Annex A: Performance evolution of HSPA and LTE

1 Contents

In this Annex, some key contextual topics relating to network or radio access technology relevant to our response are outlined.

2 HSPA Roadmap

High Speed Packet Access "HSPA" has undergone a number of evolution steps since its introduction in 3GPP's Release 5 specifications to reach downlink data rates of up to 14.4 Mbps today (Release 6). Important for UK networks was the introduction in Release 6 of UMTS in 900 MHz, which allows HSPA and its evolutions to be operated in this low band spectrum. This has been very widely adopted in Europe, with extensive penetration of compatible devices into the customer base. The feature has exploited already by O2[1] (March 2011), and soon by Vodafone. UMTS was specified also for 1800 MHz but there has been no real interest in this technology in the industry so it has never been realised in practice.

There are many more feature evolutions specified in Releases 7 to 10[2] some of which are in trials or product development today. Many of the advanced features aimed at progressing LTE technology towards LTE-Advanced have now also been proposed for HSPA in Release 11 and beyond, and several approved as official work items within 3GPP[3].

Downlink peak data rates can be enhanced from 14.4 Mbps with the features[4] outlined in Table A1.

---

[1] http://mediacentre.o2.co.uk/Press-Releases/O2-first-to-switch-on-new-superfast-3G-900 MHz-network-2f8.aspx

[2] *3GPP Specification Releases up to Release 9 are complete. Release 10 is due to be complete in 2011, Release 11 by mid 2012. It takes approximately 18-24 months for commercial products to become available after specifications complete.*

[3] *Signals Ahead, Vol. 7, No. 15, March 2011.*

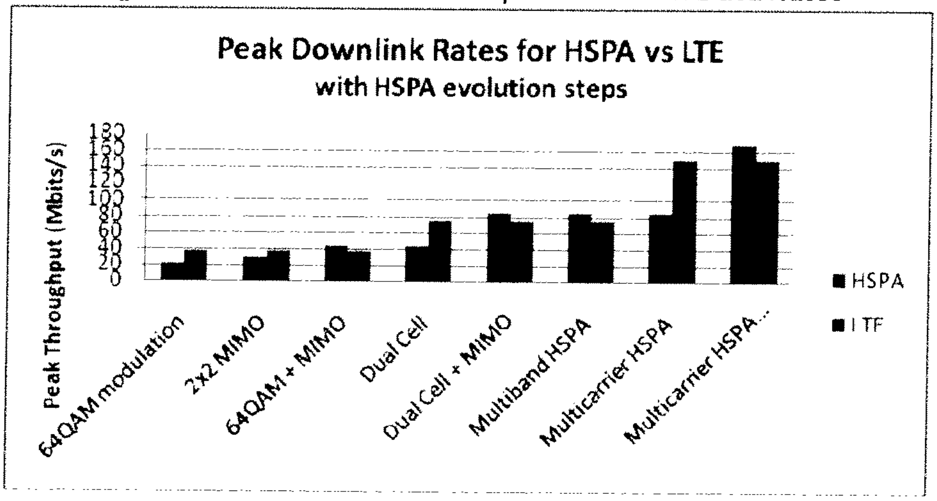
[4] *Source: 3GPP specifications.*

Table A1: HSDPA Key Evolution Steps

Feature	3GPP Release	Approximate Commercial Availability[5]
64QAM modulation	7	now
2x2 MIMO	7 & 8	now
64QAM + MIMO	7 & 8	now
Dual Cell	8	2011
Dual Cell + MIMO	9	2012
Multiband HSPA	9	2012
Multicarrier HSPA	10	2012

The peak data rates achieved by these evolutions are enabling HSPA to keep pace with LTE developments, within a very similar timeframe. Figure A1 illustrates the relative peak downlink data rates for HSPA with the corresponding LTE equivalent (2x2 MIMO in the same bandwidth).

Figure A1: HSDPA Evolution Steps vs LTE Peak Data Rates



MIMO has the advantage of providing the enhanced peak data rate on a single 2x5 MHz carrier, but provides the benefits only to users relatively close to the cell. Dual Cell requires two 2x5 MHz carriers, but provides improved experience to all users in the cell who have compatible devices. MIMO provides only modest spectrum efficiency gains (~10%)[6] and dual cell somewhat greater (~20%). Spectrum efficiency is a measure of cell capacity for a given bandwidth.

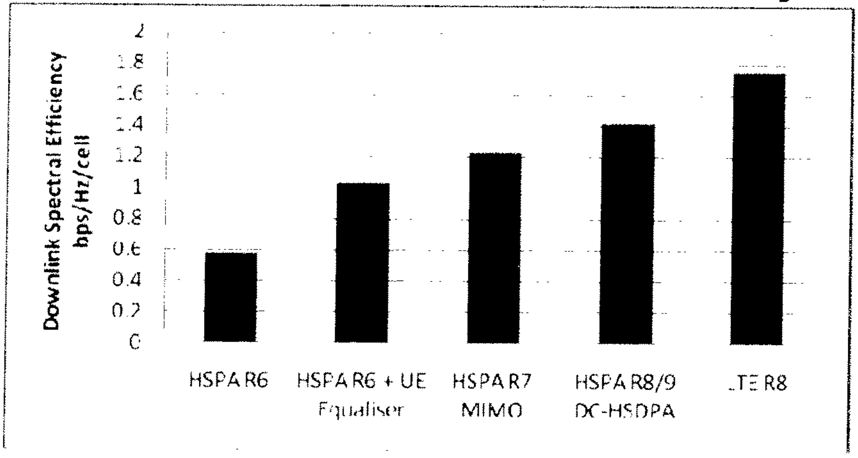
These features in particular bring the spectrum efficiency increasingly close to LTE with 2x2 MIMO, see Figure A2, and in current Release 11 specification work, yet more advanced features have been approved to extend further the peak data rate and spectrum efficiency, including 4x4 MIMO, to keep pace with more advanced LTE features.

---

[5] *Source: various vendor roadmaps*

[6] *H Holma & A Toskala, "LTE for UMTS Evolution to LTE-Advanced", table 17.1, p525.*

Figure A2: HSDPA Evolution vs LTE – Spectrum Efficiency[7]



Interactivity of HSPA receives a boost in Release 7 and 8 with Enhanced Forward (downlink) and Random (uplink) Access Channels respectively.

Using just the Release 8 features alone (already commercially available), Vodafone and O2 are able to provide a very compelling data service with high performance and significant capacity across the whole footprint using UMTS on 2x10 MHz of 900 MHz spectrum, better than is, or will be, possible with 2x5 MHz of LTE800.

This is achieved with a simple, much lower cost and risk evolution path compared to LTE800 introduction, as it is based on fully operational 3G technology and does not require new access technology in devices, avoiding the cost premium associated with new technologies such as LTE. Freeing an additional 2x5 MHz of 900 MHz band should be possible in the next 2-3 years as 3G device penetration grows further into the installed base.

3 LTE Progress

LTE network launches, commitments and trials are announced frequently, providing increasing evidence of a strong move towards the realisation of this technology to provide enhanced services to customers. 20 commercial networks have been launched in 14 countries.[8] *Typically the early launches are in the 2.6 MHz band.*

Due to the variety of spectrum holdings across different countries and operators, there is interest in LTE in many bands. Network equipment is typically available for all key European bands including 900 MHz, largely due to the fact that it is possible to create common radio frequency units across different access technologies, and the technology itself is defined mainly in the signal processing functions, the vast majority of which are band independent.

LTE800 has gained some attention in the last year or so due to European auctions of this band, and some early deployments (e.g. in Germany), especially for rural broadband services. Strong growth in the device ranges will require launches for mobile services in several countries, which should start to emerge in 2012-2015. In the UK a meaningful launch will only be possible in 2013.

---

[7] *Reproduced from H Holma & A Toskala, "LTE for UMTS Evolution to LTE-Advanced", fig 10.25, P289.*

[8] *GSA White Paper "Evolution to LTE Report", 11 May 2011.*

This is already 2 years behind UMTS900 launch in UK. With the relatively low multi-national demand for LTE800 handsets compared to UMTS900, in practice the difference in effective operation is closer to 5 years. UMTS900 is also unencumbered by major interference challenges such as those anticipated for LTE800.

LTE900 is therefore a relatively simple upgrade from UMTS900 or refreshed GSM900 equipment. Plans for LTE900 deployment have already been announced by Net4Mobility[9] in Sweden. Ofcom recognises[10] that it is likely to be possible to use the 900 MHz and 1800 MHz bands for LTE on a broadly similar timescale to 800 MHz and 2.6 GHz.

Vodafone and O2 have the option to refarm their 900 MHz band to LTE, either now or in a second step as part of a transition story from UMTS900 to LTE900. Everything Everywhere clearly does not have this option.

4 Performance Aspects of HSPA and LTE

The principal benefit of the higher data rates achievable with 2x10 MHz and 2x20 MHz LTE is not the higher peak data rate (e.g. over 100 Mbps) but the typical data rates experienced by users. These must be sufficient to meet the great majority of today's applications, especially video. Greater typical user data rates are perceived by users as improved reliability of the data connection, and therefore a key factor in customer satisfaction and therefore competitiveness of an operator.

Typical user data rates that can be achieved with LTE are linked directly to the operating bandwidth for a given load level. Thus 2x10 MHz of spectrum can deliver a typical user experience at least double that achievable with 2x5 MHz. This is confirmed by Ofcom in the Consultation, which defines the relationship between bandwidth and single user throughput as linear,[11] with the modifying comment[12] indicating that this relationship needs to take into account different overheads of 2x5, 2x10, 2x 20 MHz bandwidths. This improving trend in overheads with bandwidth[13] tends to make double bandwidths slightly better than double the single user throughput. Figure A3 shows the resulting relationship between single user throughput and bandwidth for three example locations in the cell: towards the cell edge, within the cell and well within the cell.

---

[9] *A joint venture between Telenor and Tele2:* http://www.google.co.uk/url?sa=t&source=web&cd=5&ved=0CDYQFjAE&url=http%3A%2F%2Fwww.3gamericas.org%2Fdocuments%2FGlobal%2520Status%2520Update%2520May%252027%25202010.pdf&ei=i1zGTcPWCI-KhQfnkMiABA&usg=AFQjCNFPiozm5EiJnYZut4ulzim8kQrm0g

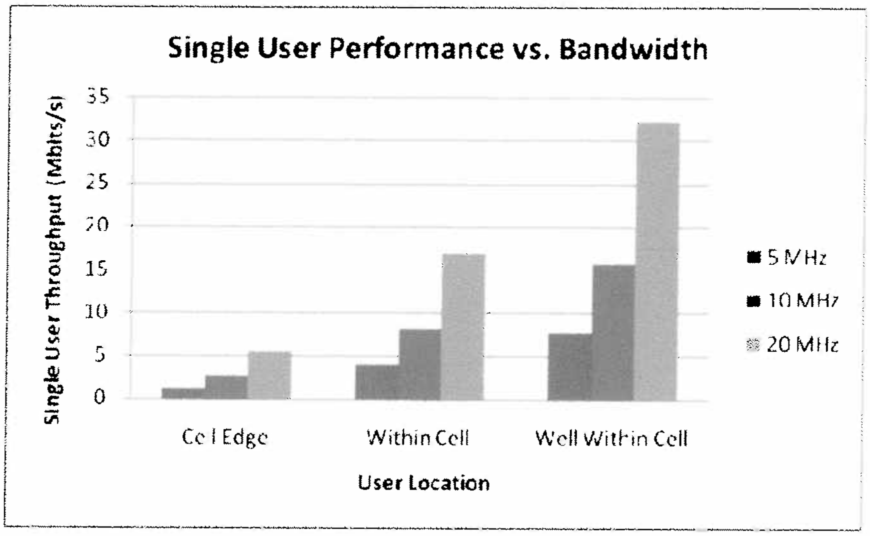
[10] *Paragraph 5.88*

[11] *Equation (12) in Section A8.40 shows a fixed relationship between throughput (bps) and bandwidth (Hz) for a given SINR (signal to interference-plus-noise ratio).*

[12] *Paragraph A8.46*

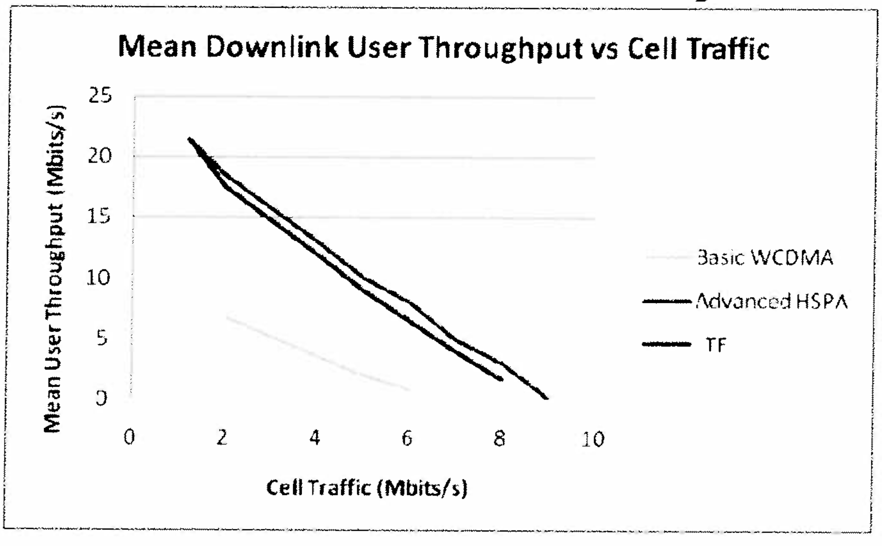
[13] *H Holma & A Toskala, "LTE for UMTS Evolution to LTE-Advanced", fig 10.22, p286.*

Figure A3: Single User Performance vs. Bandwidth



The typical user data rates experienced by users are also dependent on the traffic load in the cell (Note this is different to the network load described in Annex 7 of the Consultation which refers to load in other cells. Here we are referring to the load created by multiple users within one cell). As the network becomes increasingly loaded, an individual user's typical user data rate reduces. This relationship is illustrated in Figure A4 below.

Figure A4: Mean Single User Performance vs. Loading within Cell[14]



This illustrates further how close the performance in terms of typical user experience is expected to be for advanced HSPA and LTE, as well as in terms of peak throughput and spectrum efficiency described earlier in this section.

---

[14] *Reproduced from "3G Evolution: HSPA and LTE for Mobile Broadband" by Dahlman, Parkvall, Skold & Beming, Fig 23.3.*

5 Voice on LTE

Everything Everywhere and H3G are in a unique position in Europe in that they do not have access to low frequency spectrum with which to provide a voice solution to reach deep indoors from a practical deployment of outdoor macrocellular sites. It is estimated that access to low frequency spectrum will provide access to [redacted] locations for voice.

With access to 800 MHz spectrum, high frequency operators will only be able to offer voice service to those users who in deep indoor locations when there is a native voice solution on LTE, the timing of which is highly uncertain. Thus it will only be after that point in time that they can begin to address the competitive disparity on voice with LTE800. 900 MHz incumbent operators are able to address these users already today with GSM900 and in some areas UMTS900, with full service capability and full mobility between radio access technology layers.

The industry is firmly behind the use of IMS to deliver Voice over LTE "VoLTE." Although early steps have been taken with VoLTE on a very limited scale and with very limited functionality in some countries (e.g. Verizon in 2011), it is not expected that a complete integrated end to end solution acceptable to customers - with full service capability and essential mobility between radio access technology layers (e.g. handover to/from 3G) -will be achieved much before 2014. Even then it will only be possible on compatible handsets, but multi-operator influence should seek to maximise this level of compatibility in this timeframe.

Until VoLTE is fully available, operators launching LTE smartphones in any band will have to rely upon the Circuit Switched Fallback "CSFB" feature from the 3GPP standard. For operators with 900 MHz incumbents, this is not problematic as circuit switched voice (on GSM900 or UMTS900) will be available across their full LTE coverage area, regardless of spectrum band (800 MHz or 2.6 GHz). However high frequency operators with access only to 800 MHz will not be able to rely on this due to the reduced coverage footprint of their high frequency signals.

When a native voice solution is available on LTE800 and LTE800 smartphones have achieved a reasonable penetration, it will naturally attract a loading of voice calls from those users for whom only the 800 MHz signal is visible due to its propagation characteristics. This will be especially marked for Everything Everywhere, due to the size of its retail and wholesale customer base. It will not be possible to steer these users onto another layer (e.g. UMTS2100 or GSM1800) as those other layers may not be available in many locations. This means that part of this carrier's capacity will be consumed by voice traffic, diluting (in some cases) significantly the capacity available for data services. For 900 MHz incumbents, there are options of GSM900 and UMTS900 to serve these users, leaving 800 MHz unencumbered for an enhanced data service experience.

Low frequency mobile spectrum continues to be an essential enabler for long term provision of voice services to deep indoor users across wide areas. Indoor radiating solutions such as femtocell or WiFi do not bring satisfactory solutions for the following reasons.

Femtocell technology is available for addressing specific in-building coverage holes, but is by no means cost effective for addressing a widespread coverage challenge. WiFi provides a useful complement for customers' data service, but is not able to provide a satisfactory solution for voice for the vast majority of customers. Two key approaches for voice over WiFi exist today – UMA (Unlicenced Mobile Access) and over-the-top voice over IP. UMA technology is available only to a limited range of devices, and worldwide support for this technology is not strong enough to promote significant further penetration. The customer experience of over-the-top voice over IP service would be highly variable and would not be regarded as acceptable to many customers.

Annex C: Cornish Trial of Rural Broadband Not-spots

1 Contents

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

9 *Press Release*

BT wholesale

everything everywhere

Everything Everywhere and BT Wholesale to deliver the UK's first live customer trial of 4G high speed broadband technology

- Trial to showcase the benefits and potential of 4G LTE[1] mobile technology for customers
- The collaboration will see mobile and fixed broadband coming together for the first time in the UK
- The field trial will be launched in Cornwall, and will be the first of its kind in the UK to involve customers

May 25th, 2011. United Kingdom. Everything Everywhere and BT Wholesale have today announced a collaboration that will see the first live trial of next generation 4G LTE[1] high speed broadband to customers. The live proof of concept trial is the first of its kind in the UK and will see the two companies sharing their fixed telecommunications and mobile technology to provide high speed wireless broadband to customers in rural Cornwall.

An initial test at BT's laboratories at Adastral Park in Suffolk is already underway, with the field trial set to test realistic 4G broadband broadband data speeds outside of laboratory conditions. The field trial will start this September and run to early next year, involving up to 100 mobile and 100 fixed line customers living around the St Newlyn East area of South Newquay, Cornwall. Both the laboratory and live field phases will test the application of 4G LTE as a shared fixed and mobile platform.

The field trial will utilise 2 x 10MHz of test 800MHz spectrum and will test its capability as a compelling and long term complementary solution to fixed broadband technology for customers who currently get low speeds or are unable to get broadband altogether. These customers are typically in rural areas of the country, which can be extremely difficult to reach with fixed broadband technology.
The trial will take place at test sites South of Newquay in Cornwall providing a combined coverage area of 25 square kilometres, with approximately 700 premises which have no or limited access to broadband

services today. Everything Everywhere will also look to test 4G enabled mobile handsets and broadband dongles as part of the trial.

Residents in the St Newlyn East and surrounding area who wish to learn more or who may want to participate in the trial can register their interest at www.4Gwirelessbroadbandtrial.co.uk. The trial will be free of charge to all triallists, and is being implemented with support from technology partners Nokia Siemens Networks and Huawei. The Cornwall Development Company is also supporting the trial.

Tom Alexander, CEO, Everything Everywhere, said: "Our ambition is to have the best 4G network and be pioneers in enabling Britain's superfast wireless future .

"We strongly believe that, by sharing our network and mobile assets in this way, we can make a valuable contribution to the economics of rural broadband services. Our work with BT is providing a test bed for new technologies such as 4G LTE which, with the correct allocation of sub 1GHz spectrum from the Government, has the potential to make a real impact on the way in which we communicate in the future. The government has previously stated its desire for the UK to have the best in class superfast broadband network in Europe by 2015, and we hope to help this vision become a reality."

Sally Davis, CEO of BT Wholesale said: "BT is committed to bringing the highest speed broadband to everyone in the UK, whether that's over fibre, copper or airwaves. This is a great mixed economy example of innovation and collaboration by two organisations pushing the boundaries of technology for the benefit of customers. The expectation of what we will learn is truly exciting, as much for the customers who are unable to get a broadband service in a number of rural communities across the country."

- ends -

Notes to editors

LTE, which stands for Long Term Evolution technology is a fourth-generation (4G) telecommunication technology that can reach download speeds of more than 100 megabits per second

Contacts:

Everything Everywhere Press office:
Everything.everywhere@golinharris.com or 0870 373 1500

BT Press Office

020 7356 5369. From outside the UK dial + 44 20 7356 5369. All news releases can be accessed at our web site: http://www.btplc.com/News

About Everything Everywhere

Everything Everywhere Limited is the company running two of the UK's most famous brands – T-Mobile (UK) and Orange (UK).

Owned jointly by Deutsche Telekom and France Telecom respectively, Everything Everywhere Limited is the UK's biggest communications company, with a combined customer base of almost 28 million people and more than 720 retail stores across the country. Everything Everywhere Limited plans to transform the industry by giving customers instant access to everything everywhere, offering the best value, best choice and best network experience in the country.

About BT

BT is one of the world's leading providers of communications solutions and services operating in more than 170 countries. Its principal activities include the provision of networked IT services globally; local, national and international telecommunications services to our customers for use at home, at work and on the move; broadband and internet products and services and converged fixed/mobile products and services. BT consists principally of four lines of business: BT Global Services, Openreach, BT Retail and BT Wholesale.
In the year ended 31 March 2011, BT Group's revenue was £20,076 million.

British Telecommunications plc (BT) is a wholly-owned subsidiary of BT Group plc and encompasses virtually all businesses and assets of the BT Group. BT Group plc is listed on stock exchanges in London and New York.
For more information, visit www.bt.com/aboutbt

[redacted]

Annex D: Analysis of Total Spectrum Cap Switching Flexibility

1 Contents

1. Summary

- *Compare the same package for all four MNOs: 2x10 MHz of 800 MHz and 2x20 MHz of 2.6 GHz.*
- *Price differential between 800 MHz and 2.6 GHz auction may develop throughout the primary rounds.*
- *Under a 2x105 MHz cap:*
  - *Vodafone, O2 and H3G would be able to switch one 800MHz lot to three 2.6GHz lots, maintain eligibility and switch back to 800MHz at a later point. (H3G can switch a second lot too).*
  - *EE cannot retain sufficient eligibility if switching away from 800MHz*
- *Under a 2x120MHz cap:*
  - *All MNOs could switch one 800MHz block to 2.6GHz and back again.*
  - *Vodafone and O2 would be able to switch both blocks of 800MHz*

2. Cap at 2x105 MHz:

2.1 Vodafone Switching Flexibility

- *Vodafone enters auction with 2x38.2 MHz qualifying spectrum in total and 2x17.4MHz in Low Frequency band spectrum*
- *Assume that Vodafone's preferred package at reserve prices is 2x10 MHz of 800 and 2x20 MHz 2.6G - 1*
- *As relative prices changed, Vodafone could switch one 2x5 MHz block of 800 MHz to additional 2x30 MHz of 2.6 GHz without loss of eligibility (and retain the ability to switch back) – 2 & 3*
- *As relative prices changed they may wish to switch an additional 2x5 MHz block of 800 MHz to 2.6 GHz. This could be done by bidding on 2.6 TDD and 2x60 MHz of 2.6 FDD. However this time they would violate total cap at 105 MHz – 5*
- *So they would be constrained to switching only to an additional 2x10 MHz of 2.6 and thus be forced to reduce eligibility to 60 – 6*

Figure D1: Cap at 105 MHz; Vodafone Switching Flexibility

Vodafone Switching Options	Package			Eligibility		
Title	800	2.6	Total	800	2.6	Total
1 Preferred Package	10	20	30 (68.2)	60	20	80
2 *Switch from 800 to 2.6*	*(-5)*	*(+30)*	*(+25)*	*(-30)*	*(+30)*	*(0)*
3 Post Switch Package	5	50	55 (93.2)	30	50	80
4 Second Switch Desire	(-5)	(+30)	(+25)	(-30)	(+30)	(0)
5 Desired Post Second Switch Package	0	80	80 (118.2)	0	80	80
6 Constrained Second Switch	0	60	60 (98.2)	0	60	60

Italics represents scenario delta, brackets in total package total column represents total spectrum position

2.2 O2 Switching Flexibility

- *O2 enters auction with 33.2 MHz qualifying spectrum in total and 17.4 MHz in Low Frequency band*

- *Assume that O2's preferred package is 2x10 MHz of 800 and 2x20MHz 2.6 - 1*
- *As relative prices changed, O2 could switch out from one 2x5 MHz block of 800 MHz to additional 30MHz of 2.6 without loss of eligibility (and retain the ability to switch back) – 2 & 3*
- *As relative prices changed they may wish to switch out of an additional 2x5 MHz block of 800 MHz to 2.6 GHz. This could be done by bidding on 2.6 TDD and 2x60MHz of 2.6 FDD. However this time they would violate total cap at 105 MHz – 5*
- *So they would be constrained to switching only to an additional 2x20 MHz of 2.6 and thus be forced to reduce eligibility to 70. This would be sufficient to switch back to 2x10 MHz of 800 but only 2x10 MHz of 2.6 - 6*

Figure D2: Cap at 105 MHz; O2 Switching Flexibility

O2 Switching Options	Package			Eligibility		
Title	800	2.6	Total	800	2.6	Total
1 Preferred Package	10	20	30 (63.2)	60	20	80
2 Switch from 800 to 2.6	*(-5)*	*(+30)*	*(+25)*	*(-30)*	*(+30)*	*(0)*
3 Post Switch Package	5	50	55 (88.2)	30	50	80
4 Second Switch Desire	*(-5)*	*(+30)*	*(+25)*	*(-30)*	*(+30)*	*(0)*
5 Desired Post Second Switch Package	0	80	80 (113.2)	0	80	80
6 Post Second Switch Package	0	70	70 (103.2)	0	70	70

Italics represents scenario delta, brackets in total package total column represents total spectrum position

2.3 H3G Switching Flexibility

- *H3G enters auction with 2x15 MHz qualifying spectrum in total and 0 MHz in Low Frequency band*
- *Assume that Hutch preferred package is 2x10 MHz of 800 MHz and 2x20 MHz 2600 MHz- 1*

- *As relative prices changed, H3G could switch from one 2x5 MHz block of 800 MHz to additional 2x30MHz of 2.6 GHz without loss of eligibility (and retain the ability to switch back) – 2 & 3*
- *As relative prices changed they may wish to switch out of an additional 2x5 MHz block of 800 MHz to 2.6 GHz. This could be done by bidding on 2.6 TDD and 2x60MHz of 2.6 FDD. – 5*
- *So they would retain enough eligibility (80) to switch back to their preferred package.*

Figure D3: Capt at 105 MHz; H3G Switching Flexibility

H3G Switching Options	Package			Eligibility		
Title	800	2.6	Total	800	2.6	Total
1 Preferred Package	10	20	30 (45)	60	20	80
2 *Switch from 800 to 2.6*	*(-5)*	*(+30)*	*(+25)*	*(-30)*	*(+30)*	*(0)*
3 Post Switch Package	5	50	55 (70)	30	50	80
4 Second Switch	(-5)	(+30)	(+25)	(-30)	(+30)	(0)
5 Post Second Switch Package	0	80	80 (95)	0	80	80

Italics represents scenario delta, brackets in total package total column represents total spectrum position

2.4 EE Switching Flexibility

- *EE enters auction with 65 MHz qualifying spectrum in total and 0 MHz in Low Frequency band*
- *Assume that EE preferred package is 2x10 MHz of 800 MHz and 2x20 MHz 2.6 GHz – 1*
- *As relative prices changed, EE might want to switch out from one 2x5 MHz block of 800 MHz to additional 2x30 MHz of 2.6 GHz – 2 & 3*
- *However, EE cannot switch because it is capped by the total cap. So the maximum bid on 2.6 GHz is 2x30 MHz in total – an increase of 2x10 MHz. EE is forced to reduce eligibility by 20 points – 4*
- *So EE after the first switch can only ever switch back to 2x10MHz of 800 MHz and NO 2.6 GHz*
- *After a second switch, EE would only be able to retain 40 points. Enough to switch back to only 2x5 MHz of 800 MHz and 2x10 MHz of 2.6 GHz*

- *2x5/5 MHz blocks in 2.6 GHz could allow EE to go to the full cap in 4*

Figure D4: Cap at 105 MHz; Everything Everywhere Switching Flexibility

	Everything Everywhere Switching Options	Package			Eligibility		
	Title	800	2.6	Total	800	2.6	Total
1	Preferred Package	10	20	30 (95)	60	20	80
2	*Desired Switch from 800 to 2.6*	*(-5)*	*(+30)*	*(+25)*	*(-30)*	*(+30)*	*(0)*
3	Desired Post Switch Package	5	50	55 (120)	30	50	80
4	Constrained First Switch	5	30	35 (100)	30	30	60
5	*Desired Second Switch*	*(-5)*	*(+10)*	*(+5)*	*0*	*70*	*70*
6	Constrained Second Switch	0	40	40 (105)	0	40	40

Italics represents scenario delta, brackets in total package total column represents total spectrum position

3. *Cap at 2x120MHz:*

3.1 *Vodafone Switching Flexibility*

As before:

- *Vodafone enters auction with 2x38.2 MHz qualifying spectrum in total and 2x17.4 MHz in Low Frequency band*
- *Assume that Vodafone's preferred package is 2x10 MHz of 800 MHz and 2x20 MHz 2600 MHz - 1*
- *Vodafone could switch from one 2x5 MHz block of 800 MHz to additional 2x30 MHz of 2.6 GHz and retain the ability to switch back – 2 & 3*
- *As relative prices changed, Vodafone could switch an additional 2x5 MHz block of 800 MHz to further 2x30 MHz of 2.6 GHz without loss of eligibility (and retain the ability to switch back) - 4 & 5*

Figure D5: Cap at 120 MHz; Vodafone Switching Flexibility

Voda Switching Options	Package			Eligibility		
Title	800	2.6	Total	800	2.6	Total
1 Preferred Package	10	20	30 (68.2)	60	20	80
2 *Switch from 800 to 2.6*	*(-5)*	*(+30)*	*(+25)*	*(-30)*	*(+30)*	*(0)*
3 Post Switch Package	5	50	55 (93.2)	30	50	80
4 *Second Switch*	(-5)	(+30)	(+25)	(-30)	(+30)	(0)
5 Post Second Switch Package	0	80	80 (118.2)	0	80	80

Italics represents scenario delta, brackets in total package total column represents total spectrum position

3.2 *O2 Switching Flexibility*

As before:

- *O2 enters auction with 2x33.2 MHz qualifying spectrum in total and 2x17.4 MHz in Low Frequency band*
- *Assume that O2's preferred package is 2x10 MHz of 800 MHz and 2x20 MHz 2600 MHz - 1*
- *O2 could switch from one 2x5 MHz block of 800 MHz to additional 2x30 MHz of 2.6 GHz without loss of eligibility and retain the ability to switch back – 2 & 3*

- *As relative prices changed, O2 could switch an additional 2x5 MHz block of 800 MHz to a further 2x30 MHz of 2.6 GHz without loss of eligibility (and retain the ability to switch back) - 4 & 5*

Figure D6: Capt at 120 MHz; O2 Switching Flexibility

O2 Switching Options	Package			Eligibility		
Title	800	2.6	Total	800	2.6	Total
1 *Preferred Package*	10	20	30 (63.2)	60	20	80
2 *Switch from 800 to 26*	*(-5)*	*(+30)*	*(+25)*	*(-30)*	*(+30)*	*(0)*
3 Post Switch Package	5	50	55 (88.2)	30	50	80
4 *Second Switch*	*(-5)*	*(+30)*	*(+25)*	*(-30)*	*(+30)*	*(0)*
5 Post Second Switch Package	0	80	80 (113.2)	0	80	80

Italics represents scenario delta, brackets in total package total column represents total spectrum position

3.3 *EE Switching Flexibility*

As before

- *EE enters auction with 65 MHz qualifying spectrum in total and 0 MHz in Low Frequency band*

- *Assume that EE's preferred package is 2x10 MHz of 800 MHz and 2x20 MHz 2600 MHz – 1*

- *As relative prices changed, EE could now switch from one 2x5 MHz block of 800 MHz to additional 2x30 MHz of 2.6 GHz without loss of eligibility (and retain the ability to switch back) – 2 & 3*

Figure D7: Capt at 120 MHz; Everything Everywhere Switching Flexibility

Everything Everywhere Switching Options	Package			Eligibility		
Title	800	2.6	Total	800	2.6	Total
1 *Preferred Package*	10	20	30 (95)	60	20	80
2 *Switch from 800 to 2.6*	*(-5)*	*(+30)*	*(+25)*	*(-30)*	*(+30)*	*(0)*
3 Post Switch Package	5	50	55 (120)	30	50	80

Italics represents scenario delta, brackets in total package total column represents total spectrum position

Annex F: Coverage Obligations

1 Contents

One of Ofcom's primarily regulatory objectives with the release of the 800MHz spectrum has been to push the availability of high quality mobile broadband further out in the country to areas currently underserved. A key part of ensuring this is the idea that some of the spectrum at 800MHz will come with coverage obligations.

2 Summary

Everything Everywhere does not believe that the coverage obligation target is achievable with a 2x5 MHz carrier at 800 MHz due to insufficient downlink power or excessive intercell interference. It is anticipated that with a 2x5 MHz carrier operating at 85% load, the highest long term average data rate that can be achieved is approximately 1.5 Mbits/s at the cell edge with 90% probability, regardless of the cell size.

With a 2x10 MHz LTE800 carrier, the intercell interference level is acceptable, and it becomes feasible to support a 2 Mbps service over a high proportion of Everything Everywhere's urban and suburban and dense suburban sites with 90% coverage probability. A 2x10 MHz bandwidth is a minimum condition for the coverage obligation to be achievable. Detailed analysis for the UK and its population distribution is required to complete the validation.

3 Further Details

3.1 Signal-to-Interference+Noise Ratio (SINR) Required for 2 Mbits/s

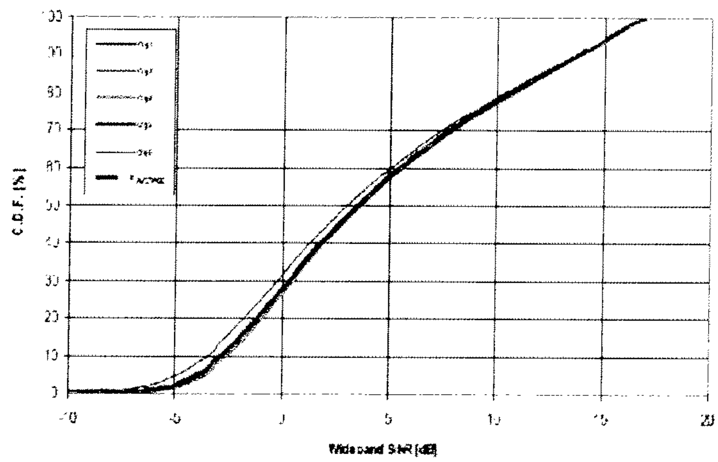
As indicated in Annex B, section 3.7, Ofcom states in A8.91 that an SINR of -4.7 dB is assumed when calculating the signal level required to meet the coverage obligation. Everything Everywhere believes that this value is erroneous due to the two factors indicated in Annex B. The correct value should be -0.85 dB, derived as follows:

- *It is assumed that, for a service at limit of range, 85% load is achieved by using 100% resource in 85% of the time[1]*
- *Therefore, the link must support 2.35 Mbits/s in 25 resource blocks for 2x5 MHz (94.1 kbits/s in 180 kHz or 0.52 bits/s/Hz)*
- *Using Ofcom's relationship in Equation 12 of Annex 8, the SINR needed to achieve this is -0.85 dB*
- *For 2x10 MHz bandwidth, the link must support 2.35 Mbits/s in 50 resource blocks (47.0 kbits/s in 180 kHz or 0.26 bits/s/Hz), requiring an SINR of -4.55 dB*

3.2 Coverage Obligation with 2x5 MHz Carrier at 800 MHz

Everything Everywhere does not believe that the coverage obligation is achievable within a 5 MHz channel. The principal reason for this is that Everything Everywhere believes that in a suburban environment, the cell edge Signal-to-Interference+Noise Ratio (SINR) that is typically achievable in a 100% loaded network to 90% confidence is around -3 dB. This is obtained from industry simulations calibrated by a number of independent companies[2]. The key figure from that reference is inserted below:

Figure F1: Signal to Interference+Noise Ratio Distribution Across Suburban Cells



[1] In fact, if it is assumed that a 85% load is achieved by using 85% resource 100% of the time, the SINR value becomes -0.7 dB, so the assumed approach provides the more stringent SINR condition

[2] "Calibration for IMT-Advanced Evaluations", EU Project WINNER+, v0.7, 21/05/2010, http://projects.celtic-initiative.org/winner+/WINNER+%20and%20ITU-R%20EG%20documents/Calibration%20for%20IMT-Advanced%20Evaluations.pdf.

It can be seen here that the SINR of several organisations corroborate this data point (taking the 10% point of the CDF for the 90% confidence point). To allow for an 85% load on the network, it is necessary to reduce the SINR accordingly, to -2.3 dB[3].

Given that an SINR of -0.85 dB is needed to achieve a 2 Mbits/s data service in a 5 MHz LTE channel at an 85% load (see earlier section) this performance level will clearly not be met at the required confidence level (network delivers -2.3 dB). In fact, from Figure F1 it can be seen that this SINR level is only reached with about 78% confidence (22% of locations below the -0.85 dB point).

Separately, using Ofcom's assumptions for link budget parameters (which equates to 0 dB interference margin), Everything Everywhere calculates that in 2x5 MHz, the obligation can be reached in suburban area at a range of 1.99 km, due to downlink power limitation (see section 5.4 of this Annex). [redacted]

Clearly the SINR distribution is the more dominant of these two factors in this case.

3.3 Coverage Obligation with 2x10 MHz Carrier at 800 MHz

With 10 MHz carrier, the SINR needed to achieve the 2 Mbits/s data service is -4.55 dB so it is possible to achieve the required 2 Mbits/s data service in this LTE channel from an SINR perspective.

Using Ofcom's assumptions for interference margin, Everything Everywhere calculates that in 2x10 MHz, the obligation can be reached in the suburban area at a range of 2.58 km (see section 5 of this document), with the uplink constraint limiting this range. The bit-rate at this range is approximately 3 Mbps with 90% confidence). Using industry assumptions on interference margin (3 dB), the range is still marginally limited by the uplink constraint and the achievable throughput drops to about 2.16 Mbits/s (see Table 3). [redacted]

3.4 Errors in Calculation of Target Outdoor Wanted Power

A number of errors were identified in the section relating to the calculation of the target outdoor wanted power. These are described in Annex B so not mentioned further here.

4 Conclusion

It is clear that an operator requires 2x10 MHz as a minimum condition to meet the coverage obligation that Ofcom are seeking to achieve. A 2x5 MHz allocation will not be sufficient.

A number of errors have been identified in the specification of the obligation and the example parameters for measuring compliance. Everything Everywhere requests that Ofcom reassess the viability of achieving the coverage obligation in light of the errors identified.

---

[3] $-3\ dB - 10\log_{10}(0.85)$

[redacted]

5 Supporting Information

5.1 General Link Budget Assumptions

Though Everything Everywhere has its parameter values for link budget calculations, for the purposes of enabling direct comparison with Ofcom's results, we have used throughout our analysis the same assumptions and parameter values as Ofcom. This includes the propagation laws (Extended Hata & associated parameters), mean penetration losses and associated standard deviations, shadowing standard deviations for each environment type as well as the 5dB for body loss.

5.2 Link Budget to Estimate the Range of 2 Mbits/s Service in 2x5 MHz of 800 MHz spectrum Using Ofcom Assumptions

The link budget below summarises the key parameters affecting the estimation of the range of a 2 Mbits/s service in 5 MHz at 800 MHz, using Ofcom assumptions, including the 0 dB interference margin.

In the first half of the table, the path loss which achieves the required total throughput (2 Mbits/s) is calculated through a generate-and-test process, using the interference margin assumed by Ofcom. This determines the achieved SINR at cell edge from which the total throughput can be calculated using Equation 12 of Annex 8 of the Consultation.

In the second half of the table, the path loss is used, with the penetration and shadowing parameters to give 90% confidence plus body loss to derive the range for the suburban environment. This uses the Extended Hata equation in same way as Ofcom does in the Consultation.

Table F1: Link Budget for 2 Mbits/s Service in 5 MHz Using Ofcom Assumptions

Parameter	Value	Unit
Interference margin (Ofcom)	0	dB
Path loss at cell range for service	152.5	dB
Max available wanted signal level (based on EIRP of 58.5 dBm)	-94.04	dBm
Interference level	-94.74	dBm
Effective noise + interference	-93.21	dBm
Achieved SINR at cell edge	-0.84	dB
Throughput per resource block	93.83	kbits/s
Total downlink throughput	**2.00**	**Mbits/s**
90% Area coverage probability		
Mean Penetration loss (Suburban)	9.6	dB
Penetration loss standard deviation	7	dB
Shadow margin standard deviation	6.6	dB
Multi server shadow margin including penetration loss + shadow margin combined	11.9	dB
Handover margin	0	dB
Body loss	5	dB
Maximum path loss (including margins)	135.67	dB
Range	**1.99**	**km**

5.3 Link Budget to Estimate the Range of 2 Mbits/s Service in 2x10 MHz of 800 MHz spectrum Using Ofcom Assumptions

The link budget below summarises the key parameters affecting the estimation of the range of a 2 Mbits/s service in 10 MHz at 800 MHz, using Ofcom's assumptions, including the interference margin.

In the first half of the table, it was identified that the link was uplink limited at 156.5 dB (141 dB minimum coupling loss + 15.5 dB antenna gain). This determines the achieved SINR at the cell edge from which the total throughput can be calculated using Equation 12 of Annex 8 of the Consultation. Here the total throughput exceeds the 2 Mbits/s at the point that the uplink fails.

In the second half of the table, the path loss is used with other loss parameters to give 90% confidence for the suburban environment as for the previous 5 MHz case.

Table F2: Link Budget for 2 Mbits/s Service in 10 MHz Using Ofcom Assumptions

Parameter	Value	Unit
Interference margin (Ofcom)	0	dB
Path loss at cell range for service	156.5	dB
Max available wanted signal level (based on EIRP of 58.5 dBm)	-94.98	dBm
Interference level	-95.69	dBm
Effective noise + interference	-92.56	dBm
Achieved SINR at cell edge	-2.42	dB
Throughput per resource block	70.56	kbits/s
Total downlink throughput	**3.00**	**Mbits/s**
90% Area coverage probability		
Mean Penetration loss (Suburban)	9.6	dB
Penetration loss standard deviation	7	dB
Shadow margin standard deviation	6.6	dB
Multi server shadow margin including penetration loss + shadow margin combined	11.9	dB
Handover margin	0	dB
Body loss	5	dB
Maximum path loss (including margins)	139.6	dB
Range	**2.58**	**km**

5.4 Results Using the Interference Margin from WINNER

If the above analysis is repeated for WINNER interference margin of -3 dB (a figure verified by many industry simulations), the key figures come out as follows[5]:

Table F3: Link Budget results for 2 Mbits/s Service Using Industry Assumptions

Band	Parameter	Value	Unit
5 MHz	Total downlink throughput at cell edge	1.31	Mbits/s
	Range	1.99	km
10 MHz	Total downlink throughput at cell edge	2.16	Mbits/s
	Range (limited by uplink)	2.58	km

[5] Note, the other parameters of the link budget are identical to those shown in Table1 and 2. It is only the value in the first row which is altered.

It is clear that the target 2 Mbits/s performance cannot be met with this interference margin in a 5 MHz bandwidth. The highest achievable downlink throughput is 1.52 Mbits/s if the cell is allowed to shrink arbitrarily small. A range of 1.99km is used here to demonstrate the difference the interference margin makes compared to the result with the Ofcom assumption on interference margin of Table 1.

5.5 Information on the SINR Distribution Results from WINNER

Figure F1 is derived from the European collaborative project WINNER+, referenced earlier. The parameters used in the simulations which produced the results are contained in ITU-R document M.2135[6]. Some of the key parameters are summarised below. Please refer to this reference document for further information.

Figure F2: WINNER Simulation Setup & Cell Range Definitions

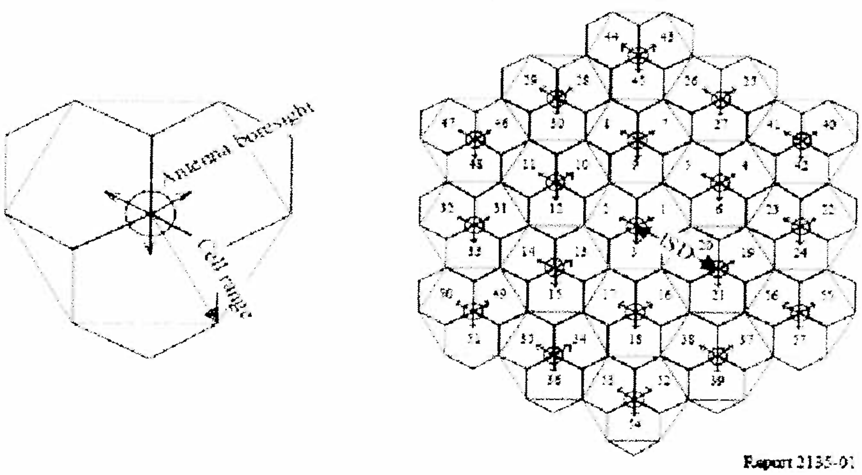


Table 4: Key Parameters for WINNER Simulations

Parameter	Value
Environment	Suburban
Intersite Distance	1300m
Equivalent Range	764m
Antenna downtilt	6 deg
Building penetration loss	20 dB fixed, 50% users indoors
Shadow margin	8 dB
SINR at 90% confidence	-3 dB
Probability SINR > -0.85	~ 78%

5.6 Everything Everywhere Target Network Site Radius Distribution

[redacted]

[6] http://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-M.2135-1-2009-PDF-E.pdf

[redacted]

[redacted]

[redacted]