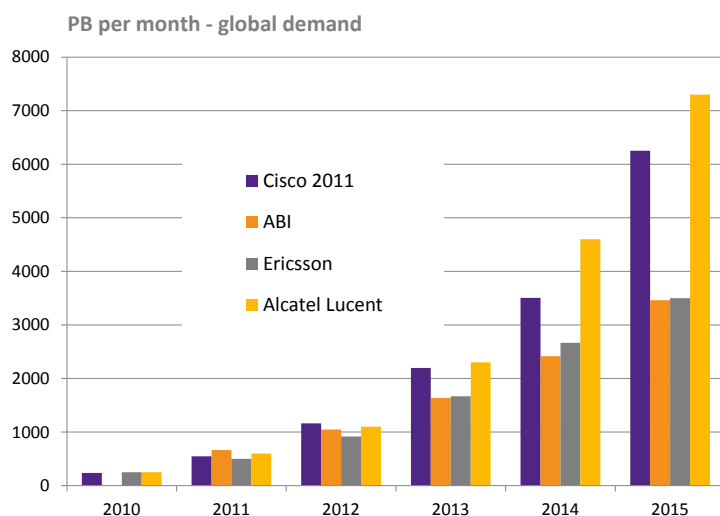
⁴⁷ *Global mobile broadband traffic report, H2 2010*, Allot, 2011.

⁴⁸ *Global Mobile Data Traffic Forecast update, 2010-2015*, Cisco, February 2011.

⁴⁹ EC, 15th Implementation Report.

⁵⁰ Nomura. December 2009. "Telecommunication services".

Figure 2-1: Global mobile data to 2015 – PB per month⁵¹ - four published sources compared.



Fourthly, the increase in mobile network speeds and capabilities leads to an enhanced user experience which drives greater demand for multimedia services. Where current mobile data speeds are constraining demand for multimedia services, demand will increase as the capability of networks is improved.

Fifthly, content providers and operators are now offering a range of mobile multimedia services. For example:

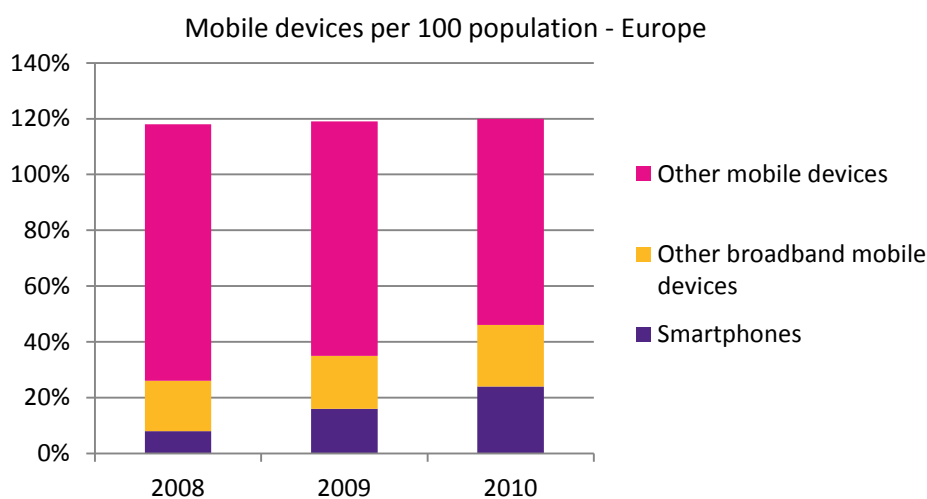
- Sky in the UK has launched sports content on its Sky Mobile TV service for subscriptions of between €6 and €10 per month.
- Eurosport is also offering sports content for a subscription of around €3 to €5 per month.
- Digital in Spain is offering a wide range of content to 3G users at subscription prices of around €6 per month.
- Orange in France offers 60 TV channels such as French national, TNT (DTV) and thematic channels via an iPhone application. Subscription prices start from €6 per month, or on a pay-as-you-go basis: by volume (1 EUR cent/10Kb), or per session (€0.50 for 20 minutes).
- In Italy, la Repubblica, one of the major newspapers is offering a subscription of €2.00 per week excluding connectivity costs.
- In the UK, the Telegraph Newspaper launched a subscription based iPad application for £9.99 per month for a daily issue of the newspaper in May 2011.
- In the US, the New York Times is offering digital subscriptions providing unlimited access to the NYTimes.com Web site from any computer or device, plus access to applications on portable devices. There are three options with subscriptions ranging from US\$3.75 per week to US\$8.75 per week. The charges cover content only; connectivity is charged for separately by the mobile operators.

⁵¹ Peta Bytes per month. One Peta Byte = 10¹⁵ Bytes.

- The French Association of Mobile Multimédia announced that the mobile multimedia market in France is worth €1.2 billion (€800 million from the distribution of content and mobile services and €430 million from advertisement and marketing)⁵².
- Since 1 April 2011, Amazon has sold 105 Kindle books for every 100 print books⁵³.

Sixthly, the installed base of smart phones is growing rapidly as illustrated in Figure 2-2. Such phones support enhanced mobile multimedia capability. The recent explosive growth in demand for tablets, prompted by the launch of the iPad, could further stimulate demand for mobile multimedia. Other manufacturers are offering tablets and the market is expected to develop strongly.

Figure 2-2: The growth in the share of smartphones in Europe.



Source: ITU and Comscore

Finally, the future incremental cost of carrying mobile multimedia traffic is likely to be modest when compared with current willingness to pay for mobile services. Technical advances in mobile networks will result in a significant reduction in unit cost as well as increases in speed.

2.3 Consumption of real-time versus stored multimedia content

Some analysts argue⁵⁴ that demand for mobile multimedia can largely be met by side loading content to mobile devices for subsequent viewing on the move. There are a number of ways to do this. The mobile user might, for example:

- Use a public WiFi network to download mobile multimedia content.
- Subscribe to a service which downloads content to his or her device overnight – via a Wi-Fi network, a pico cell, or even over the wide area mobile network - so as to use up spare capacity

⁵² <http://www.solucom.fr/file/download/3055>

⁵³ <http://phx.corporate-ir.net/phoenix.zhtml?c=176060&p=irol-newsArticle&ID=1565581&highlight>

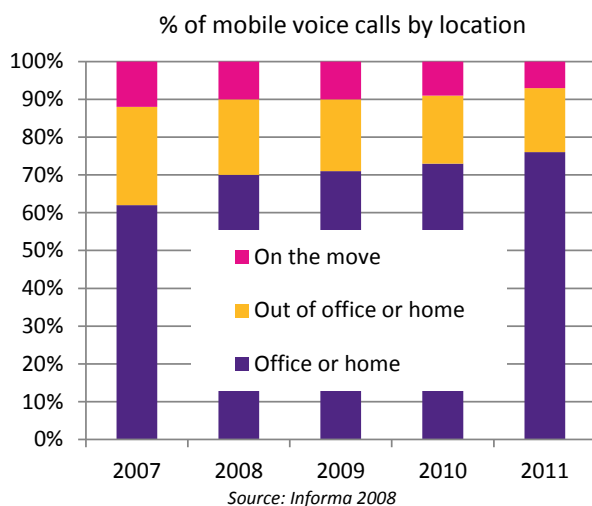
⁵⁴ For example see *Mobile broadband in Europe – forecast and analysis – 2010 to 2015*, Analysys Mason, June 2010.

during the early hours of the morning. This content is stored on the mobile device and viewed later.

Such services are likely to play a substantial role in the delivery of mobile multimedia. But there is also strong evidence to suggest that such services will complement rather than replace enhanced mobile multimedia delivered directly over mobile networks:

- Enhanced mobile multimedia is the only way to deliver a truly interactive experience that allows the user to discover and interact with content at any time or place.
- Enhanced mobile multimedia is the only way to meet end users' demand to view major events⁵⁵ in real time on the move. Willingness to pay for such services is likely to be high.
- Analysys Mason and Cisco both estimate that only a minority of mobile data traffic is currently offloaded to the fixed network for receipt on a mobile device via Wi-Fi or a pico cell. But they disagree on how this proportion will change in future. Cisco predicts that off loads will remain steady at around 25%. Analysys Mason believes that the proportion could rise to 70%.
- The future unit cost of data will fall due to the improved capacity of 3G/4G services. Nor should we underestimate the willingness of end-users to pay extra for convenience. As Figure 2-3 shows, end users are happy to make voice calls more easily from their mobile phones, when they have access to a cheaper and higher quality fixed line service at home or in the office.

Figure 2-3: Mobile voice calls by location.



⁵⁵ e.g. major sport and cultural events and news

3 The case for a supplemental downlink at 1.4 GHz

The case for considering an SDL at 1.4 GHz rests on:

- The asymmetric nature of mobile broadband and mobile multimedia traffic.
- The need for additional spectrum to support traffic growth in a timely manner.
- Following the current release of 800 MHz and 2.6 GHz, the likely absence of other new bands being available on a European basis for enhanced mobile multimedia services before 2018 or later.
- The desirable propagation characteristics of the 1.4 GHz band.
- The potential for economies of scale on a global basis.

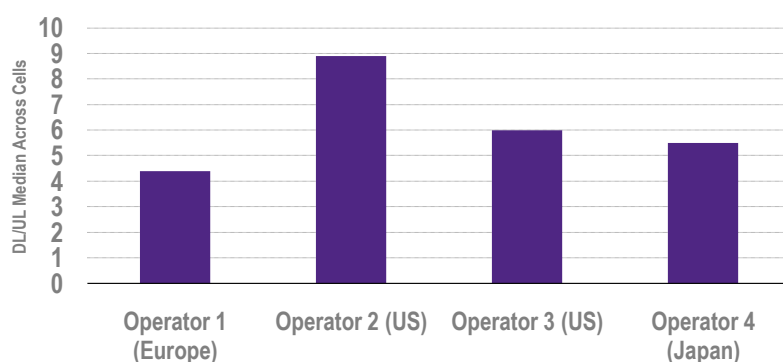
Support for each of these points is given in this Section.

3.1 Mobile traffic is highly asymmetric

Mobile users download much more data than they upload – for example downloads of videos, photos, music, maps, applications etc. This means, mobile broadband traffic is mainly carried by the downlink (see Figure 3-1). There are no comprehensive sources of data on the ratio of downlink (DL) to uplink (UL) traffic. A number of studies involving traffic measurements suggest values for the ratio of the downlink to uplink traffic of between 4:1 and 9:1⁵⁶.

Figure 3-1⁵⁷: Mobile downlink traffic as a multiple of uplink traffic.

DL/UL Traffic Asymmetry



Source: Qualcomm

To generate the traffic forecasts required to assess the benefits of the supplemental downlink at 1.4 GHz, we have made estimates of the proportion of downlink traffic by application and then weighted

⁵⁶ See Figure 3-1 and measurements reported in <http://lib.tkk.fi/Dipl/2009/urn100072.pdf> and <http://www.cs.ucla.edu/~falaki/pub/imc153s-falaki.pdf>.

⁵⁷ The data is based on measurements in live networks. Median value is shown.

these proportions by the application mix of mobile data traffic (as estimated by Allot for 2010⁵⁸ and by Cisco for 2010 and 2015⁵⁹). The results are shown in Table 3-1. They suggest that the current ratio of downlink to uplink traffic is around 6:1 and that this could rise to 10:1 over the next five years, as the proportion of video traffic in the total mobile traffic grows. Furthermore, we do not expect growth in user generated content (UGC) to invalidate this forecast. For every UGC upload there are many more people (friends, family and others) who will download the content.

All spectrum used at present by mobile operators is paired but there is more capacity in the downlink because of the higher related transmission efficiency. The ratio between DL and UL capacity is around 2:1, which implies there is a significant imbalance between DL/UL traffic ratio and DL/UL capacity ratio when relying solely on paired spectrum. A supplemental downlink provides only downlink capacity and would therefore help meet the likely growing demand in downlink traffic.

Table 3-1: The ratio of downlink to uplink traffic.

	% downlink	% Traffic Allot 2010	% Traffic Cisco 2010	% Traffic Cisco 2015
Web browsing/e-mail	80%	26%	31%	22%
Video	98%	37%	50%	66%
VoIP and IM	50%	4%	2%	1%
File sharing	80%	30%	14%	6%
Other	60%	3%	3%	5%
% in downlink		85%	88%	91%
DL/UL ratio		5.7	7.3	10.1

Sources: Plum analysis, Cisco (2011), Allot (2010)

3.2 Additional spectrum is required to support traffic growth

Mobile traffic is growing rapidly and high growth rates are forecast to continue for some time (see Section 2.2). The need for additional licensed spectrum to support this traffic growth has been recognised in the draft RSPD which was voted on by the European Parliament on 11 May 2011 at first reading⁶⁰. The draft RSPD proposes that at least 1200 MHz is allocated for mobile data services by 2015. To achieve this target at least 300-500 MHz more licensed spectrum needs to be allocated to mobile services on a harmonised basis⁶¹.

⁵⁸ *Global Mobile Broadband Traffic Report*, Allot, H2 2010.

⁵⁹ *Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2010-2015*, Cisco, February 2011.

⁶⁰ <http://www.europarl.europa.eu/sides/getDoc.do?type=REPORT&reference=A7-2011-0151&language=EN&mode=XML>. The draft will be subject to a second reading approval following the Council conclusions on 27 May 2011

⁶¹ The currently allocated spectrum amounts to 885MHz comprising: 60 MHz at 800 MHz; 70 MHz at 900 MHz; 150 MHz at 1800 MHz; 120 MHz at 2.1 GHz; 60 MHz at 2 GHz for MSS; 35MHz in unpaired allocations around 2 GHz (currently no equipment); 190 MHz at 2.6 GHz; and 200 MHz at 3.4-3.6 GHz. Also it needs to be recognised that within the existing allocations, over 200 MHz is only partially harmonised and may not be available for use for some time yet.

The 1.4 GHz band is one of the priority bands for harmonisation for wireless broadband services called on by the European Parliament in the draft RSP. Other bands mentioned are 700 MHz (694-790 MHz which is currently used for TV broadcasting) and the 2.3 GHz (2300-2400 MHz which is currently used for a variety of civil and military uses), neither of which is readily available for use (see Section 3.4).

3.3 Timeline for deployment of a supplemental downlink at 1.4 GHz

The timeline for availability of devices with SDL 1.4 GHz capability depends on the timing of a number of interrelated regulatory and market decisions, namely:

- The adoption by the ECC of a harmonized band plan for the 1.4 GHz band. This first requires the ECC to undertake an analysis for potential uses of the band and then come to a decision about the most appropriate future use of the band and associated least restrictive technical conditions⁶². It is expected that this process will be completed by the end of 2012. This allows 18 months to conduct the impact analysis and make decisions about the least restrictive technical conditions.
- Completion of 3GPP standardization activity⁶³. The 3GPP specifications already contain much of the capability that would be required to combine operation on the current European cellular paired spectrum with a supplemental downlink at 1.4GHz. AT&T plans to use a similar arrangement⁶⁴ and work items are already in the 3GPP work plan for this (scheduled for March 2012). A work item would still be required for a 1.4GHz SDL but the AT&T item should cover almost all of the technical issues that will need to be addressed. Once a harmonised band plan is defined by the CEPT, a request can be made to 3GPP to undertake the necessary work to include the 1.4 GHz SDL in the specifications for HSPA+ Release 9 (dual carrier and dual band) and later releases, as well as LTE Release 10, i.e. the first LTE release which supports multiple carrier aggregation, and later releases. This could be done by the end of 2013⁶⁵.
- Chipset availability. Release 9 dual band/dual carrier chipset solutions for HSPA+ are already in the planning stage⁶⁶. Qualcomm expects Release 9 chipsets to become available to enable commercial devices in 2014. This development would happen in parallel with the work in 3GPP. Adding requirements for a 1.4 GHz band supplemental downlink does not impact the timeline for availability of Release 9 dual-band dual-carrier capable chipsets.
- Clearing and release of the 1.4 GHz band to the market. In most countries the band is already cleared and unused. Regulators could start to release the band for an SDL as soon as the ECC band plan is adopted. As the 3GPP process nears conclusion and chipsets start to be produced,

⁶² ECC FM(11)131 Annex 05, www.ero.dk

⁶³ The key things the specifications would need to cover are:

- The capability to aggregate channels across bands (i.e. bonding channels in different bands to create greater bandwidth): This is supported in HSPA+ R9 (and beyond) and LTE R10 (and beyond) standards, but each specific band combination has to be defined in 3GPP.
- Channel management, power control and handover: Likewise this should all be within the capability of the existing specifications. Quality management information for two downlinks could be handled in a single uplink connection.

⁶⁴ Assuming they get the regulatory approval to acquire a block of 700 MHz spectrum from Qualcomm.

⁶⁵ Based on experience with progressing specifications in 3GPP for AT&T's use of SDL at 700 MHz.

⁶⁶ Note that RF band support is a release-independent feature in 3GPP, hence the 1.4 GHz band can be supported by Release 9 devices (dual band and dual carrier) although 1.4 GHz band numerology and conformance test specifications will be part of a later 3GPP release.

this will give confidence that the SDL application will be deployed. The band can be released in advance of deployment, which suggests release could happen in 2013/14.

- Equipment availability. Manufacturers will need to design, test and build devices and base stations and other network equipment supporting the 1.4 GHz band. In addition, operators will need to test such equipment. It is expected that this process will take at least 12 months, suggesting potential operational deployment in 2014/15. A viable commercial market forecast is required before device manufacturers will commit to development of 1.4 GHz SDL and, in many ways, this could be the critical path issue. However, we understand that there are few technical or fabrication issues that are likely to be raised (see Appendix B).

In summary, this leads to the timeline shown below.

Figure 3-2: Indicative timeline for operational deployment of the 1.4 GHz band.



3.4 Timetable for release of other spectrum bands for mobile broadband in Europe

The value of releasing the 1.4 GHz band depends on whether other substitute spectrum may become available in the next 5 to 10 years. Starting from today, all countries in Europe have planned or are planning to release the 800 MHz and 2.6 GHz bands in the next two years. There is equipment available for use in both bands and services are already deployed in some countries.

Which other bands might be released over the next 10-15 years? Looking so far out is necessarily somewhat speculative, but we have based our suggestions on bands identified in the draft RSPP⁶⁷, as well as national initiatives in Europe and elsewhere. We have also examined bands that are allocated to, or have been suggested for, IMT services in the ITU-RR (for Region 1) but for which there is no agreed European band plan.

Table 3-2 gives a number of candidate bands, ordered by the likely timing for release, including the 1.4 GHz band for completeness. In each case, we summarise the current status of the band, initiatives that suggest it might be a candidate for future release and our views on the possible timing of deployment based on the difficulty of clearing the band and the harmonisation/standardisation initiatives that would need to be undertaken before equipment would be mass produced for the band.

⁶⁷ <http://www.europarl.europa.eu/sides/getDoc.do?type=REPORT&reference=A7-2011-0151&language=EN&mode=XML>

Table 3-2: Possible bands for future release.

Potential band for release	Current status	Initiatives to release band for MBB	Possible timing
1.4 GHz	Allocated to T and S DAB. No use for this purpose. Band currently empty in many European countries.	ECC study. ECC band plan required. The band is a priority band in the draft RSPP approved by the European Parliament. ⁶⁸	2014/2015 to start deployment in Europe. Expect deployment to be quick given little other use of the band.
800 MHz band	In the process of being cleared and assigned throughout Europe.	Already harmonised.	Expect deployment in to be occurring in all countries by 2014/15.
2.6 GHz band	In the process of being cleared and assigned throughout Europe.	Already harmonised.	Expect deployment in to be occurring in all countries by 2014/15.
2.3-2.4 GHz	Co-primary fixed and mobile. Used by aeronautical telemetry, PMSE, defence systems, wireless cameras. IMT band under ITU-RR.	Priority band in RSPP and there is work in ETSI. ⁶⁹ Norway and Russia have made releases; UK, Sweden and Ireland may release part of the band. Band allocated for WiMax and TDD-LTE in Asia. Used for regional wireless communications services in US. Additional 20 MHz to be released in National Broadband Plan.	2013 onwards but this will be on a national/partial basis for the time being (depends also on the RSPP and incumbents use). Note: LTE equipment is being made available for the Asian market.
3.4-3.6 GHz	Primary allocation to mobile service in the ECA. Main use is for broadband fixed wireless access ⁷⁰ . Also FSS, Amateur use ⁷¹ . IMT band under ITU-RR.	ECC developed two alternative a common European band plans (FDD and TDD). 3GPP work ongoing. US releasing some of the band for MBB in some geographical areas.	2017 on. 3GPP work will have to be finalised. Current BWA spectrum assignments need to be refarmed and associated licenses waived to allow mobile uses before the band can be widely deployed for mobile broadband (LTE).

⁶⁸ <http://www.europarl.europa.eu/sides/getDoc.do?type=REPORT&reference=A7-2011-0151&language=EN&mode=XML>

⁶⁹ ETSI TR 102 837 V1.1.1 (2010-08). ETSI ERM; System Reference Document; Broadband Wireless Systems in the 2 300 MHz to 2 400 MHz Range. http://www.etsi.org/deliver/etsi_tr/102800_102899/102837/01.01.01_60/tr_102837v010101p.pdf

⁷⁰ In line with ERC/Rec13-04 and ERC/Rec14-03 and EC Decision 2008/411/EC. The latter requires Member States to make the 3.4 – 3.6 GHz band for terrestrial electronic communications networks by 21st November 2008 and the 3.6 – 3.8 GHz band by 1st January 2012 on a non-exclusive basis. This is reflected in the European Common Allocation Table (ERC Report 25, 2009) where the Mobile Service is indicated as co-primary from 3.4 to 3.8 GHz.

⁷¹ ECC Report 25

Potential band for release	Current status	Initiatives to release band for MBB	Possible timing
3.6-3.8 GHz	Co-primary mobile and FSS. Mobile use is non-exclusive. Main use is FSS.	Harmonised band plan developed in ECC (in PT1). 3GPP work ongoing. To be of value to MBB would need to designate the band as mobile only or enable effective sharing with satellite use.	Beyond 2020. Co-existence with satellite use is the biggest problem ⁷² .
700 MHz (698-790 MHz)	Used by TV broadcasting, PMSE.	In US and Asia band allocated to MBB. In Europe Finland has indicated it will review status of band in 2017. The French government has signalled it will also support its inclusion in the WRC-016 agenda ⁷³ .	2020- 2025. Very difficult to release because of use by DTT and PMSE. Initially would require a co-primary mobile allocation at WRC-16 first and then European harmonisation. Based on release of 800 MHz ⁷⁴ this suggests deployment around 2025.
Part of 2.7-3.4 GHz	Civil and military radars and navigation systems.	Under examination in the US and the UK ⁷⁵ . However, a significant amount of technical work is required before possibilities for release can be identified given safety critical and sensitive nature of the radars.	2025 on if at all.

Source: Plum analysis

Our conclusions about the likely timetable for release and deployment are shown in Figure 3-3. It suggests that, following the current releases at 800 MHz and 2.6 GHz, additional spectrum for mobile broadband services on a European basis is most likely to come from the 1.4 GHz band and then, three to four years later from the 3.5 GHz band. The 2.3 GHz band may also get released but we expect this would only be a partial release in Europe, either with geographical and/or spectral restrictions.

In summary, in the period to 2020, the 1.4 GHz band will be the only new band that is likely to be capable of offering good wide area coverage for mobile broadband (downlink) and enhanced mobile multimedia services.

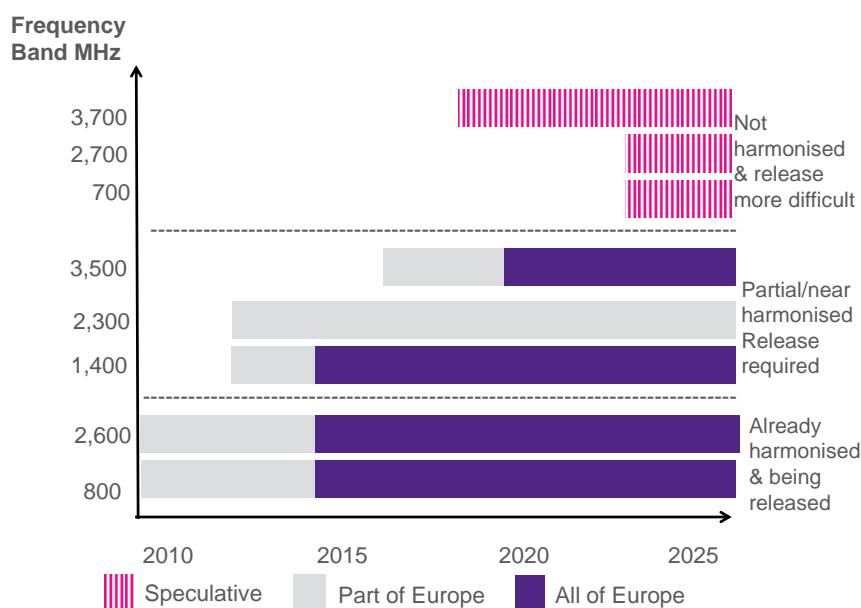
⁷² Supporting material from CEPT (e.g. ECC/DEC/(07)02, ECC/REC/(04)05 and ECC Report 100) indicates that ubiquitous use of terminals in a terrestrial network is not really possible when earth stations are used in the same geographic area (i.e. coordination is required).

⁷³ <http://www.telecompaper.com/news/minister-seeks-regulator-co-operation-2nd-digital-dividend>

⁷⁴ See Figure 8, Authorised Shared Access, Ingenious, 20 January 2011.

⁷⁵ See "Plan and Timetable to make available 500 MHz of spectrum for wireless broadband", US Department of Commerce, October 2010; "Enabling UK growth – releasing public spectrum, DCMS, March 2011.

Figure 3-3: Possible timings of for release of spectrum bands for mobile services.



Source: Plum analysis

The discussion above does not refer to unpaired spectrum in the bands 1900-1920 MHz and 2010-2025 MHz. These are both IMT bands in the European Common Allocation Table. The 1900-1920 MHz band was assigned in many of the 3G auctions in Europe with most countries allocating 5 MHz blocks to several operators. We are not aware of any equipment that uses this band and hence there are no deployments. There are trials underway for use of the spectrum as a downlink with integrated mobile broadcast technology which would allow the provision of mobile TV broadcasting services, but downlink use of the band would reduce the available spectrum to only 15 MHz (1x15MHz) or even less⁷⁶. Furthermore, the band is fragmented between operators⁷⁷. There are also on-going proposals to use this band as uplink.

The 2010-2025 MHz band lies within the 2GHz IMT band and is not widely used in Europe though it has recently been auctioned in Norway and Germany and there are plans to release it in the UK and Switzerland⁷⁸. The band may be used for TDD services or as an FDD uplink. The European Commission is proposing to apply least restrictive technical conditions to the bands to allow greater flexibility of use. However, CEPT Report 39 indicates that “other measures are needed to realise the efficient and flexible use of this spectrum.”⁷⁹ In short, this band seems unlikely to be usable for mass market enhanced mobile multimedia and broadband services in the near term.

So in summary, these additional bands offer limited capacity and there is uncertainty over whether they could be used to deliver mass market mobile multimedia services in the next 5-10 years.

⁷⁶ <http://www.erodocdb.dk/Docs/doc98/official/pdf/CEPTREP039.PDF>

⁷⁷ ECO Information Document, “The Use of Mobile Bands in CEPT”, January 2011, ECO.

⁷⁸ <http://www.erodocdb.dk/Docs/doc98/official/pdf/CEPTREP039.PDF>;

http://stakeholders.ofcom.org.uk/binaries/consultations/release_2010_2025/statement/statement.pdf

⁷⁹ <http://www.erodocdb.dk/Docs/doc98/official/pdf/CEPTREP039.PDF>

3.5 Propagation characteristics

The 1.4 GHz band is intermediate between 800/900 MHz and 2.1 GHz, and as such its propagation characteristics are intermediate between these bands. Moving from 2.1 GHz to 800/900 MHz results in roughly a doubling of the propagation distance and hence a quadrupling of coverage areas from base stations⁸⁰. All else being equal (including transmission power), the 1.4 GHz band would offer significant advantages in terms of coverage relative to say bands that could be made available above 2 GHz. These advantages could be even greater in this instance because the Maastricht Agreement allows transmission at a higher power than typical cellular networks⁸¹, subject to cross border coordination.

This means use of the 1.4 GHz band under current regulation is more akin to those at 800/900 MHz and so the band could be deployed in rural areas using existing infrastructure. In addition in urban areas more reliable in-building penetration could be possible, as compared with use of higher frequencies.

3.6 Potential for a global market

As part of the impact analysis for the 1.4 GHz band, an important valuation criterion is the opportunity for economies of scale in respect of future uses of the band⁸².

The allocation of the 1.4 GHz band to broadcasting, and in particular DAB services, has been adopted in numerous countries outside Europe and, as in Europe, DAB services have not been implemented in this band. Hence if a European allocation for an SDL is adopted, there is the potential for this allocation to be taken up in these other countries. Figure 3-4 shows the countries where this would be possible i.e. where there is a broadcasting allocation for DAB in the frequency range 1452-1492 MHz. Taken together with European support this gives significant potential for economies of scale in equipment production and service development to be realised.

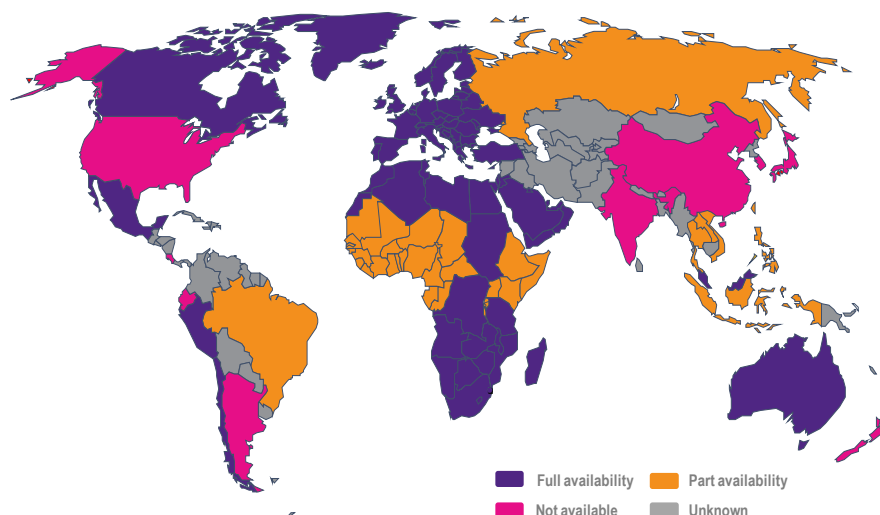
⁸⁰ Hata model calculations.

⁸¹ The advantages depend on the anchor frequency that SDL spectrum is bonded with.

⁸² Minutes for 71st Meeting of the WG FM, Luxembourg, 31 January - 4 February 2011, FM(11)062 Rev1, Issued 4 February 2011, <http://www.cept.org/ecc>

Figure 3-4: Map showing potential availability of 1.4 GHz band for SDL on a global basis.

1.4 GHz band availability worldwide



Source: Plum analysis of data from regulators websites

3.7 Summary of the incremental costs and benefits of an SDL at 1.4 GHz

In this section we have shown that there is a substantial case for considering harmonized use of 1.4 GHz for a supplemental downlink. The reasons for this are that:

- It provides for much needed downlink capacity given the asymmetric nature of mobile broadband and mobile multimedia traffic. It will thereby significantly enhance the user experience by enabling faster downloads and support for a much greater number of users.
- Equipment for use of the band for an SDL could become available by 2014/15.
- The 1.4 GHz spectrum band is readily available in Europe and in numerous countries outside Europe. This means there is a strong possibility of realising significant economies of scale.
- Following the current release of 800 MHz and 2.6 GHz spectrum, there are no other new bands which will become widely available on a European basis before 2018 for mobile downlinks to deliver enhanced multimedia and broadband services.
- At 1.4 GHz the SDL has more desirable propagation characteristics than other bands that could become available before 2020 (e.g. 2.3 GHz and 3.5 GHz).

4 New business models facilitated by a 1.4 GHz SDL

The availability of a supplemental downlink at 1.4 GHz should significantly increase the supply of spectrum with good propagation characteristics and provide opportunities to introduce new business models. The availability of a large block of downlink spectrum provides the opportunity for experimental business models and facilitates innovation. These new models may well:

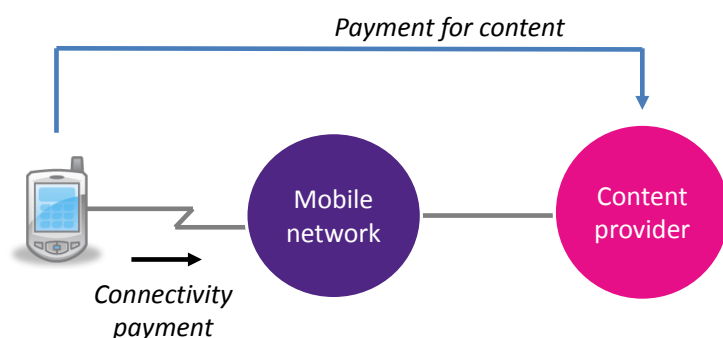
- Trigger market growth by meeting new end-user needs.
- Increase competition within the mobile data market.

In this section we outline four possible new business models that could take advantage of the 1.4 GHz band for mobile multimedia and compare them with the traditional mobile internet access business model.

4.1 The traditional model

Historically, the business model for providing mobile internet access has been for consumers to purchase data access from a mobile operator - either as part of a bundle of services for a phone and tablet or by buying a data card for a laptop. The consumer pays for data access either on a contract basis (usually a fee per month)⁸³, or on a prepaid basis where the consumer purchases an amount of data for fixed fee. The market has evolved from selling data as an add-on device (datacard) to integrated devices (SIMs in laptops and tablets and bundling of data in smartphones) which has improved the consumer mobile broadband experience. Figure 4-1 shows how the traditional business model is used for buying content..

Figure 4-1: The traditional model for buying mobile data connectivity.



⁸³ Potentially subject to additional charges for usage beyond a data cap.

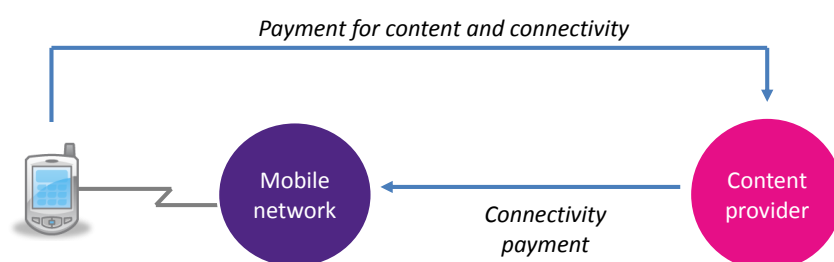
4.2 Model 1: sponsored connectivity

A content provider sells content to consumers with mobile connectivity bundled in the price of the content (e.g. Amazon Kindle). Consumers no longer need to take out a mobile data subscription to access the content from their mobile devices. Likely benefits include:

- Reduced transaction costs for end-users.
- Consumers purchase a product that better meets their needs – content combined with connectivity rather than each item being sold separately – and this is reflected in an increased willingness to pay.
- Increased product and price differentiation, which helps to expand the market.
- Allowing end-users access to specific content without the need for separate data subscriptions to a range of access devices (laptop, e-reader, tablet, phone).

The model for sponsored connectivity is depicted in the Figure below.

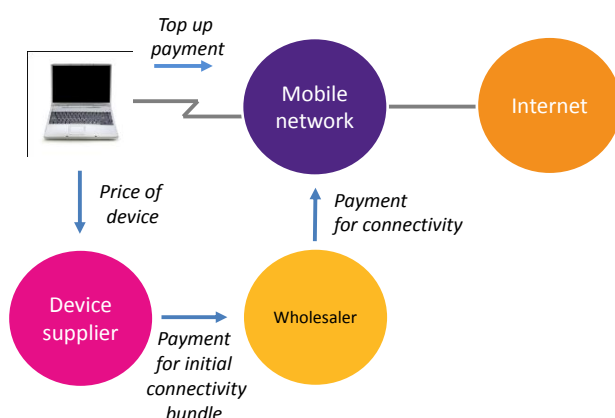
Figure 4-2: Sponsored connectivity.



4.3 Model 2: connectivity bundled with the device

In such a model, the device supplier preloads the device with mobile broadband credits and exposes the user to the benefits of ubiquitous mobile broadband so that they do not only rely on Wi-Fi and fixed broadband. See Figure 4-3.

Figure 4-3: Bundled mobile data connectivity.



The likely benefits are similar to Model 1.

- Reduced transaction costs for end-users.
- The utility to consumers from the tangible products purchased in addition to the benefits from connectivity.
- Increased product and price differentiation, which helps to expand the market.
- Device manufacturers may have a better view on likely data requirements associated with devices and by offering bundled packages may reduce for consumers the uncertainty and risk related to the selection of an appropriate connectivity package.

The Figure below illustrates a current example of the bundled connectivity model.

Figure 4-4: Commercial offer in Dubai bundling connectivity to the purchase of a smartphone.



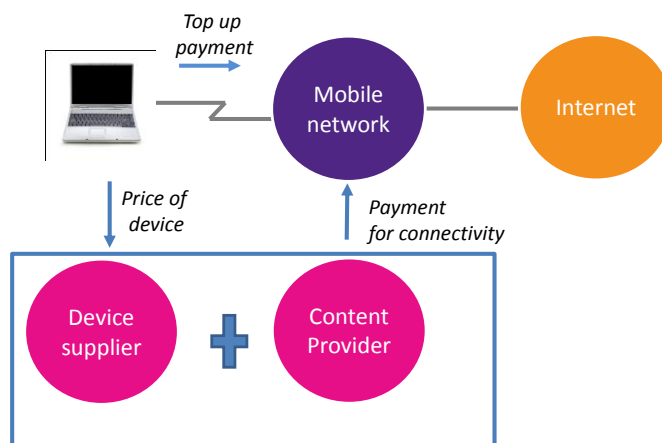
4.4 Model 3: Content bundled with the device

The device supplier may pre-load some content and may also offer some associated free applications to the user for supplementary content downloads. Assuming these are relatively high bandwidth applications (e.g. Maps) that exploit the benefits of the 1.4 GHz band, then it seems reasonable to

expect that the user will pay for most but not necessarily all of the connectivity. The likely benefits for the consumer include:

- Reduced transaction costs associated with the purchase of content separately from the device.
- The benefits to consumers from easy access to the pre-loaded and supplementary content.
- Savings in connectivity costs for the end user as less content needs to be downloaded.

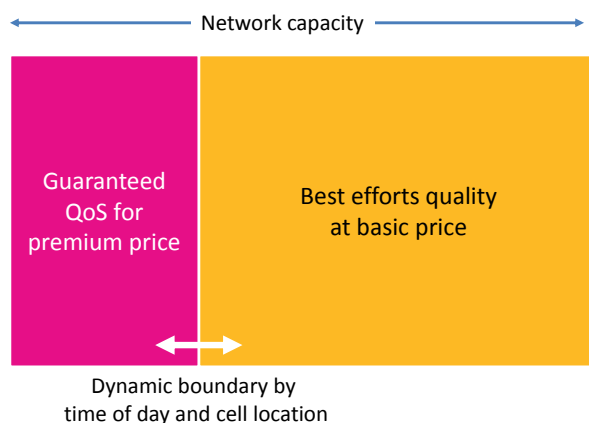
Figure 4-5: Bundled content with device.



4.5 Model 4: managed mobile service

A mobile operator uses its expanded network capacity from the 1.4 GHz supplemental downlink to provide a managed service with guaranteed speeds (for a given signal strength) in return for a premium price. Such a service has a wide range of potential applications within the business sector e.g. guaranteed quality of service to support sales and engineering staff operating in the field/away from the office. The managed mobile service model is depicted in the Figure below.

Figure 4-6: Managed mobile service.





This model allows major product differentiation and a substantial increase in the benefits from mobile broadband to businesses and individuals who place a high value on service quality.

5 Benefits from an SDL at 1.4 GHz

5.1 Introduction

In this section, we assess the benefits of using the 1.4 GHz band for a supplemental downlink. We have identified five main benefits. These are additive and are summarised in Table 5-1. We quantify the first two benefits and discuss the others in qualitative terms. The description of benefits given below is relative to a base case of continued allocation of the band to digital audio broadcasting (terrestrial and satellite DAB).

Table 5-1: The benefits of deploying a 1.4 GHz supplemental downlink.

Ref	Impact of SDL	Benefits	Assessment
1	More urban and suburban capacity at lower cost than building new base stations	Lower prices overall for end-users (in a competitive market).	Quantitative
2	Better service in terms of higher data speeds and ability to support more users. Possibly better coverage including indoor coverage, depending on the anchor paired frequencies used.	Greater willingness to pay by end-users and increased consumer surplus.	Quantitative
3	High-speed data in rural areas.	Contribute towards achieving Digital Agenda target of 30 Mbps for all by 2020 at lower cost.	Qualitative
4	Facilitate innovative new business models.	Increased competition in supplier of mobile data and multimedia services.	Qualitative
5	Early adoption of supplemental downlink by European firms to support the development of mobile multimedia services.	European firms better able to compete in global mobile services markets.	Qualitative

The incremental costs relative to the base case also need to be considered. These are:

- The cost of upgrading mobile networks. This is considered in Section 5.3.
- The cost of developing the least restrictive technical conditions. The costs of developing and agreeing a harmonised band plan comprise the administrative costs associated with such an exercise. These are expected to be modest in the context of the potential benefits discussed below and so are not considered further.
- The incremental costs for devices. The incremental costs of modifying devices to receive a 1.4 GHz downlink are also expected to be small as little additional equipment is required (an additional diplexer and filter^{84 85}).

⁸⁴ The radio frequency front-end will need an additional diplexer and a band-pass SAW filter, see Appendix B.

There is no cost in terms of forgone services, as national governments will still retain the flexibility to deploy terrestrial digital radio services in the band if they wish to do so.

Before discussing each of the benefits in more detail, we briefly review the existing literature which values the benefits of spectrum for mobile broadband. This provides an indication of the benefits that could be derived from a supplemental downlink at 1.4 GHz which will support mobile broadband and enhanced mobile multimedia services.

5.2 Previous estimates of the economic benefits from spectrum used for mobile broadband

Table 5-2 summarises a number of previous studies on the value of spectrum for mobile broadband.

Table 5-2: Summary of studies estimating the economic value of mobile broadband.

Study	Date	Finding	Economic value of mobile broadband - €/MHz/pop
Hazelett and Munoz	2008	UK 3G auction generated US\$35 billion in consumer surplus from auction of 140MHz of spectrum.	4.57
		In the US, consumer surplus from using another 30Mhz for mobile between 1997-2003 would have yielded gains of US\$46 billion.	4.49
Analysys Mason /Dotecon/ Aegis for Ofcom	2006	Private value (consumer + producer surplus) of 56MHz of digital dividend spectrum (800 MHz) for mobile broadband in UK is £2.5 billion.	1.08
Analysys Mason/Hogan and Hartson for ARCEP	2008	Private value of 72MHz digital dividend spectrum in France for mobile broadband is €26.2 billion.	6.82
Analysys Mason for Dutch Ministry of Economic Affairs	2008	Private value of 72MHz digital dividend spectrum for mobile broadband in the Netherlands is €0.5 to 6.9 billion.	0.51 to 7.01
Spectrum Value Partners for Ericsson, Nokia, Orange, Telefonica and Vodafone	2008	Private value for Europe 80MHz of digital dividend spectrum us €111 billion to €180 billion.	2.79 to 4.52

⁸⁵For example, with HSPA+, adding requirement for 1.4 GHz band supplemental downlink uses the architecture Rel-9 dual-band/dual-carrier capable chipsets that are under development. Antennas in devices use shared antenna across bands 800 MHz-2.6 GHz.

Study	Date	Finding	Economic value of mobile broadband - €/MHz/pop
SCF for Deutsche Telekom	2007	Estimate the direct benefit of allocating 40MHz spectrum for wireless broadband as €101 billion and the benefit of 240MHz spectrum to wireless broadband as €463 billion.	3.88 to 5.07
Analysys Mason/ Dotecon/ Hogan and Hartson for the European Commission	2009	Net benefits of 72MHz digital dividend spectrum as between €17 billion to €43 billion (allowing for costs of digital switchover).	0.5 to 1.47
Europe Economics for Ofcom	2006	Net economic benefit of mobile telephony in the UK in 2006 is £22 billion.	1.61

Sources: See Appendix D – currency conversion rate at time of study.

Table 5-2 illustrates both the significant value from using spectrum for wireless broadband and the wide range of benefit estimates. The values range from €0.51 to €7.01 per MHz per pop, with a number of studies clustering at the upper end of this range.⁸⁶

These numbers would equate to a benefit of between €10 billion and €140 billion for the 1.4 GHz band for Europe⁸⁷.

5.3 The net benefits of additional urban and suburban capacity with SDL at 1.4 GHz

5.3.1 Scenarios for spectrum availability

To estimate the net benefits of additional spectrum in providing capacity in urban and suburban areas we need to make assumptions on spectrum availability both across the sector and at an operator level. We assume:

- 800 MHz and 2.6 GHz spectrum is available across Europe by 2014.
- 1.4 GHz SDL is ready for deployment across Europe by 2014.
- Substantial quantities of 3.4-3.6 GHz and/or 2.3 GHz spectrum are available for mobile broadband (LTE) deployment to provide additional urban capacity across Europe by 2019.
- There are four operators within a country.

For spectrum assignment to operators we consider three scenarios:

⁸⁶ It is important to note that the Analysys Mason (2009) estimate is net of the significant cost of digital switchover and does not include the benefits for the eight member states (including UK, Germany and France) which had already decided to use the digital dividend spectrum for wireless broadband. This is why their estimates are much lower than those obtained in other studies.

⁸⁷ Defined in this report to cover the European Economic Area i.e. the EU plus Iceland, Liechtenstein and Norway.

- **Spectrum Assignment Scenario 1:** Each of the four mobile operators in a typical country gets 10 MHz of downlink 1.4 GHz spectrum and uses it, as a supplement to their assigned paired spectrum, to increase capacity and enhance user experience with faster data rates.
- **Spectrum Assignment Scenario 2:** the 40 MHz is split equally between two operators. For example, an operator has 2x5 MHz of mobile spectrum at below 1 GHz and acquires 20 MHz of 1.4 GHz downlink spectrum at auction. The balance of 20 MHz goes to another operator to supplement 2x15 MHz of spectrum at below 1 GHz.
- **Spectrum Assignment Scenario 3:** the 40 MHz is assigned to a single operator or third party which would then wholesale capacity to all operators as required. For example, an operator acquires all 40 MHz of 1.4 GHz spectrum and offers it on a wholesale basis in combination with 2x10 MHz of sub-1 GHz spectrum. Alternatively, an equipment vendor who is running a network for a mobile operator, purchases the 1.4 GHz spectrum in its entirety, upgrades the network and acts as a wholesaler. In addition to selling capacity to operators and MVNOs, the wholesaler might offer a range of services (see Section 4 for more detailed discussion) which includes:
 - Sponsored connectivity for content providers.
 - Connectivity bundled with devices for device suppliers.
 - Managed mobile data for retail service providers to offer to corporate clients.

5.3.2 Estimates of avoided costs from using an SDL at 1.4 GHz

Deploying a 1.4 GHz SDL allows mobile operators to avoid significant costs in urban and suburban areas, if and when they run out of capacity there. SDL at 1.4 GHz has two main effects:

- The mobile operator can initially upgrade existing base stations with the 1.4 GHz SDL rather than using the more expensive option of building additional base stations.
- Once the additional capacity from the SDL upgrades is used up, the mobile operator can deploy new base stations which are more cost effective. We estimate that, by 2015, a new base station which uses the 1.4 GHz SDL might offer 18% more downlink capacity for 9% greater cost, when compared with a new base station without an SDL.

In a competitive market these lower costs will result in lower end user prices for mobile broadband and mobile multimedia services. We describe how we have quantified the economic benefits from additional urban and suburban capacity in Appendix C.

5.3.3 Estimates for Spectrum Assignment Scenario 1

We follow Spectrum Assignment Scenario 1 for the main calculations and then consider the impact of moving to Spectrum Assignment Scenarios 2 and 3. We assume that:

- Downlink capacity is the constraint on traffic growth and model only downlink capacity as the driver of additional urban and suburban investment. Given the growing asymmetry in traffic demand, with a likely 10:1 ratio in favour of the downlink by 2015⁸⁸, this seems a reasonable assumption.

⁸⁸ As discussed in Section 3.

- The SDL spectrum is assigned equally to all four operators and all operators upgrade the network to implement 1.4 GHz SDL.
- The 1.4 GHz spectrum is available for an SDL from 2014 onwards.
- Long term release of 3.4-3.6 GHz spectrum to mobile broadband offers cost efficient capacity for upgrading existing base stations from 2019 onwards. This reflects the fact that at least 80 MHz of additional downlink spectrum⁸⁹ at 3.4-3.6 GHz spectrum could be available to the operators by then.
- Net present values are calculated over a 10 year period from 2014 with a 10% discount rate.

Our estimates rely on three main parameters where there is a wide range of forecasts and estimates:

- Future mobile data traffic demand. We have made high and low demand projections that we believe might reasonably reflect upper and lower bounds on expected demand. These projections are specified in Appendix A. We have modelled only the low projection of demand for mobile data in our estimates of the economic benefits of SDL at 1.4 GHz.
- The long-term download speeds enjoyed by end-users. We have modelled download speeds of both 5 Mbps and 12.5 Mbps by 2025.
- The cost of new base station and SDL upgrades.

Given these varying assumptions, we have estimated the avoided costs for two demand scenarios:

- **Demand Scenario 1.** This measures avoided costs in the situation where all urban and most suburban base stations are upgraded with the SDL before 2019. This occurs under the low demand projection of Appendix A in the situation where end-users enjoy downlink speeds of 12.5 Mbps by 2025⁹⁰. We have modelled the avoided costs and we estimate them at **€26 billion**.
- **Demand Scenario 2.** This measures avoided costs in the situation where base stations are upgraded with the SDL to a limited extent. This occurs under the low demand projection of Appendix A where end-users enjoyed downlink speeds of 5 Mbps by 2025. Under this scenario we estimate avoided cost benefits of **€4 billion**.

We have also looked at the impact of varying the cost assumptions set out in Appendix C, as the cost of radio access network equipment falls over the next few years. We have assessed the impact of halving the capital and operating expenditure for SDL upgrades and new base stations which is specified there. The results are shown in the Table 5-3.

We can see that:

- The estimates are much more sensitive to the demand scenarios than to the equipment cost assumptions.
- Overall the NPV of the avoided cost net benefits varies between €4bn and €26bn for Europe.

⁸⁹ As per the 2x80 MHz FDD (3410-3490 MHz (uplink) / 3510-3590 MHz (downlink)) or TDD band plans developed by ECC PT1 in May 2011

⁹⁰ Can also occur under the high demand projection of Appendix A in the situation where end users enjoy just 5 Mbps by 2025

Table 5-3: Avoided cost benefits of additional urban and suburban capacity - € billion net present value

BTS and SDL upgrade costs	Avoided cost NPV in € billion for:	
	Demand Scenario 1	Demand Scenario 2
End user downlink speed	12.5 Mbps	5 Mbps
Demand projection from Appendix A	Low	Low
New BTS €150k SDL upgrade €30k Urban site establishment €150k Urban site rental €30k pa	26	4
New BTS €75k SDL upgrade €15k Urban site establishment €150k Urban site rental €30k pa	24	4

Source: Plum analysis

5.3.4 Estimates for Spectrum Assignment Scenarios 2 and 3

The conclusions set out above assume Spectrum Assignment Scenario 1, in which all four operators in a typical member state get 10 MHz each of the 1.4 GHz SDL. We now consider what happens to the net benefits under:

- Demand Scenario 1 plus Spectrum Assignment Scenario 2, in which the 40 MHz is split equally between two operators.
- Demand Scenario 1 plus Spectrum Assignment Scenario 3, in which the 40 MHz is assigned to a single operator or third party which then wholesales capacity to all operators as required.

The position is clearest under Spectrum Assignment Scenario 3, where the wholesaler upgrades one of the four networks and the upgrade costs for the other three networks are avoided. SDL upgrade costs are then reduced from €17 billion to €4 billion, which increases the net benefits⁹¹ by approximately €13 billion to give a total value of €39 billion. Under Spectrum Assignment Scenario 2 upgrade costs are incurred by two network operators, reducing them from €17 billion to €9 billion and increasing the net benefits by approximately €8 billion to give a total value of €34 billion. Table 5-4 summarises these results.

⁹¹ As shown in Table 5-4.

Table 5-4: Impact of the Spectrum Assignment Scenarios on avoided cost benefits.

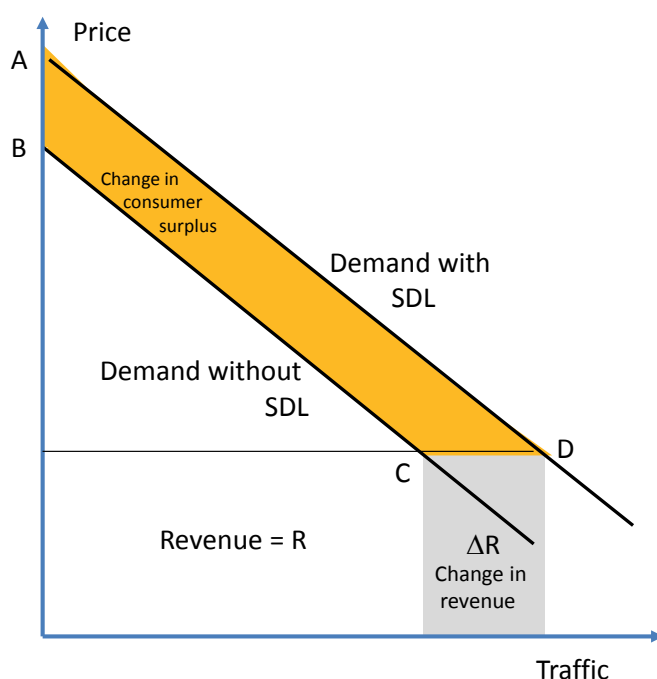
Assumptions about demand and equipment costs	NPV in €billion of avoided costs under Spectrum Assignment Scenario:		
	1	2	3
Demand Scenario 1, High equipment cost	26	34	39

5.4 The benefits of enhanced user experience

The previous section estimates how the 1.4 GHz SDL can lower the cost of supplying urban and suburban capacity for mobile data. This benefit is shared between producers and consumers, with the bulk of the benefit going to consumers in a competitive market.

In addition implementation of the 1.4 GHz SDL should shift the demand curve for mobile data upward and to the right as shown in Figure 5-1 - given that it enables higher download data speeds and better in building coverage in urban areas. This shift in the demand curve increases the consumer surplus by the shaded area ABCD of Figure 5-1.

Figure 5-1: The impact of the SDL on demand.



The economic literature on valuing services states that the value of consumer surplus from a product can be estimated using the following formula:

$$\text{Consumer surplus} = (0.5 * \text{revenue})/e$$

where e is the price elasticity of a product (expressed as the absolute value). This approach was used to estimate the economic value of mobile services in the US in an academic study⁹² and in studies for Ofcom on the economic impact of spectrum⁹³. To estimate the increase in consumer surplus using this approach, we need both an estimate of revenue from mobile multimedia services provided over an SDL at 1.4 GHz and the price elasticity of demand.

5.4.1 Estimating incremental revenues from an SDL at 1.4 GHz

There are two approaches to estimating future revenues from 1.4 GHz spectrum:

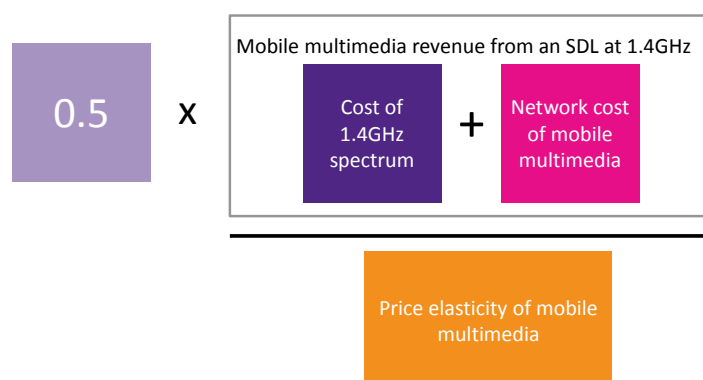
- Forecast the NPV of mobile broadband revenues and assign a proportion of this NPV to services provided over an SDL at 1.4 GHz.
- Forecast the net present value of the cost of providing mobile multimedia service over an SDL at 1.4 GHz and assume that revenue will at least cover the costs of providing the capacity⁹⁴. This cost would also include the cost to operators of acquiring spectrum.

We have used the latter approach, given that future mobile broadband revenues are highly uncertain and it is difficult to determine the incremental increase in revenue due to the availability of the 1.4 GHz SDL.

The cost of mobile multimedia services consists of (i) the network costs and (ii) the cost of spectrum. We have not included retail costs for mobile multimedia as the supplementary downlink will be used with other spectrum and the incremental retail costs associated with the downlink are likely to be modest.

Our methodology for estimating the incremental benefit to consumers from higher speeds and better coverage of 1.4 GHz spectrum is set out in Figure 5-2 below.

Figure 5-2: Methodology for estimating incremental benefit to consumers.



One potential drawback with a cost based approach is that operators may earn economic profits (in

⁹² Jerry Hausman. 2002. "Mobile Telephone", *Handbook of Telecommunications Economics*, Volume 1, Elsevier.

⁹³ Europe Economics. 2006. "Economic Impact of the use of radio spectrum in the UK".

⁹⁴ This method allows the operator to earn a reasonable return on capital employed so long as we use a commercial discount rate in calculating the net present value of costs.

excess of normal returns) from mobile multimedia in which case the cost based approach will underestimate future revenue⁹⁵. This means our estimates are likely to be conservative.

5.4.2 The cost of providing services at 1.4 GHz

The incremental cost of providing 1.4 GHz services is estimated at between €4.2 billion⁹⁶ and €16.8 billion⁹⁷ for Europe, based on the costing assumptions and scenarios set out in Section 5.2. We have used the cost assumptions for Spectrum Assignment Scenario 1, as a proxy for estimating revenue from 1.4 GHz. It is difficult to estimate the impact of Spectrum Assignment Scenarios 2 and 3. These scenarios would lead to lower implementation costs but might lead to higher spectrum values.

5.4.3 Estimated value of 1.4 GHz spectrum

A full description of our approach to estimating the value of 1.4 GHz spectrum, based on auction values and reserve prices is set out in Appendix E.

The 1.4 GHz band is expected to have similar but not necessarily equivalent properties to sub 1 GHz spectrum, in terms of data speeds and in-building coverage. This suggests that the sub 1 GHz spectrum value is an upper bound on the value of 1.4 GHz frequencies, while the value could also be lower depending on the scale of harmonization and the depth of the 1.4 GHz band supplemental downlink ecosystem.

Based on the results of the auctions and regulators' reserve prices, we suggest the value of sub 1 GHz spectrum for EU countries lies in the range of €0.40 to €0.70 per MHz per pop – this is the net present value of the spectrum over the duration of the relevant licences (usually 15-20 years). For the purposes of our assessment we propose to use the following values for 1.4 GHz spectrum (see Table 5-4).

⁹⁵ While auction values will incorporate some of the expected future profits (in excess of normal returns) from mobile broadband this depends on the competitiveness of the auction. The more competitive the auction, the more likely it is that auction prices will lead to normal returns.

⁹⁶ Under Demand Scenario 2 where only a modest percentage of BTS are upgraded with the SDL.

⁹⁷ Under Demand Scenario 1 where virtually all urban and suburban BTS are upgraded with the SDL.

Table 5-4: Range of estimates for net present value of 1.4 GHz band.

Estimate of spectrum value	Description	1.4 GHz value in €/MHz/pop	Total value of 40 MHz of 1.4 GHz spectrum across EEA countries (€bn)
Low	Value of 1.4GHz is significantly below sub 1 GHz spectrum	0.25	5.0
Medium	Value of 1 GHz lies at lower bound of sub 1 GHz spectrum	0.40	8.0
High	Value of 1 GHz spectrum is similar to mid to upper end of sub 1 GHz range.	0.60	12.0

Source: Plum analysis, Appendix E

We estimate the net present value of 1.4 GHz spectrum as between €5 to €12 billion for Europe. These estimates appear to be conservative, given that the estimated cost savings from the spectrum derived in the previous section are either at the upper end or higher than the range of values reported in Table 5-4. This suggests that early auctions may not have captured the full market value of spectrum.

5.4.4 Estimated revenues from enhanced mobile multimedia services provided over an SDL at 1.4 GHz

Based on the spectrum value and the expected cost of providing 1.4 GHz services over a 10 year period, we estimate the net present value of revenues from mobile multimedia services to be between €9 and €30 billion for Europe⁹⁸.

⁹⁸ Defined here to be the European Economic Area

Table 5-5: Revenue estimates for enhanced mobile multimedia over an SDL at 1.4 GHz (net present value).

	Low (€bn)	Medium (€bn)	High (€bn)
Spectrum value ⁹⁹	5.0	8.0	12.0
Cost of providing service	4.2 ¹⁰⁰	10.5 ¹⁰¹	16.8 ¹⁰²
Net present value of enhanced mobile multimedia revenues over an SDL at 1.4GHz	9.2	18.5	28.8

Source: Plum analysis

5.4.5 Price elasticity estimates

Finally, we derive the value of consumer surplus by dividing the revenue estimate by an estimate of the price elasticity of mobile broadband services. There are a number of studies on the price elasticity of mobile services, but little evidence is available on price elasticity of mobile broadband:

- The UK Competition Commission estimated the price elasticity of mobile subscriptions and calls as -0.3 in its 2003 inquiry¹⁰³. It also noted that parties had submitted estimates of between -0.08 to -0.54.
- An early international study across 64 countries found the price elasticity of subscriptions as -0.36¹⁰⁴.
- An Austrian study found that a long run price elasticity of -0.74 for business customers and -0.36 for consumers¹⁰⁵.
- Europe Economics (2006) used price elasticity for mobile services of -0.3 and -0.47 in their estimate of consumer surplus for UK mobile market.
- Hausman and Sidak (2007) estimate elasticity of Irish mobile market as -0.84.
- Haucap (2010) estimated a price elasticity of -0.72 for the post-paid market and -0.33 for the pre-paid market in Turkey¹⁰⁶.

There have also been a number of studies on price elasticity of the US mobile market:

- Hausman (1999) estimated the price elasticity of US mobile access at -0.5.¹⁰⁷

⁹⁹ From Table 5-4.

¹⁰⁰ Demand Scenario 2 of Table 5-1.

¹⁰¹ Interpolation between Demand Scenarios 1 and 2.

¹⁰² Demand Scenario 1 of Table 5-1.

¹⁰³ UK Competition Commission. 2003. *Mobile Termination Inquiry*. London.

¹⁰⁴ H. Ahn and M. Lee. 1999. "An econometric analysis of the demand for access to mobile telephone networks". *Information Economics and Policy*. 297-305.

¹⁰⁵ Ralf Dewenter and Justus Haucap. 2008. "Demand elasticities for mobile telecommunications in Austria". *Jahrbucher fur Nationalokonomie und Statistik*, 228.

¹⁰⁶ Justus Haucap, Ulrich Heimeshoff and Mehmet Karauka. 2010. "Competition in the Turkish Mobile Telecommunications Market: Price Elasticities and Network Substitution". http://www.dice.uni-duesseldorf.de/Forschung/Dokumente/012_Haucap_Heimeshoff_Karacuka.pdf

¹⁰⁷ Jerry Hausman. 1999. "Cellular Telephone, new products and the CPI", *Journal of Business Economics and Statistics*. 17.

- Ingraham and Sidak (2004) estimated the elasticity for the US mobile market as between -1.12 to -1.29.
- Hazelett and Munoz (2008) estimate the elasticity of demand for US mobile services as -0.7999¹⁰⁸.

The range of estimates from previous studies suggests that it might be reasonable to use a central estimate of -0.5 and undertake sensitivity testing using value of -0.3 and -0.7 for the price elasticity of mobile broadband. The negative value of price elasticities reflects that an increase (decrease) in the price of product results in a decrease (increase) in demand. In the estimation of consumer surplus, it is the absolute value of the price elasticity which is used. We use the absolute values for the rest of section 5.

5.4.6 Estimate of consumer surplus

The estimated consumer surplus from enhanced mobile multimedia services provided over a supplemental downlink at 1.4 GHz is set out in the table below.

Table 5-6: Estimates of consumer surplus from an SDL at 1.4 GHz (net present value).

	Low (€bn)	Medium (€bn)	High (€bn)
Net present value of enhanced mobile multimedia over SDL on 1.4GHz (from Table 5-5)	9.2	18.5	28.8
Price elasticity	0.5	0.5	0.5
Consumer surplus from enhanced services	9.2	18.5	28.8

The net present value of the consumer surplus is estimated to range from €9.2 billion to €28.8 billion. The range largely reflects the wide range of predictions for the future demand for mobile multimedia services. However, it is clear that the benefits to European consumers are significant.

The use of price elasticities of 0.3 and 0.7 (absolute value) would have the impact as set out in the table below.

Table 5-7: Estimate of consumer surplus with alternative price elasticities.

Alternative price elasticity (absolute value)	Low (€bn)	Medium (€bn)	High (€bn)
0.3	15.3	30.8	48.0
0.7	6.6	13.2	20.6

Source: Plum analysis

¹⁰⁸ Thomas Hazelett and Robert Munoz. 2008. "A Welfare Analysis of Spectrum Allocation Policies", George Mason University.

5.5 The benefit of higher speed for rural broadband

The upgrade of 3G/4G networks with a supplemental downlink at 1.4 GHz has the potential to significantly improve mobile data speeds in rural areas, where mobile services have an important role to play in delivering cost-effective next-generation broadband. This should allow governments to get closer to the European Commission's Digital Agenda target of 30 Mbps for all by 2020.

The broadband speed available over an 3G/4G network will depend on available capacity and demand on the network. The 800 MHz spectrum will provide 30 MHz of downlink capacity for use by LTE networks. An additional 40 MHz capacity at 1.4 GHz will more than double this downlink capacity, more than double downlink speeds for the same traffic loading in a cell, or more than double the number of users that could be supported. The impact on individual operators will depend upon which of the spectrum assignment scenarios described in Section 5.3 applies. The key point, from a European policy perspective, is that the additional downlink capacity will enable higher speed access to be delivered to remote and rural customers.

Other bands which may become available before 2020, such as the 3.5 GHz spectrum, will not provide significant additional capacity and higher speeds to rural end-users. The propagation characteristics of these bands mean that it is not likely to be cost-effective to add capacity using such spectrum in rural areas. This second digital dividend (using spectrum in the 700 MHz band) would help, but it is not likely that this spectrum will become widely available until well after 2020.

5.6 The benefit of increased competition in the mobile data market

The competition benefits from 1.4 GHz spectrum for an SDL are likely to be two-fold:

- Additional competition in the supply of mobile data services. This will depend on the extent to which competition in a market is constrained by limited spectrum for 3G/4G in the sub-1 GHz spectrum. In a number of countries, the size of operators' 800 MHz assignments are expected to be small¹⁰⁹ and some operators may either miss out on sub-1 GHz spectrum or only have one 2x5 MHz block of spectrum. In the absence of the 1.4 GHz SDL, the limited availability of spectrum is likely to constrain competition.
- Development of new business models, as discussed in Section 4 above, will lead to new and increased competition, including on the content side.

These benefits are likely to be maximised if the supplemental downlink spectrum is assigned in an asymmetric way between operators (Spectrum Assignment Scenarios 2 or 3) rather than assigned equally to the four operators (Spectrum Assignment Scenario 1). Asymmetry produces more disruptive competition than symmetric assignment, and this is likely to lead to stronger competition.

We now discuss each competition benefit in more detail.

¹⁰⁹ Auctions rules of 800 MHz in most Europe countries impose spectrum caps that limit the maximum spectrum holdings per operator to 2x10 MHz or 2x15 MHz in the 800 MHz.

5.6.1 Enhanced competition

The availability of 1.4 GHz for a supplemental downlink will enable players with capped or little 800 MHz spectrum to compete more aggressively in the market and potentially enable entry by players without 800 MHz spectrum. Increased competition is likely to result in lower prices for consumers and increased innovation in the provision of mobile broadband services. The potential scope of the benefits is indicated by the size of the mobile broadband market.

As discussed in Section 2.2 the European mobile data market might be valued at approximately €70 billion by 2020. This means that enhanced competition in mobile multimedia services is likely to offer significant benefits for consumers (e.g. even a small price reduction would imply a substantial saving on a European basis).

Hazelett and Munoz (2008) tested the impact of availability of spectrum and market concentration on mobile service prices using econometric analysis in 29 countries between 1998 and 2003¹¹⁰. They found that increased market concentration increases prices and that increased availability of spectrum reduces prices. So additional availability of 1.4 GHz spectrum should stimulate competition in mobile data and multimedia markets resulting in lower prices for consumers and improved choice and innovative new products.

5.6.2 New mobile broadband and multimedia business models

In addition to stronger competition from new or better resourced competitors, additional spectrum will provide scope for experimentation with innovative business models to deliver mobile multimedia services. The recent history of the internet and online markets suggest that new services have the potential to rapidly take off and achieve widespread use by consumers. However, the launch of new products and services is highly uncertain and risky – many are likely to fail. Innovative business models provide scope for new players to enter the market and to bundle services, hardware and access together. This will increase the likelihood that new products and services will be developed with significant benefits to consumers.

5.7 Early adoption advantage to the European mobile business in multimedia services

The use of the 1.4 GHz band for mobile multimedia in Europe may have a number of benefits for manufacturers of equipment and to service providers. The number of countries outside Europe where 1.4 GHz could be used as a supplemental downlink shows the potential for these early mover advantages. The map in Figure 3-4 illustrates the potential scope for use of 1.4 GHz in the Middle East, Africa, Asia Pacific and the Americas.

International adoption of the 1.4 GHz for supplemental downlink will be of great benefit to European content and service providers and to technology providers¹¹¹.

¹¹⁰ Thomas Hazelett and Robert Munoz. 2008. "A Welfare Analysis of Spectrum Allocation Policies", George Mason University.

¹¹¹ Potential markets will exist in Europe and potentially in many countries outside Europe where the 1.4 GHz band is currently allocated to DAB services. In addition, service providers will also have the opportunities in the US market for supplying innovative multimedia services as an SDL is planned there.

There is reason to believe that early deployment of the 1.4 GHz supplemental downlink in Europe may result in innovation in the provision of content and services which could lead to considerable producer surplus. The history of the Internet is that network effects can result in the creation of very large companies in a rapid space of time such as Google, Skype, Facebook, Twitter etc.

The development of mobile multimedia is at a relatively early stage. It requires substantial innovation for success and is likely spawn a number of commercially successful companies. These developments may take place with or without 1.4 GHz spectrum. However, the availability of a large block of downlink spectrum will provide additional space for experimental business models and facilitate innovation. This will increase the likelihood that commercially successful innovation in mobile multimedia occurs in Europe.

5.8 The overall net benefits of a 1.4 GHz SDL

In this section we have discussed the overall benefits of using the 1.4 GHz band for a supplemental downlink for enhanced mobile multimedia and broadband services. We have quantified two principal benefits:

- The *avoided costs* from using the SDL to meet rising demand for mobile broadband rather than investing in additional base stations. This benefit is shared between producers and consumers, with the bulk of the benefit going to consumers in a competitive market

The net benefits to consumers (*or consumer surplus*) that arise from implementing an SDL at 1.4 GHz including faster download speeds in urban and suburban areas, support for a greater number of users and better in-building coverage. Our estimate of the size of these benefits is set out in the Table 5-8 below.

Table 5-8: Summary of net present value of quantified benefits of SDL at 1.4 GHz for enhanced mobile multimedia and broadband services.

Quantified benefit	Low (€bn)	Medium (€bn)	High (€bn)
Avoided costs	4	15 ¹¹²	26
Consumer Surplus from enhanced user experience	9	18	28
Total	13	33	54
Value as €/MHz/pop	0.66	1.67	2.71

Source: Plum analysis

The net present value¹¹³ of quantified benefits for Europe, from the use of 1.4 GHz for a supplemental downlink for mobile broadband and enhanced multimedia, ranges from €13 billion to €54 billion with a medium estimate of €33 billion. Alternative spectrum assignments of SDL at 1.4 GHz¹¹⁴ would even increase the net present value by approximately €13 billion to give a total value of €67 bn.

¹¹² Interpolation between the low and high estimates of avoided cost benefits.

¹¹³ Calculated over a 10 year period with a 10% discount rate.

¹¹⁴ As shown in Table 5-4

The wide range of predictions about future demand for mobile broadband and the nature of mobile multimedia services provided over 1.4 GHz results in a significant range of quantified benefits. The estimates lie within the range of estimates from previous studies of €10 billion to €140 billion (or of €0.51 to €7.01 per MHz per pop).

The quantified benefits may be on the conservative side given that we have modelled only the impacts of a low projection of demand for mobile data. Modelling the impacts of a high demand projection would produce higher values for the benefits. Our estimate is also likely to be conservative given that the rapid growth in mobile broadband since many of these studies were undertaken will have increased the benefits of spectrum for wireless broadband.

There are three additional major benefits from the use of a 1.4 GHz SDL. Such use:

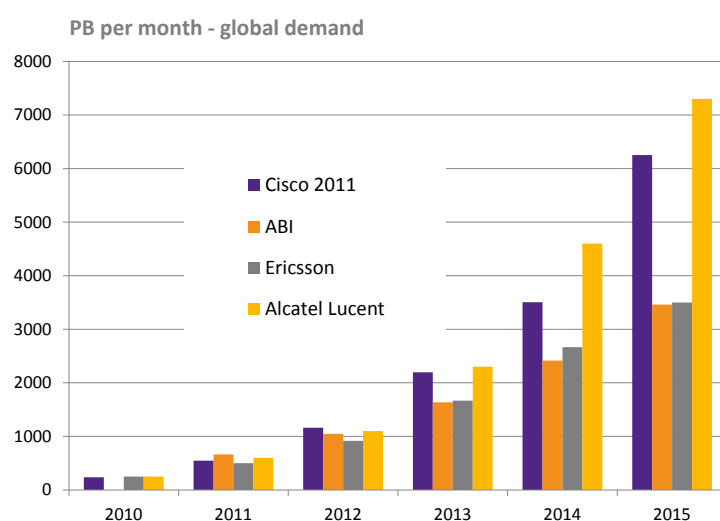
- Supports delivery of the Digital Agenda target to provide 30 Mbps access to 100% of the EU by 2020. This is an extremely challenging target and is unlikely to be delivered by the market. Wireless has a key role in providing high speed broadband to remote and rural customers. However, the target implies that significant wireless capacity and faster data rates will be required in rural areas. An SDL at 1.4 GHz spectrum can play a key role in providing capacity to meet Digital Agenda targets and reduce the requirement for public subsidies.
- Increases competition in the mobile broadband and content markets. Limited availability of spectrum below 1GHz means that in many countries, operators will have little¹¹⁵ or no low frequency spectrum to provide mobile broadband services. The availability of additional spectrum at 1.4 GHz for an SDL will enable players to compete more aggressively in the supply of high speed mobile broadband and multimedia content. Increased competition is likely to result in lower prices for consumers. It is also likely to result in having more mobile broadband capacity to experiment new business models.
- Gives European suppliers an early advantage in the development of mobile multimedia services using a supplementary downlink. There is considerable scope for the adoption of 1.4 GHz for a supplemental downlink outside Europe such as in the Middle East, Australia, Canada and Mexico. Implementation of the standard in Europe will open up new business opportunities in international markets, particularly for service providers with successful business models.

¹¹⁵ Auction rules of the 800 MHz auction rules in most Europe countries impose spectrum caps that limit the maximum spectrum holding per operator to 2x10 MHz or 2x15 MHz in the 800 MHz

Appendix A: Forecasts of mobile data traffic

In this appendix, we review published forecasts of mobile data traffic. Figure A1 presents the predictions of three equipment suppliers - Cisco, Ericsson and Alcatel Lucent - and of one consulting organisation – ABI Research. We note that there is a substantial variation in the forecasts with the biggest prediction being twice the smallest by 2015.

Figure A1: Global mobile data to 2015 – PB per month¹¹⁶ - four published sources compared



We have excluded from consideration:

- The UMTS Forum Report 37 of 2006. This is too old. Predictions were made before the market had developed.
- The UMTS Forum Report 44 of 2011. This relies on forecasts from IDATE which produce similar projections to those shown in Figure A1.
- Estimates and forecasts made by the Informa Group. Informa estimates for the base year of 2010 are out of line with other published estimates¹¹⁷.

There are three other studies which suggest that the forecasts shown in Figure A1 may be pessimistic:

- Allot¹¹⁸ claims to measure growth in mobile data traffic. It reports a 190% growth globally in 2010. Cisco estimates that mobile data traffic grew by 159%.
- The Boshulte Schmee Group¹¹⁹ claims that the Cisco forecasts are gross underestimates and should be multiplied by 10. This finding looks like something of an outlier and we have discounted it.

¹¹⁶ PetaBytes per month. One PetaByte = 10¹⁵ Bytes.

¹¹⁷ For example Informa estimates that mobile networks globally carried 75 PB of traffic per month in 2010 compared with estimates from other sources of between 236 to 321 PB per month.

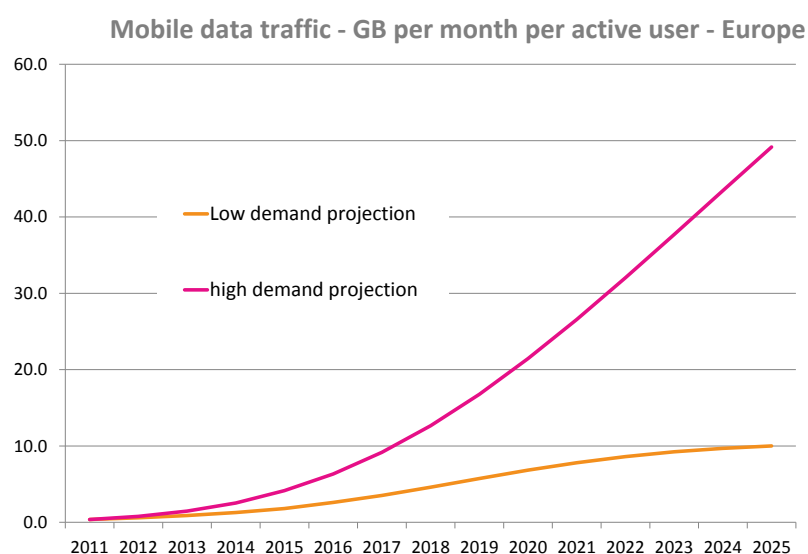
¹¹⁸ *Global Mobile Broadband Traffic Report*, Allot, H2 2010.

¹¹⁹ *The mobile traffic deluge*, Boshulte Schmee Group, 2011.

Finally, the PA Consulting report for Ofcom projected in early 2009 the mobile data traffic in order to assess the likelihood of a spectrum crunch in the UK. It estimated that UK mobile networks would carry between 0.06 and 0.4 PB of data in the busy hour by 2015. The PA Consulting estimates, while not especially useful for our study, do illustrate the wide range in magnitude in predictions of future demand for mobile broadband.

Based on Figure A1, we have made two demand projections for mobile data in Europe – a high demand projection using the Cisco forecasts and a low demand projection using the ABI forecasts. These are shown in Figure A2 with projections to 2025 based on a best fit to a Gompertz curve.

Figure A2: Demand for mobile data in Europe.

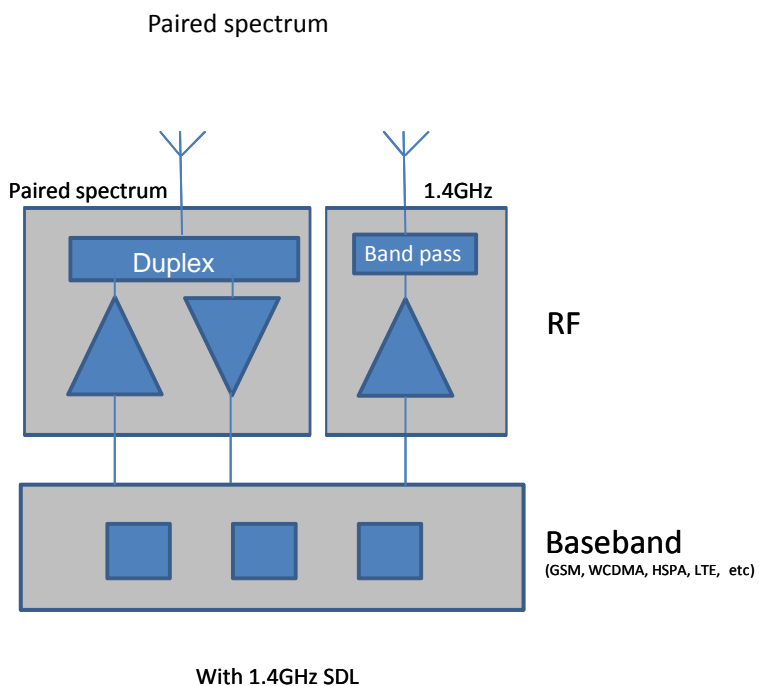
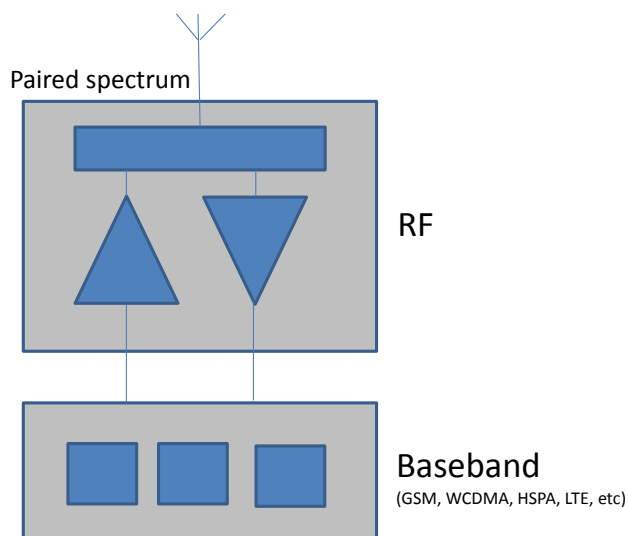


We have modelled only the low projection of demand for mobile data in our estimates of the economic benefits of SDL at 1.4 GHz.

Appendix B: Changes required to base stations and devices¹²⁰

B.1 Base Station

The diagrams below show current and possible 1.4 GHz SDL implementations:



¹²⁰ This Appendix has been informed by discussions with Ericsson and Qualcomm.

Ericsson believes very little modification would be required to the baseband aspects to support 1.4 GHz SDL. Radio frequency (RF) aspects would need development: the main additions would be another RF power amplifier (PA) and band pass filter and possibly an additional antenna. Concerning the 1.4 GHz SDL radio implementation there are products in the Ericsson portfolio (developed for the Japanese market) that operate close to 1.4 GHz SDL and thus with some minor modification, the PA can be adapted to characteristics required for this application. The mask required by Maastricht for operating in 1.4 GHz band may present a challenge, and would require the development of a new band pass filter, with considerably tighter specification than most current cellular applications. The level of complexity and the cost of the required filters will depend on the technical conditions that may be defined by CEPT and the application of the Maastricht mask.

The availability of base station equipment supporting the proposed spectrum depends on the harmonisation of 1.4 GHz SDL by ECC and consequently standardization activities in 3GPP (Third Generation Project). Since the 3GPP Release 9, there is support for aggregation between different bands for HSPA (multi-carrier features) and for LTE Release 10 contains similar features (Intra band carrier aggregation). Adding a new combination is a straight forward task for 3GPP to standardise and thus no significant problem is foreseen.

Base station fabrication: There are few problems foreseen and if there are any challenges these are likely to be with antennas. Adding several new antennas on a large multi-sector site with a congested mast could be an issue but this problem is already faced on a daily basis. More likely to present a possible problem is the addition of another antenna into a small base station antenna system module but as the number of bands increases this is an issue that is often addressed and handled. However, none of these issues is likely to be a show stopper.

B.2 Devices

Device chipset and RF front-end solutions in devices need to be developed to support operation with Supplemental Downlink in 1.4 GHz band.

At the chipset level (baseband and RF transceiver) and taking the example for HSPA+, a solution capable of supplemental downlink entirely leverages the architecture of a Release 9 dual-carrier/dual-band capable chipset. RFIC transceivers from Qualcomm already in production (such as RTR8600) have capability to tune into the L-band, including the 1452-1492 MHz frequency range, and such capability is retained in the next generation RFICs currently in the design phase.

Assuming, as expected, the device uses a shared antenna across bands (two, to provide receive diversity), the RF front-end will need an additional diplexer and a band-pass SAW filter. Results of simulations conducted by suppliers confirm feasibility of manufacturing a 2100 MHz/1.4 GHz band diplexer with existing technology that has enough isolation (>25dB) between the high and low frequency ports and low insertion loss (< 0.5dB), that is, similar performance of those achieved by 2100 MHz/900 MHz diplexers. Diplexers and Rx filters come in small packages, 2.0x1.25mm and 1.4x1.1mm, respectively, using current technology, hence have limited impact on PCB real estate. For comparison purposes, note that support for an additional RF band requires a duplexer (2.5x2.0mms) a PA (3.0x3.0mms), a Tx filter (1.4x1.1mm package), and a Rx filter (1.4x1.1mm) for the diversity chain; hence it has larger impact on PCB real estate than adding support for 1.4 GHz band supplemental channel.

The timeline for availability of devices with supplemental downlink channel capability will depend primarily on the adoption by the ECC of a harmonized band plan and completion of 3GPP standardization activity and availability of dual-carrier dual-band capable chipsets. For example for HSPA+:

- If a harmonized ECC band plan for the 1.4 GHz band was adopted in Europe by the end of 2012 then it would need to be submitted to 3GPP for inclusion in the standard. Note that RF band support is a release-independent feature in 3GPP, hence the 1.4 GHz band can be supported by Release 9 devices although 1.4 GHz band numerology and conformance test specifications will be part of a later 3GPP release.
- Release 9 chipset solutions from Qualcomm are currently in the planning stage and chipsets are expected to become available to enable commercial devices in 2014. Adding requirements for a 1.4 GHz band supplemental downlink does not impact the timeline for availability of Release 9 dual-band/dual-carrier capable chipsets, since a solution capable of the former entirely leverages the architecture of the latter.

Appendix C: The avoided cost model

C.1 Basic approach

To estimate the costs avoided in urban areas as a result of deploying a 1.4 GHz SDL we:

- Divide the European Economic Area into five geotypes – hotspot, dense urban, urban, suburban and rural areas and model the costs avoided per square kilometre for each geotype. Assumptions about the characteristics and quantity of each geotype are set out in Table C1.
- Make projections of growth in mobile data traffic per head of population in the EEA. See Figure A2.
- Calculate the busy hour downlink traffic demand per square kilometre for each of the three projections, after adjusting for effective utilisation of the downlink.

Table C1: The geotypes of our model.

Geotype	Hotspot	Dense urban	Urban	Suburban	Rural
Active population per sq km	300,000	45,000	16,000	2,000	30
Existing BTS per sq km	78	20	6	1.8	0.15
Area in sq km in Europe	141	454	8854	288225	4427325

Sources: Analysys Mason, Qualcomm, Gridded Population of World database

Then for each geotype we:

- Calculate busy hour downlink capacity per square kilometre, given projections of spectrum efficiency, likely spectrum supply, practical network utilisation levels and operational inefficiencies.
- Calculate the additional downlink capacity which is required per square kilometre to meet demand.
- Calculate the additional network equipment which is required per square kilometre to provide this additional capacity in 2018¹²¹. There are two options:
 - Option 1: no SDL. Here we calculate the number of additional base stations required without an SDL upgrade.
 - Option 2: SDL available. We calculate the number of SDL upgrades to existing base stations plus the number of additional enhanced base stations¹²².

¹²¹ We assume that substantial quantities of 3.4-3.6 GHz and/or 2.3 GHz spectrum are available for mobile broadband (LTE) deployment to provide additional urban capacity across Europe by 2019.

¹²² Enhanced with the additional capacity provided by the SDL.

Figure C1 shows the difference between the two options in the number of additional base stations required to meet demand, using the low demand projection and the assumption that users enjoy long term downlink speeds of 12.5 Mbps.

- Estimate the net present value¹²³ of costs of an SDL upgrade and of an additional base station with the five standard spectrum bands.
- Estimate the net present value of cost avoided as a result of moving from Option 1 to Option 2

We then multiply the net present value of the cost avoided per square kilometre for each geotype by the area of each geotype in the EEA to get the total avoided cost. Table C2 provides the resulting estimates for the high demand projections, again in the situation when users enjoy long term downlink speeds of 12.5 Mbps.

Figure C1: The impact of the SDL upgrade on the number of base stations required.

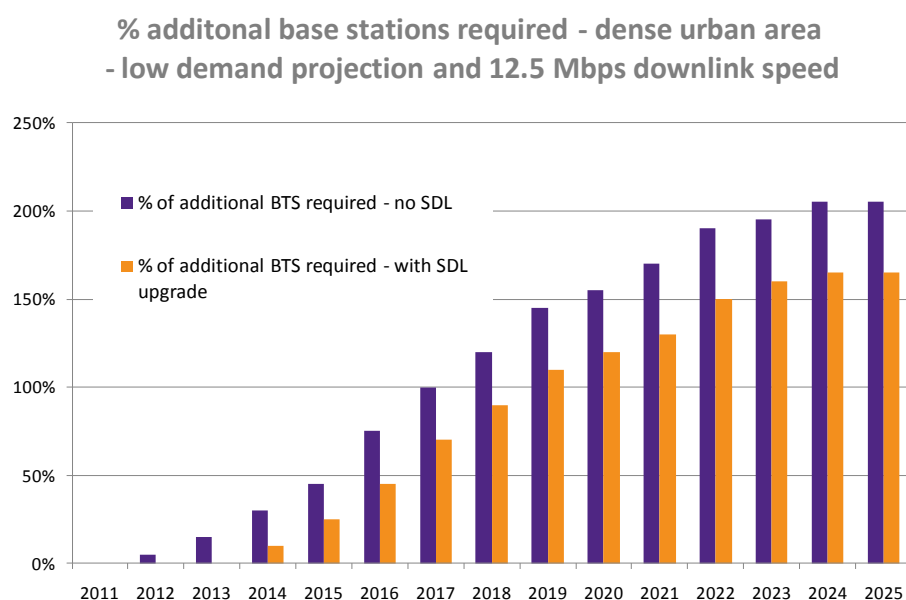


Table C2: The NPV of the benefit of additional urban and suburban capacity¹²⁴.

Geotype	Hotspot	dense urban	urban	suburban	rural	total
Existing BTS per sq km	78	20	6	1.8	0.15	
% additional BTS needed per sq km - no SDL - 2018	274%	120%	167%	8%	0%	
% additional BTS needed per sq km - with SDL - 2018	219%	90%	133%	0%	0%	
% of BTS with SDL upgrade - 2018	100%	100%	100%	46%	0%	
New BTS avoided with SDL	43.0	6.0	2.0	0.1	0.0	
NPC per BTS (€000) - 10 year life	624	624	624	624	624	

¹²³ Over a 10 year period with a 10% discount rate.

¹²⁴ Under Demand Scenario 1 with the low demand projection and long term downlink speeds of 12.5 Mbps.

Geotype	Hotspot	dense urban	urban	suburban	rural	total
NPC of an SDL upgrade (€000) - 10 year life	54	54	54	54	54	
Net avoided cost per sq km (€000)	22620	2664	924	45	0	
Area of EEA in sq km	141	454	8854	288225	4427325	
Total net avoided cost for EEA (€m)	3198	1210	8182	12990	0	25579

C.2 Key assumptions

We set out the key assumptions we use in carrying out these calculations in Table C3.

Table C3: The key assumptions in estimating the avoided costs.

Parameter	Value	Source
% of daily traffic in the busy hour	10%	Plum work for GSMA
Effective utilisation of traffic in the downlink	60%	Plum estimate
Paired spectrum available for data (MHz - downlink only)		See Table C4
2010	60	
2015	200	
2020	245	
2025	270	
Spectrum efficiency for data (bps per Hz)		FCC National Broadband Plan. Qualcomm, Analysys Mason
2010	0.35	
2015	0.65	
2020	1.15	
2025	1.25	
Percentage of traffic in the downlink		See Section 3
2010	85%	
2015	89%	
2020	90%	
2025	90%	
Utilisation of theoretical network capacity by individual operators	80%	Plum assumption
Utilisation of network capacity to achieve:		Plum assumption
5Mbps downlink speeds by 2025	74%	
12.5 Mbps downlink speeds by 2025	37%	
Costs (€000)		Estimates used in previous Plum studies
establishing a new base station	150	
equipping with five spectrum bands	150	
upgrade for SDL	30	
site rental per year	30	
maintenance as a proportion of capex	12%	
Discount rate per annum for net present value	10% pa ¹²⁵	Plum assumption
Lifetime of equipment	10 years	Plum assumption

¹²⁵ We have used a commercial discount rate of 10% pa rather than a social discount rate of (say) 4% pa to calculate the NPV of net benefits. This, together with the assumption of an economic life of 10 years for additional equipment, means that our estimates of the benefits of avoided costs are likely to be conservative

Table C4: Paired spectrum supply for data – downlink only – all operators.

Band (MHz)	2010	2015	2020	2025
800	0	30	30	30
900	0	20	35	35
1800	0	20	50	75
2100	60	60	60	60
2600	0	70	70	70
Total	60 ¹²⁶	200	245	270

C.3 The cost of implementing the SDL

We estimate that:

- The net present cost of implementing a 1.4 GHz SDL on an existing BTS is €54,000 (over a ten-year period at a discount rate of 10%).
- The number of existing BTS per square kilometre in each geotype is as specified in Table C5.
- The total cost of the SDL upgrade is as calculated in Table C5.

Table C5: The net present cost of implementing the SDL upgrade¹²⁷.

	hotspot	dense urban	urban	suburban	rural	total
Existing BTS per sq km	78	20	6	1.8	0.15	
NPC of an SDL upgrade (€000) - 10 year life	54	54	54	54	54	
Area of EEA in sq km	141	454	8854	288225	4427325	
% of BTS with SDL upgrade - 2018	100%	100%	100%	46%	0%	
Cost of SDL upgrade (€m)	595	491	2869	12866	0	16820

¹²⁶ Rising to 120 MHz in 2011 and 2012, 180 MHz in 2013 and 190 MHz in 2014 in a typical European country.

¹²⁷ Under Demand Scenario 1 with the low demand projection and long term downlink speeds of 12.5 Mbps.

Appendix D: Spectrum valuation literature

Thomas Hazlett and Robert Munoz, “A Welfare analysis of Spectrum Allocation Policies”, January 2008.

This paper undertakes an econometric analysis of market outcomes and auction approaches for mobile spectrum to assess the social welfare implications of efficient spectrum allocation versus revenue raised from auction proceeds. The central idea is that the benefits of efficient allocation of spectrum vastly exceed the benefits of revenue raised from an auction. The data is derived from 29 countries, 19 of which use auctions, covering the period between 1999 and 2003.

The study finds that larger quantities of spectrum and more intense competitiveness (as measured by an HHI index) are strongly associated with lower prices. The study estimates the elasticity of demand for mobile services as -0.7999, which they note is lower than other elasticities reported for US market (-1.12 to -1.29), but similar to those reported elsewhere (Hausman and Sidak estimate elasticity of Irish mobile market as -0.84).

The study determines estimates the impact of spectrum on price and then these results are used to derive the impact of allocating an additional 20, 80, 140 and 200 MHz of spectrum, including the scope for spectrum to enable more competition.

They estimate that:

- the UK 3G auction suggests that \$35 billion of consumer surplus gains from the auction of 140 MHz of spectrum in 2001 (compared with total auction proceeds of \$34 billion).
- An increase of 60 MHz of spectrum in the US would generate \$8.24 billion per annum, compare with a licence value of \$9.1 billion.
- Allocation of 30 MHz of PCS C-block spectrum (which was allocated to uneconomic bidders) to market participants would have generate consumer surplus of \$46 billion in period of 1997 to 2003.
- Total US wireless phone data yields annual consumer surplus of at least \$150 billion and total revenue from selling licences is \$25 billion. On this basis, they state that the ratio of consumer surplus to producer surplus (as measured by spectrum values) is greater than 10:1.

Analysys Mason, “Exploiting the digital dividend – a European approach“

Summaries previous country studies as follows. Private value refers to sum of consumer and producer surplus.

- Analysys Mason/DotEcon/Aegis for Ofcom, 2006
 - Estimates private value of digital dividend spectrum for wireless broadband as £2.5 billion (discounted value over 20 years) for up to 56 MHz spectrum. Also estimates value of using spectrum for broadcast mobile TV as between £0.3 to 3.0 billion. However, they note this study was prepared before use of 790 – 862 MHz band for wireless broadband was proposed and may understate benefits.
- Analysys Mason, Hogan and Hartson for ARCEP

- Estimates private value of allocating 72 MHz to wireless broadband services as €26.2 billion (discounted value over 12 years). Estimates value of using digital dividend to create one broadcast mobile TV multiplex as €2.0 billion.
- Analysys Mason for Dutch Ministry of economic affairs
 - Estimates private value of allocating 72 MHz digital dividend to wireless broadband as €0.5 billion to €6.9 billion (discounted value over 22 years). Broadcast mobile TV has value of €0.2 to €0.9 billion.
- Spectrum Value Partners for Ericsson, Nokia, Orange, Telefonica and Vodafone.
 - Estimated private value for Europe based on three representative countries (Italy, Netherlands, and Slovakia) of releasing 80 MHz of spectrum as €111 billion to €180 billion.
- SCF Study for Deutsche Telecom – The Mobile Provide, 2007.
 - Compared value of two scenarios, (i) where 40 MHz of digital dividend is allocated to wireless broadband and (ii) where 240 MHz is allocated to mobile broadband. They estimate that option (ii) would generate €463 billion of direct industrial output compared €101 billion under option (i).

Based on these studies, Analysys estimated the private value of allocating 72 MHz to wireless broadband as €50 billion to €190 billion and for broadcast mobile TV as between €2.5 billion and €25 billion.

Analysys Mason estimates the economic value of the 790-862 MHz digital dividend spectrum under a number of scenarios. They count the incremental benefits of:

- Not preventing use of 790 to 862 MHz spectrum in any member state (this appears to be value of wireless broadband based on per person value of wireless broadband).
- Increased value from economies of scale and roaming.
- Greater certainty for manufacturing.
- Additional benefits from spectrum outside 790 to 862 MHz range.

They count the following costs:

- Loss of DTT multiplexes.
- Upgrade and change to broadcasting networks.
- Consumer switching costs from change in broadcast platform.
- Development of alternative free to air platform.
- Consumer switching costs from alternative free to air platform.

The benefits are estimated as follows:

- They estimate the NPV over 15 years of using the spectrum for wireless broadband of €127 to €312 on a per person basis, depending on whether demand is low or high. This benefit includes benefit of increased capacity, ability to provide coverage in rural areas and benefits of increased competition.
- Economies of scale are to be worth 1.5% of handset and network equipment costs for countries that would have adopted digital dividend (absent EU decision).

- Greater certainty for manufacturers is estimated to bring forward launch by one year and increases value by 10%.

The net benefits under a range of scenarios are between €0 and €95 billion, with most estimates in the range €44 to €75 billion (including all costs relevant to digital switchover).

Europe Economics, Economic Value of Radio Spectrum for Ofcom, 2006.

EE estimate net economic benefit of mobile as £22 billion and total consumer surplus as £18.9 billion and producer surplus £2.8 billion. They estimate consumer surplus using a number of methods:

- Updating earlier estimates for inflation and change in value of mobile market.
- Using consumer surplus formula of $CS=PS/2e$. They use price elasticities of -0.47 (Teligen 2000) and -0.3 (Ofcom, MTR).
- Using WTP data and prices to estimate consumer surplus.

Appendix E: Value of spectrum

Firstly, we estimate the cost of 1.4 GHz spectrum based on precedent from auctions and reserve prices set by regulators for forthcoming auctions.

E.1 Auction values for frequencies below 1 GHz

The value of the sub 1 GHz spectrum for mobile services will be an upper bound for the value of the 1.4 GHz spectrum, noting that the propagation characteristics of an SDL at 1.4 GHz are likely to be similar to those of the 800 MHz and 900 MHz mobile bands (see Section 3). There have been relatively few recent auction of sub 1 GHz spectrum which might provide guidance on the value of low frequency spectrum for mobile broadband. Auctions of 900 MHz for mobile voice services are unlikely to provide a reasonable guide to the value of spectrum for mobile broadband and therefore we have not included them in our analysis. Since 2008, there have been auctions for sub 1 GHz spectrum in USA, Germany, Sweden, Denmark and Hong Kong. We have excluded the auction result for Denmark as it was for a small amount of additional 900 MHz spectrum for an existing operator and unlikely to be representative of the value of spectrum for mobile multimedia. The results of these auctions are set out in the Table E-1 below.

Table E-1: Recent sub 1 GHz auction results.

Country	Date	Frequency band	Amount of spectrum	Revenue	Exchange rate at time	€/MHz/Pop
Germany	May 2010	800MHz	60	€3,576,475,000	1.2652	0.7260
Sweden	May 2011	800MHz	60	SEK2,054,000,000	0.11370	0.4133
Hong Kong	March 2011	832.5-837.5 MHz paired with 877.5-882.5 MHz; 885-890 MHz paired with 930-935 MHz	20	HKD1,952,000,000	0.12855	1.2786
Hong Kong	June 2010	678-686MHz	8	HKD175,000,000	0.12855	0.3260
USA	March 2008	696-806MHz	62	USD19,120,378,000	1	0.7108

Source: Plum

The Table E-1 illustrates the wide ranging outcomes from auction results. We propose to give the most weight to the outcomes of 800 MHz auction results in USA, Sweden and Germany, as they were for significant amounts of spectrum and therefore are more likely to reflect the actual value of the spectrum to the sector. The results from Hong Kong may have been affected by the relatively small amount of spectrum sold and that the spectrum is to be used to provide mobile TV.

The outcomes of the US, German and Swedish auctions suggest that sub 1 GHz frequency may have a value of between €0.40 to 0.70 per MHz per pop.

E.2 Other auction values

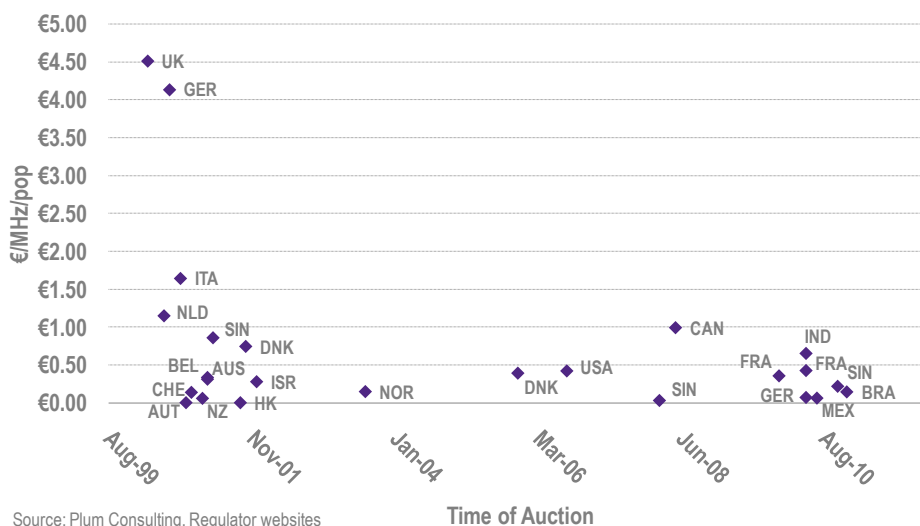
There have been a significant number of higher frequency auctions at 1800/2100/2600 MHz. The results from the auctions are summarised in the figures below.

Value/MHz/pop of international 1800/1900MHz auctions in EUR



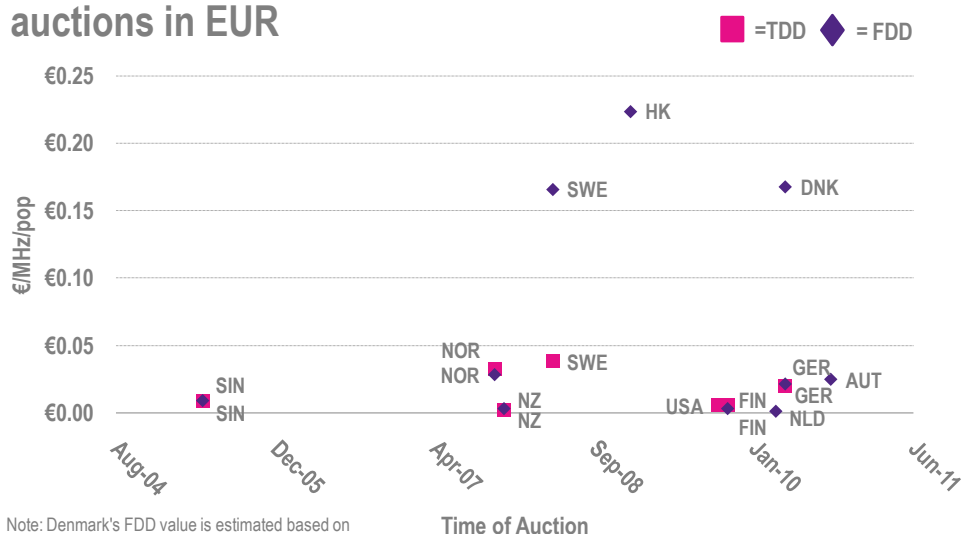
Source: Plum Consulting, Regulator websites

Value/MHz/pop of international 2.1GHz auctions in EUR



Source: Plum Consulting, Regulator websites

Value/MHz/pop of international 2.5GHz auctions in EUR



Note: Denmark's FDD value is estimated based on aggregate auction results

Source: Plum Consulting, Regulator websites

The auction outcomes indicate a broad dispersion of values for higher frequency spectrum and that while recent auction are lower than outcomes around 2000 that were inflated by the “dotcom boom”, there still remains a considerable divergence in values. However, it is clear that higher frequency spectrum has a much lower value than sub 1 GHz spectrum – possibly in the range of 1% to 10% of sub 1 GHz spectrum values.

E.3 Reserve prices

ComReg has set minimum or reserve prices for a forthcoming auction of 800 MHz and 900 MHz spectrum in Ireland based on a value of €0.56/MHz/pop^{128, 129}. ComReg proposes to set the minimum fee for 1800 MHz spectrum as 50% of this value i.e. €0.28/MHz/pop. The reserve price for the 1800 MHz spectrum was based on a consultant's report which estimated the relative value of 1800 MHz spectrum to 800/900 MHz spectrum as between 45% to 60%¹³⁰.

In Portugal, the regulator has proposed the following reserve prices for forthcoming auctions.

¹²⁸ This is based, based on advice from a consultant who estimated value as between €0.40 to €0.58MHz/pop ComReg. 2010. “800,900 &1800Mhz spectrum release. 10/71.

http://www.comreg.ie/publications/800_mhz_900_mhz_and_1800_mhz_spectrum_release.583.103695.p.html ;

¹²⁹ Dotecon. 2010. “Award of 800MHz and 900MHz spectrum – update report on benchmarking”.

http://www.comreg.ie/publications/award_of_800_mhz_and_900_mhz_spectrum_-_update_report_on_benchmarking.583.103697.p.html

¹³⁰ ComReg. 2010. Inclusion of the 1800 MHz Band into the proposed joint award of 800 MHz and 900 MHz Spectrum. 10/105.

http://www.comreg.ie/publications/inclusion_of_the_1800_mhz_band_into_the_proposed_joint_award_of_800_mhz_and_900_mhz.583.103767.p.html

Table E-2: Proposed reserve prices for a forthcoming auction in Portugal.

Frequency band	€/MHz/pop
791-821 MHz to 832-862 MHz	0.5170
880-890 MHz to 925-935 MHz	0.2820
1710-1740 MHz to 1805-1835 MHz	0.0282
1900-1910 MHz	0.0188
2500-2570 MHz to 2620-2690 MHz	0.0282

Source: Anacom Draft Auction Regulations, March, 2011.

The reserve price for 800 MHz spectrum is similar to the ComReg reserve price and the reserve price for 900 MHz spectrum is somewhat lower, while higher frequency spectrum has a much lower reserve price, around 4% to 6% of that for the 800 MHz spectrum.

The reserve prices for the lower frequency spectrum are consistent with the range from the auction results, while the higher frequency spectrum is valued somewhat above many auction results in Ireland.

Glossary

1.4 GHz	1452-1492 MHz
1.5 GHz	European Parliament denomination of 1452-1492 MHz or 1.4 GHz
3G	Third-Generation Mobile Communications
3GPP	Third Generation Project Partnership
4G	Fourth-Generation Mobile Communications
ARCEP	Autorité de Régulation des Communications Électroniques et des Postes
ARPU	Average Revenue per User
BTS	Base Transceiver Station
BWA	Broadband Wireless Access
CEPT	European Conference of Postal and Telecommunications Administration
DAB	Digital Audio Broadcasting
DTT	Digital Terrestrial Television
ECA	European Common Allocation online database
ECC	Electronic Communications Committee
ETSI	European Telecommunications Standards Institute
EU	European Union
FCC	Federal Communications Commission
FDD	Frequency Division Duplex
FM PT 50	Project Team 50 of Working Group FM of the ECC
FS	Fixed Service
FSS	Fixed Satellite Service
GB	Giga Byte
GSMA	GSM Association
HHI	Herfindahl-Hirschman Index
HSPA+	High-Speed Packet Access. Evolution of the UMTS/WCDMA, Release 7 and beyond
IMT	International Mobile Telecommunications
ITU-RR	International Telecommunications Union's Radio Regulations
LTE	Long-Term Evolution
MBB	Mobile Broadband
NPV	Net Present Value
PA	Power Amplifier
PB	Peta Byte
PCS	Personal Communications Service
PMSE	Programme Making and Special Events
RF	Radio Frequency
RFIC	Radio Frequency Integrated Circuit
RSPP	Radio Spectrum Policy Programme
SAW	Surface Acoustic Wave
SDL	Supplemental Downlink
SIM	Subscriber Identity Module

TDD	Time Division Duplex
UGC	User-Generated Content
UHF	Ultra High Frequency
VHF	Very High Frequency
WRC	World Radiocommunications Conference